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Louisiana State University and Agricultural and Mechanical College, pblanch@lsu.edu

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FACTORS INFLUENCING THE EFFICACY OF DELAYED AUDITORY FEEDBACK IN TREATING DYSARTHRIA ASSOCIATED WITH PARKINSON'S DISEASE

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Communication Sciences and Disorders

by
Paul Gerard Blanchet
B.A., State University of New York, College at Fredonia, 1988
M.S., Northeast Louisiana University, 1990
December 2002

DEDICATION

Although the document you are about to read was written by me, it is really about three gentlemen with Parkinson's disease who gave generously of their time and effort to participate in this study. For 16 sessions, they were model participants in every way; always in attendance, prompt, enthusiastic, and eager to improve their communicative abilities. They were willing to sacrifice their own free time to help provide information that will hopefully benefit other speakers with Parkinson's disease. Their perseverance was, and still is, incredibly inspiring to me. Without such selfless individuals, research on speech interventions for Parkinson's disease patients would not be possible. It is to these men, and their supportive and hospitable families, that I dedicate this dissertation.

ACKNOWLEDGEMENTS

Most beginning doctoral students are fortunate enough to get sage advice from some of the more experienced students. For example, one of the more memorable "words of wisdom" I received early in my academic career was that "doing a dissertation is basically long periods of tedium punctuated by moments of sheer terror." Be that as it may, one of the more encouraging pieces of advice I was given was to assemble the best dissertation committee I possibly could. Fortunately, I was listening that time.

Dr. Paul Hoffman has been the best major professor I could have ever asked for. He was always willing to give generously of his time and expertise, and showed patience and kindness throughout our work together. He has taught me a tremendous amount about conducting research, and also about how to treat students and colleagues All he has ever asked in return was that someday I grow up and become a productive member of society. I'm still working on it, Boss!

Rounding out my committee were Drs. Jan Norris, Lee Mendoza, Patrick Plyler, and Mike Hawkins. They were helpful and supportive of me during this project, and throughout my education, in numerous ways. I owe them all a debt of gratitude for being on my "team." I must also acknowledge the generous assistance of Dr. Paul Dagenais of the University of South Alabama. As the author of the first experimental single-subject study in this area, Dr. Dagenais has been inspirational to me, and I respect his work immensely. I am extremely grateful for the numerous suggestions he made (via countless e-mails) during the initial stages of this project; he was never too busy to lend me a helping hand.

Also tremendously supportive was Ms. Lyn LeJeune, Assistant Director of Graduate Records, whom I wisely consulted throughout the dissertation process. She was always ready with a quick answer, and an even quicker smile, and served as a source of guidance and encouragement. She’s a wonderful representative of the graduate school, and demonstrates how friendly and helpful (and important) those folks are to doctoral students, especially during the dissertation process.

While a dissertation often seems like a solitary activity, it cannot be successfully completed without "a little help from your friends." Fortunately, I somehow managed to make some great ones along the way. Among these was Sarra D'Arcy, an outstanding graduate student in Communication Disorders. Sarra, along with Dr. Hoffman, was nice enough to perform reliability checks for this study. As her reward, I told her that I’d be glad to do reliability for her when *she* gets a Ph.D. (she's still not speaking to me). Anyway, Sarra, thanks for being so "reliable."

Special thanks must go to the administration, faculty, staff, and students from the LSU Health Sciences Center in New Orleans. They have all been extremely supportive of me since I "jumped on board" this past May, and have allowed me the time necessary to complete this project. Everyone welcomed me with open arms and made me feel right at home, and I’m very grateful for that.

Lastly, and most importantly, I could not have gotten through all of this without the love and encouragement of my parents, Fran and Charlie Blanchet. Their steadfast confidence in me made me actually believe that I could pull this off. Hey, Mom and Dad, I think it worked!

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ABSTRACT

Parkinson's disease patients exhibit a high prevalence of speech deficits including excessive speech rate, reduced intelligibility, and disfluencies. The present study examined the effects of delayed auditory feedback (DAF) as a rate control intervention for dysarthric speakers with Parkinson's disease. Adverse reactions to relatively long delay intervals are commonly observed during clinical use of DAF, and seem to result from improper "matching" of the delayed signal. To facilitate optimal use of DAF, therefore, clinicians must provide instruction, modeling, and feedback. Clinician instruction is frequently used in speech-language therapy, but has not been evaluated during use of DAF-based interventions. Therefore, the primary purpose of the present study was to evaluate the impact of clinician instruction on the effectiveness of DAF in treating speech deficits. A related purpose was to compare the effects of different delay intervals on speech behaviors.

An A-B-A-B single-subject design was utilized. The A phases consisted of a sentence reading task using DAF, while the B phases incorporated clinician instruction into the DAF protocol. During each of the 16 experimental sessions, speakers read with four different delay intervals (0 ms, 50 ms, 100 ms, and 150 ms). During the B phases, the experimenter provided verbal feedback and modeling pertaining to how precisely the speaker matched the delayed signal. Dependent variables measured were speech rate, percent intelligible syllables, and percent disfluencies.

Three males with Parkinson's disease and an associated dysarthria participated in the study. Results revealed that for all three speakers, DAF significantly reduced reading rate and produced significant improvements in either intelligibility (for Speaker 3) or fluency (for Speakers 1 and 2). A delay interval of 150 ms produced the greatest reductions in reading rates

for all three speakers, although any of the DAF settings used was sufficient to produce significant improvements in either intelligibility or fluency. In addition, supplementing the DAF intervention with clinician instruction resulted in significantly enhanced gain achieved with DAF. These findings confirmed the effectiveness of various intervals of DAF in improving speech deficits in Parkinson's disease speakers, particular when patients are provided instruction and modeling by the clinician.

INTRODUCTION

Hypokinetic dysarthria is a motor speech disorder resulting from disturbances in muscular control secondary to neurological damage (Darley, Aronson, & Brown, 1975). This type of dysarthria was dubbed "hypokinetic" based on the view that its physiological basis involved a reduction in the range of movements needed for speech production (Darley et al., 1975). Parkinson's disease is the prototypic disease associated with hypokinetic dysarthria, accounting for 98% of all such cases seen in speech-language pathology practices (Duffy, 1995).

Parkinson's disease is a degenerative disorder of the basal ganglia affecting motor control (Yorkston, Beukelman, Strand, & Bell, 2000). Due to motor symptoms such as tremor, rigidity, akinesia (i.e., paucity of movement), and bradykinesia (i.e., slowness of movement), Parkinson's disease patients exhibit a high prevalence of speech deficits (Swigert, 1997; Yorkston et al., 2000). For example, Hartelius and Svensson (1994) surveyed 230 patients and found that six percent of the respondents reported "fast speech," nine percent reported "stuttering," 27% reported "difficulty getting started," and five percent reported impaired stress or rhythm of speech. Logemann, Fisher, Boshes, and Blonsky (1978), examining speech/voice symptoms in 200 Parkinson's disease patients, observed rate disorders in 20% of the patients, while 45% exhibited imprecise consonant articulation. Similarly, Darley et al. (1975) reported that all 32 of their participants exhibited imprecise articulation.

Perceptual features of hypokinetic dysarthria typically include imprecise consonant articulation, reduced variability of pitch and loudness, variable speech rate, short rushes of speech, and inappropriate or excessive silences (Duffy, 1995; Yorkston et al., 2000). In fact, hypokinetic dysarthria is the only type of dysarthria in which rapid rate is often a prominent and distinctive perceptual feature (Duffy, 1995). Syllables are typically produced in an accelerating manner, with a reduced range of articulatory excursions. Perceptually, these syllables may sound "blurred" or seem to "run together" (Duffy, 1995). Additionally, fluency deficits impacting rate and intelligibility often include sound or syllable repetitions, difficulty initiating phonation, and palilalia (i.e., involuntary repetition of words or phrases) (Yorkston, Miller, & Strand, 1995).

Rate Control Intervention

Because of the high prevalence of rate, intelligibility, and fluency deficits, many patients with hypokinetic dysarthria benefit from a modification of speech rate. It may be easier for dysarthric speakers to control their rates than to achieve other motor goals (Duffy, 1995). In fact, speech rate may be the single most behaviorally modifiable variable for improving intelligibility. For example, Darley et al. (1975) reported a 0.78 correlation between variable rate and intelligibility. Rarely in clinical treatment can such dramatic a change be brought about by the manipulation of one variable (Yorkston, Beukelman, & Bell, 1988).

Intervention that focuses on rate control is often beneficial for several reasons. First, it improves intelligibility by increasing articulatory precision, permitting the full range of motion for the articulators to achieve their target positions more completely (Netsell, Daniel, & Celesia, 1975). Rate control strategies also increase the patient's ability to coordinate various components of the speech mechanism (e.g., the timing of phonation with articulatory gestures). Frequent phonatory disturbances such as difficulty initiating phonation (e.g., Illes, Metter, Hanson, & Iritani, 1988; Metter & Hanson, 1986), excessive duration of vowels (Kreul, 1972), and incomplete vocal fold closure (Kegl, Cohen, & Poizner, 1999) reflect the need among some Parkinson's disease patients for improved vocal fold coordination. In addition, rate control techniques that pace the speaker's rate help keep speech "moving forward," thus minimizing the need to reinitiate vocal fold activity.

Traditional rate control interventions lie on a hierarchy from "rigid" strategies which impose maximal rate control (e.g., pacing boards, alphabet boards) to techniques allowing greater speech naturalness and independent rate control (e.g., rhythmic cueing). Rigid aids such as the pacing board and alphabet board have been used effectively to reduce rate and improve intelligibility in cases of severe dysarthria (Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Helm, 1979; Lang & Fishbein, 1983). These techniques offer relatively few expenses, ease of use, minimal training requirements, and the option of home practice. Alphabet board supplementation offers the additional advantage of visual cues to aid the listener in comprehension of the message (Beukelman & Yorkston, 1977).

Unfortunately, these external devices are considered cosmetically unacceptable by some patients, require manual dexterity, may require normal vision and adequate spelling ability, and often result in adaptation or overlearning of the required movement (Yorkston et al., 1988). These strategies also tend to disrupt prosody by imposing a “one-word-at-a-time” speech pattern with pauses between words. However, they are often effective when other interventions fail, enabling severely dysarthric individuals to use oral speech earlier in treatment than would have otherwise been possible (Beukelman & Yorkston, 1977).

Rate control strategies that attempt to preserve prosody (e.g., oscilloscopic feedback, computerized pacing) require more extensive training, relatively intact cognitive abilities, greater reliance on a clinician, and sufficient time and motivation to master new motor skills (Yorkston et al., 1988). These requirements may pose a difficulty for those Parkinson's disease patients who exhibit dementia (Levin, Tomer, & Rey, 1992) or other cognitive deficits (Saint-Cyr, Taylor, & Lang, 1988). For appropriate speakers, however, visual feedback systems have been shown to be useful for training these individuals to monitor and modify their own speech behaviors in as little as nine weeks of treatment (Caligiuri & Murry, 1983; LeDorze, Dionne, Ryalls, Julien, & Ouellet, 1992).

However, in addition to the relatively high cost of some of these feedback systems, they present the challenge of necessitating a gradual fading of the visual feedback provided by the oscilloscope or computer screen. This limitation impedes the transfer of skills acquired in the clinic to "real world" speaking situations. Other non-instrumental, "behavioral" methods (e.g., cueing strategies) are sometimes used as a transition between rigid or instrumental techniques and self-monitoring of speech rate (Yorkston & Beukelman, 1981). These strategies aim toward more natural prosody and attempt to re-introduce normal rhythmic elements into the person's speech pattern. For example, Yorkston and Beukelman (1981) gradually increased the rate of one patient’s speech from 80 words per minute to 134 words per minute while maintaining 99% intelligibility. However, the seven months of treatment needed to obtain such dramatic gains underscores the relatively taxing training requirements of some behavioral interventions.

Delayed Auditory Feedback

The present study examined the effects of an alternative rate control intervention known as delayed auditory feedback (DAF). Essentially, this technique involves delaying the auditory feedback of the person's speech, which requires him or her to prolong each syllable until the feedback "catches up" to the speech production. Ideally, this induces a relatively slow, fluent speech pattern characterized by prolonged syllable nuclei (i.e., vowels), smooth transitions between syllables, and relatively stable syllable duration (Goldiamond, 1965; Ingham, 1984; Bloodstein, 1995).

Evidence from a limited number of published reports, as well as ample clinical evidence, suggests that delayed auditory feedback offers several advantages as a method of rate reduction (Yorkston et al., 2000). When used effectively by adequately trained clinicians with appropriate patients, it provides easily adjustable and often dramatic reductions in speech rate. This typically leads to increased articulatory precision, increased speech fluency, and improved intelligibility. Moreover, the smooth transitions between syllables facilitated by DAF reduces the need to reinitiate vocal fold activity (Starkweather, 1987), which is important for Parkinson's disease patients with phonatory difficulties.

Portable DAF units (e.g., Kehoe, 1998) also allow for home practice, as well as independent "self-therapy" once a patient has become proficient at the task. For example, the auditory feedback may be faded by either gradually reducing the delay interval or gradually attentuating the volume of the feedback signal. This provides a systematic method for reducing the speaker's reliance on the device. Lastly, DAF units are often used effectively as prosthetic devices (e.g., Hanson & Metter, 1980; 1983) by individuals who are simply unable to transfer therapy gains to "outside" speaking situations due to the severity of their neuromotor impairments, cognitive limitations, and/or limited access to a speech-language pathologist.

The effects of delayed auditory feedback on speech production were first reported by electrical engineer Bernard Lee (1951). While experimenting with a new tape recorder, Lee inadvertently plugged a pair of headphones into the "wrong" jack, which resulted in his voice becoming delayed by a fraction of a second. Attempting to speak in the presence of this delayed signal reportedly had a detrimental effect on his speech production (Lee, 1951). Indeed, subsequent trials by Lee (1951) and others (e.g., Black, 1951; Soderberg, 1968; Yates, 1963) confirmed such effects of this delayed "side-tone" on the speech of normally-speaking adults.

Although individual responses to delayed auditory feedback vary considerably (Ingham, 1984), the delayed signal typically induces greater speech intensity, reduced rate, prolonged vowels, and/or repetition of word-final and sentence-final sounds in an "echo-like" manner (Goldiamond, Atkinson, & Bilger, 1962). The delayed speech signal leads to the erroneous perception that speech production is not as far along as it actually is. This may cause the speaker to continue a speech gesture, resulting in the prolongation of a sound. The delayed signal may also indicate that the last sequence of gestures should not have been terminated, resulting in the speaker repeating the production of speech segments. These two phenomena may account for the variability of responses to DAF; some speakers produce sound/syllable repetitions, while others prolong vowels (Goldiamond et al., 1962).

Delayed auditory feedback was also reported to induce sound substitutions, omissions, and distortions of phonemes, (Black, 1951), as well as increased pitch in some speakers (Siegenthaler & Brubaker, 1957). Delay intervals of 180-200 ms (i.e., the typical duration of a syllable; Kent, 1997) were reported to produce maximum disruption in fluent speakers (Siegenthaler & Brubaker, 1957; Webster, 1991). Although these speech behaviors differed topographically from the disfluencies exhibited by stutterers, this DAF-induced speech pattern was initially referred to as "artificial stuttering" (Black, 1951; Lee, 1951).

These speech responses were later shown to be modified or prevented according to the level of attention paid to the delayed signal (Ingham, 1984). For example, Goldiamond et al. (1962) instructed normal speakers to listen to their voices while speaking with DAF, resulting in greatly reduced speech rates. Instructing the subjects to ignore the signal, however, did not lead to significantly reduced speaking rates. This suggested that the variability of responses to delayed auditory feedback may depend, in part, on how closely an individual attends to auditory feedback. This finding has important implications for the clinical use of DAF, and will be discussed later in further detail.

The use of delayed auditory feedback to treat developmental stuttering was later discovered serendipitously by Goldiamond (1965). Working within an operant conditioning paradigm, he attempted to demonstrate that stuttering was an operant behavior by using "aversive" stimuli such as a loud tone to decrease its frequency. Brief periods of DAF were presented following disfluencies, resulting in a decrease in stuttering frequency (Goldiamond, 1965). Next, Goldiamond presented DAF continuously, turning it off for ten seconds following stuttering. Unexpectedly, stuttering frequency decreased, as participants began speaking in a slow, prolonged manner.

Goldiamond (1965) devised a stuttering therapy in which the duration of the delay interval was gradually decreased, while speech rate was gradually increased. Participants read while using 250 ms DAF, with instructions to prolong their speech until "coincidence with the delay interval" was reached. This typically yielded a speech rate of about 25 words per minute and a stuttering frequency of less than one stuttered word per minute. Next, the delay interval was gradually decreased in 50 ms increments until fluency without DAF was achieved. Goldiamond (1965) concluded that this procedure introduced a new speech pattern, which he dubbed "prolonged speech." He reported reductions in stuttering frequency of up to 90%, as well as maintenance of fluency without DAF for up to "many months" (Goldiamond, 1965). Thus, an important aspect of Goldiamond's findings was the controlling effects of paying attention to the delayed signal (i.e., "matching" the signal).

The success of Goldiamond's protocol led to subsequent investigations, as many stuttering therapy programs using delayed auditory feedback were developed (e.g., Curlee & Perkins, 1969; 1973; Ingham & Andrews, 1973; Ryan & Van Kirk 1974; 1983; 1995). For example, Kalinowski, Armson, Roland-Mieszkowski, and Stuart (1993) found that relatively short delay intervals (e.g., 50 ms) reduced stuttering frequency by 75-80%, while longer intervals (e.g., 90-222 ms) produced up to 100% fluency in even "severe" stutterers (Ryan & Van Kirk, 1974).

As Bloodstein (1995) observed, most stutterers prolong syllables, overarticulate, or concentrate on proprioceptive and tactile feedback to overcome the disruptive effects of delayed auditory feedback. Thus, speakers who do things to "beat" the DAF are incidentally doing things that are likely to decrease stuttering as well. Besides slowing their rates, stutterers typically attempt to cancel out, or "match," the delayed signal. That is, they wait until they hear this signal before terminating production of the syllable and then beginning the next syllable of the utterance. This adds an element of predictability to the speaking task, as any signal that informs a stutterer when to begin a speech segment typically increases fluency (Starkweather, 1987).

For example, most stutterers exhibit increased fluency when they time their speech to a rhythmic beat, whether it be auditory, visual, or tactile (Bloodstein, 1995; Webster & Lubker, 1968). Perhaps a more regular rhythm supports speech production, as DAF may reduce "temporal uncertainty." This allows the speaker more time to plan temporal patterns, thus simplifying the complex task of speech production (Kent, 1983). Also, allotting equal time for each syllable produced results in a reduction of stress contrasts which reduces the necessity of making the small surges of sub-glottic pressure that produce stressed syllables. This simplification of syllable production reduces requirements for maintaining optimal glottal tension adjustments, as the vocal folds do not have to be readjusted for tension with each brief surge in sub-glottic pressure (Bloodstein, 1995). As stated above, this may be important for dysarthric individuals exhibiting difficulty initiating or maintaining phonation (Yorkston et al., 1995).

The Use of DAF with Dysarthric Speakers

Following the successful use of delayed auditory feedback with stutterers, several researchers examined its use with dysarthric speakers (e.g., Adams, 1994; Dagenais, Southwood, & Lee, 1998; Downie, Low, & Lindsay, 1981; Hanson & Metter, 1980; 1983; Yorkston et al., 1988). Results were generally mixed, but suggested positive effects of DAF on speech rate, intelligibility, and fluency for appropriate speakers. Thus, DAF has been shown to offer several advantages as a "transitional" strategy between rigid rate control techniques and behavioral interventions (Yorkston et al., 1995).

Delay intervals ranging from 50 ms (e.g., Downie et al., 1981) to 150 ms (e.g., Hanson & Metter, 1983) were used effectively, while delays in excess of 150 ms were reported to yield no further gains in rate or intelligibility (Yorkston et al., 1988). In fact, such delays reportedly produced "disastrous" effects on the speech of some individuals (Dagenais et al., 1998; Rosenbek & LaPointe, 1978). Unfortunately, there is a paucity of studies experimentally demonstrating the effects of extended use of multiple delay intervals. As a result, differential responses of individual speakers to various delay times have not been documented. Adverse reactions to relatively long delay times are commonly observed during clinical use of DAF, and seem to result from imprecise matching of the delayed signal. This has been documented with stutterers (Goldiamond, 1965), dysarthric patients (Dagenais et al., 1998; Rosenbek & LaPointe, 1978), as well as unimpaired speakers (Black, 1951; Lee, 1951; Soderberg, 1968).

To facilitate optimal use of DAF, therefore, clinicians must provide instruction, modeling, and feedback. Clinician feedback is routinely used in speech-language therapy, but has not been evaluated empirically with DAF-based interventions. Rosenbek and LaPointe (1978) suggested that the clinician should be as active in DAF training as in any other form of therapy, stating that carry-over of treatment gains can only achieved if the clinician provides feedback regarding the speaker's performance. Unfortunately, most reports of DAF-based interventions have not clearly delineated instructions or modeling procedures used by clinicians.

What is currently lacking in the literature are studies which experimentally demonstrate the effects of clinician instruction pertaining specifically to how precisely speakers match the delayed signal. The primary goal in this line of inquiry is not to demonstrate that DAF benefits some patients under some conditions, but rather which task parameters (e.g., clinician instructions, delay interval) contribute to its success or failure. Such information could later be used to "fine-tune" the DAF procedure in order to maximize its efficacy and efficiency. Toward that goal, the purpose of the present study was to evaluate the relative contributions of clinician instruction and delay interval on the effectiveness of delayed auditory feedback in treating rate, intelligibility, and fluency deficits in adults with dysarthria secondary to Parkinson's disease.

REVIEW OF THE LITERATURE

The purpose of this first of three major sections is to review the published literature related to the speech rate characteristics of speakers with hypokinetic dysarthria. This critical analysis of the perceptual, acoustic, and kinematic data will form the basis of a rationale for using rate control interventions with those Parkinson's disease patients who exhibit hypokinetic dysarthria. In order to provide some background information to aid in interpretation of the literature, brief discussions of both Parkinson's disease and hypokinetic dysarthria will first be presented.

Parkinson's Disease

Parkinson's disease (PD) is a degenerative disorder of the basal ganglia affecting motor control. Idiopathic Parkinson's disease, the most common type, occurs in approximately one percent of the U.S. population over 50 years of age, with approximately 40,000 new cases reported each year (Yorkston, 1996). The incidence of Parkinson's disease increases sharply after 64 years of age, as the peak of incidence is 75-84 years of age (Yorkston et al., 2000).

Parkinson's disease is often divided into subgroups based on etiology and associated symptoms. The term idiopathic or primary Parkinson's disease (also known as paralysis agitans) is used when the cause of the disease cannot be identified. Secondary parkinsonism includes a number of disorders with "parkinsonian" features which have an identifiable causal agent, such as toxicity, infections, neuroleptic drugs, traumatic brain injury, or cerebral vascular accidents. "Parkinsonism-plus" syndromes are conditions that include symptoms of Parkinson's disease as part of the clinical profile, such as progressive supranuclear palsy. Because these syndromes result from damage to multiple neural systems, they may produce a dysarthria that is different from that associated with Parkinson's disease (Yorkston et al., 2000).

The motor symptoms present in Parkinson's disease result from a loss of dopaminergic neurons in the basal ganglia, substantia nigra, and brainstem (Yorkston, 1996). The disease usually involves a chemical imbalance between dopamine-activated and acetylcholine-activated neurons of the corpus striatum (Yorkston et al., 1995). In some cases, dopamine content of the striatum has been found at autopsy to be one tenth of normal levels (Darley et al., 1975). The basal ganglia, through connections with the thalamus and cerebral cortex, are believed to influence the direction, speed, and amplitude of volitional movements. These ganglia may also be involved in initiation of such movements (Yorkston, Miller, & Strand, 1995).

A neurologist's diagnosis of Parkinson's disease is usually based on the presence of resting tremor, rigidity, akinesia (i.e., paucity of movement), and postural instability (Adams, 1997). The acronym TRAP (Tremor, Rigidity, Akinesia, and Postural Instability) is often used as a mnemonic for the motor symptoms of Parkinson's disease (Yorkston et al., 2000). Bradykinesia, a less extreme form of akinesia, refers to a slowness in volitional movements (Yorkston et al., 2000). Secondary signs of Parkinson's disease include stooped posture, reduced arm swing, micrographia, and masked facial expression (Adams, 1997). In addition, approximately 15% of all Parkinson's disease patients meet the criteria for dementia (Levin, Tomer, & Rey, 1992).

Hypokinetic Dysarthria

The term "dysarthria" actually refers to a group of speech disorders involving any or all of the basic motor speech processes (i.e., respiration, phonation, resonance, articulation, and prosody) resulting from disturbances in muscular control secondary to neurological damage (e.g., degenerative diseases, cerebral vascular accidents, traumatic brain injury, etc.). Dysarthria is typically characterized by some degree of weakness, slowness, incoordination, or alteration of muscle tone of the speech apparatus (Darley et al., 1975).

It has been estimated that 60-80% of Parkinson's disease patients will develop speech deficits as the disease progresses (Adams, 1997). Communication disorders often begin with decreased loudness and progress to more severe functional limitations characterized by changes in rate, articulatory precision, and intelligibility (Yorkston et al., 2000). In the seminal Mayo Clinic study of various groups of dysarthric speakers, Darley et al. (1975) delineated the speech characteristics of 32 patients with "parkinsonism." Of these 32 speakers, 16 were judged to use excessively short phrases and 19 were judged to produce excessively short rushes of speech separated by pauses. Twenty-five of the 32 participants produced inappropriate silences, which was interpreted as reflecting either difficulty initiating phonation or difficulty coordinating phonation and articulation (Darley et al., 1975).

In addition, all 32 participants exhibited articulatory imprecision. The speech rates of 28 speakers were judged to be at least "somewhat deviant." While only four participants exhibited a "festinating" pattern (i.e., acceleration during speaking similar to the gait pattern of many Parkinson's disease patients), significant variability of speech rate was exhibited by 16 speakers. The impression of festination was most likely attributable to the short rushes separated by pauses. Lastly, repetitions of word-initial phonemes were produced by 14 speakers (Darley et al., 1975).

The deviant dimensions observed only in the parkinsonism group were short rushes of speech, rapid rate, and increases in rate overall from the beginning of the sample to the end. A correlation matrix prepared from the ten most deviant speech dimensions observed in the parkinsonism patients yielded a single cluster labeled "prosodic insufficiency" (i.e., monotony of pitch, monotony of loudness, reduced stress contrasts, short phrases, variable rate, short rushes of speech, and imprecise consonants). These speech features were assumed to result from reduced range of movements and fast repetitive movements, hence the term "hypokinetic" dysarthria (Darley et al., 1975).

The perceptual features of hypokinetic dysarthria are consistent with the underlying pathophysiology of Parkinson's disease. For example, reduced range of motion (due to muscle rigidity) may result in monopitch, monoloudness, reduced stress, variable rate, short rushes of speech, and imprecise consonant articulation. Inappropriate or excessively long silences (i.e., pauses) may result from bradykinesia (Yorkston et al., 2000). Such rate abnormalities are a distinctive feature of hypokinetic dysarthria. Syllables are often rapid or accelerated, and are typically produced with a reduced range of articulatory excursions (Duffy, 1995).

Speech characteristics affecting intelligibility in Parkinson's disease speakers include features of articulation, rate, and fluency. Imprecise articulation of stop consonants often results in “spirantization,” or low frequency frication noise replacing stop gaps as a result of reduced closure between the articulators. Poor articulation also results from "articulatory undershoot," a failure of the articulators to reach their target positions (Netsell, Daniel, & Celesia, 1975). Speech rate in hypokinetic dysarthria is often variable (i.e., sometimes excessively slow, sometimes rapid). Lastly, fluency deficits include sound/syllable repetitions, difficulty initiating phonation, and palilalia (i.e., involuntary repetition of words or phrases) (Yorkston et al., 1995). These and other rate-related deficits affecting speech intelligibility will be examined more thoroughly in the following sections.

Speech Rate Characteristics Associated with Hypokinetic Dysarthria

Summary of Diadochokinetic Rates Studies

Diadochokinetic tasks are used to determine alternating motion rates (i.e., number of repetitions of a single syllable per second) and sequential motion rates (i.e., number of repetitions of a sequence of syllables per second). These tasks are useful for determining the speed and regularity of movements of the speech articulators (e.g., jaw, lips, tongue). Secondarily, they permit assessment of articulatory precision, velopharyngeal closure, and respiratory and phonatory support (Duffy, 1995). Typically, the speaker is instructed to take a deep breath and repeat a particular syllable (or sequence of syllables) for as long as possible on that one breath.

Results of syllable repetition rate studies are somewhat difficult to interpret due to methodological differences related to sample size, test stimuli, and specific dependent measures, as well as participant variables (e.g., disease severity, dysarthria severity, etc.). In general, however, findings were characterized by extreme variability in participant responding. For example, Canter (1965) reported significantly slower repetition rates for stop and glottal consonants (i.e., /ba/, /da/, /ga/, and /ha/), although some Parkinson's disease patients produced rates comparable to those of the control speakers. Dworkin and Aronson (1986) also described one patient who exhibited rates for stop consonants significantly below the normative rates. Gurd, Bessell, Watson, and Coleman (1998) reported significantly slower rates for /dʌ/, /lʌ/, /mʌ/, /hʌ/, and /mʌ kʌ lʌ/, but not for /gʌ/, /bʌ/, or /bʌdʌgʌ/. However, the response patterns of the PD speakers were highly variable. Kreul (1972) reported normal rates for stop consonants, but significantly reduced rates for vowels (suggesting the presence of phonatory deficits).

Several other studies, however, yielded syllable repetition rates within normal limits. For example, Ludlow and Bassich's (1983) Parkinson’s disease speakers exhibited normal overall rates, but significantly more variability. However, separate data for diadochokinesis and sentence imitation tasks were not reported. In a later investigation, these authors also observed normal syllable repetition rates in the Parkinson's disease group, although 25% of these individuals exhibited slower than normal rates (Ludlow, Connor, & Bassich, 1987). Connor, Ludlow, and Schultz (1989) found that although duration of isolated syllables was significantly longer for the Parkinson's disease group, the rates of repeated productions of these same syllables were within normal limits.

Hirose, Kiritani, Ushijima, Yoshioka, and Sawashima (1981) observed somewhat rapid repetition rates of several monosyllables in their study of two Parkinson's disease patients. Although group norms were not provided, the findings provided a physiological correlate of the hypokinetic speech pattern, revealing disturbances in the firing pattern of articulatory muscles which may have resulted in the reduced range of movements. Confirming these kinematic results acoustically, Caligiuri (1989) observed normal articulatory movement times, but significantly lower amplitudes and velocities. This suggested that incomplete articulatory movements may contribute to the perception of normal or fast rate in speakers with Parkinson's disease.

Similarly, Ackermann, Hertrich, and Hehr (1995) reported normal mean rates for stop consonants, but significant variability within the Parkinson's disease group. However, a high percentage of incomplete oral closures suggested that speakers compensated for slow articulatory movements by reducing the amplitude of these movements. These authors later reported similar findings with two Parkinson's disease patients who exhibited repetition rates at the upper and lower limits of the normal range, respectively (Ackermann, Konczak, & Hertrich, 1997). The two speech patterns identified (i.e., "speech hastening" and "impaired self-pacing") may have helped to reconcile previous findings of both slowed and increased diadochokinetic rates among Parkinson's disease patients. Both participants, however, produced faster repetitions (when instructed to do so) with reduced lip displacement, providing further evidence of articulatory undershoot. Kegl, Cohen, and Poizner (1999) observed a similar failure to achieve "articulatory" closure, specifically pertaining to the vocal folds. Normal voice onset times (VOT) suggested adequate initiation of phonation, contrary to previous findings (e.g., Kreul, 1972). However, longer voiced segments within syllables may have been used as a compensatory strategy to avoid repeated initiations of phonation.

Sentence Tasks

In the first in a series of experiments, Ackermann and Ziegler (1991) obtained perceptual and acoustic speech measures from 12 Parkinson's disease patients, 12 young normal speakers, and 12 elderly normal speakers. Twelve sentences produced imitatively were rated on a seven-point scale of dysarthria severity. Acoustic measures included mean syllable duration of four syllables from each test sentence, and intensity during closure (IDC) of the stop-plosive /p/. This latter variable was ingeniously created as a physiological measure of incompleteness of closure (i.e., “undershooting), as lower values indicated less complete lip closure (i.e., less intensity of the speech signal). Results yielded no significant group difference for mean syllable duration, and no significant correlation between mean syllable duration and degree of dysarthria severity. However, the Parkinson's disease group did obtain significantly higher IDC scores than both control groups. There was also a significant correlation between perceived dysarthria severity and IDC score (Ackermann & Ziegler, 1991).

This preserved syllable rate (similar to findings of Ludlow et al., 1987) was accompanied by incomplete oral closure in most Parkinson's disease speakers, indicating reduced amplitude of lip movements. Despite bradykinesia, these individuals seemed to produced normal syllable rates at the expense of movement excursion. This "trade-off" between rate and articulatory precision is similar to that often made with handwriting. That is, the micrographia often observed in Parkinson's disease is analogous to hypokinetic speech in that smaller movement excursions are used to compensate for the inability to execute high velocity strokes (Ackermann & Ziegler, 1991). The “speed-accuracy trade-off” is well known from normal speech production, as increased speech rate is often achieved by reducing movement amplitudes rather than speeding up the movements themselves (Kent, 1983).

The abilities of nine Parkinson's disease speakers to vary their rates from slowest possible to fastest possible was investigated by Volkmann, Hefter, Lange, and Freund, (1992). Speakers read the same sentence ten times at increasingly faster rates. Measures taken were total sentence duration, pause duration, and interpause utterance duration. The investigators then calculated speech rate (in syllables per second), articulation rate (i.e., speech rate minus pauses), variability of speech rate (i.e., the difference between maximal and minimal rates of the sentence), and pause percentage (i.e., percentage of time devoted to pauses in the test sentence).

Results revealed significantly reduced speech rate, articulation rate, maximal syllable rate, and variability of speech rate for the Parkinson's disease speakers. However, minimal syllable rate and pause percentage values were not significantly different from those of the control speakers. Therefore, the slowing of speech could not be explained by increasing pause duration. The correlation was weak between pause percentage and speech rate ($r = -.03$), but strong between articulation rate and speech rate ($r = .96$). A significant correlation between duration of speech segments and total sentence duration indicated that speech rate was controlled primarily by phoneme duration (r = .86). Lastly, no significant correlation between disease severity and speech timing parameters was observed (Volkmann et al., 1992).

Thus, the Parkinson's disease patients exhibited difficulty in modifying their speech rates. This did not involve altering pause duration, but did appear to involve the timing of articulation. The slowing of absolute speech rate was attributed to the patients' limited capacities to vary syllable duration. In other words, most of the Parkinson's disease speakers presented problems in changing the relative durations of segments within a sentence (Volkmann et al., 1992).

LeDorze, Ryalls, Brassard, Boulanger, and Ratte (1998) examined the relationship between rate and intelligibility ratings (i.e., an indication of dysarthria severity). For ten speakers with Parkinson's disease and 20 control participants, intelligibility of spontaneous speech and reading samples was judged using a seven-point rating scale. Test stimuli were 20 sentence pairs (e.g., declarative and interrogative versions of the same sentence). Both groups exhibited mean sentence rates of 4.7 syllables per second, and both groups produced interrogatives significantly faster than declaratives. In a previous paper, the authors hypothesized that interrogatives are produced more quickly in order to conserve residual air to support the rise in fundamental frequency needed to produce a question (LeDorze, Ouellet, & Ryalls, 1994). The authors also noted that although most of the Parkinson's disease speakers spoke at rates within the normal range, higher speech rates were moderately correlated with lower intelligibility scores (r = 0.649 for declaratives, r = 0.620 for interrogatives). These results should be interpreted with caution, however, as intelligibility ratings were based on spontaneous speech and reading samples rather than on the sentence task used during the experiment.

Fraile and Cohen (1999) further evaluated the apparent voicing control deficits observed in Parkinson's disease (i.e., continuous phonation and reduction of pause duration). Twenty-one patients and eleven control speakers produced sentences imitatively in three linguistic modes (i.e., interrogative, imperative, and declarative intonation). Measures taken included total sentence duration, total number of pauses, and ratio of total pause duration to total sentence duration. Significant main effects of group for number of pauses and the "pause to total" ratio revealed that the mean number of pauses and their relative duration were lower for the Parkinson's disease patients than for the control speakers (Fraile & Cohen, 1999).

Thus, the speakers with Parkinson's disease demonstrated a significant reduction of voiceless periods despite normal total sentence durations. The deficit, therefore, appeared to be a problem with the temporal organization of sequences of speech movements. Again, this may have resulted from difficulty inhibiting laryngeal activity. Alternatively, it may have served as a compensatory strategy to maintain a normal overall speech rate by minimizing pause time (Fraile & Cohen, 1999).

<u>Summary of Sentence Rate Studies</u>

As discussed in the previous section, Ludlow and Bassich's (1983) Parkinson's disease speakers exhibited normal but highly variable sentence rates. However, separate data for the diadochokinetic and sentence imitation tasks were not provided. Ackermann and Ziegler (1991) also used a sentence imitation task, with results yielding no significant group difference for mean syllable duration. However, the Parkinson's disease group did obtain significantly higher incomplete closure scores, indicating reduced lip movement amplitude. That is, the Parkinson's disease speakers seemed to produce normal syllable rates at the expense of movement excursion. In a third study using a sentence imitation task, Fraile and Cohen (1999) found that pauses were less frequent and shorter in duration for the PD speakers than for the control speakers. Thus, the Parkinson's disease group demonstrated a significant reduction of voiceless periods, but normal total sentence duration. This may have reflected the use of continuous phonation to compensate for a difficulty with inhibition of laryngeal activity, as was posited by Kegl et al., (1999).

Using a sentence reading task, Ludlow et al. (1987) observed significantly less change in sentence duration (from regular to fast) in the Parkinson's disease speakers, despite normal sentence rates. Connor et al. (1989) and LeDorze et al. (1998) also reported normal sentence rates. In contrast, Volkmann et al. (1992) reported significantly reduced speech rate, articulation rate, maximal syllable rate, and variability of speech rate during sentence reading. However, relatively slow overall rate apparently resulted from slow articulation rate rather than excessive pause duration. Thus, the Parkinson's disease exhibited slow articulatory gestures as well as an impaired ability to modify their overall speech rates when instructed to do so.

Reading Passages

As part of the seminal investigation discussed above, Canter (1963) measured the speech rates (in word per minutes, or WPM) of 17 Parkinson's disease patients during a paragraph reading task. Median reading rates were 172.6 WPM for PD speakers and 177.6 WPM for the control speakers. Although this difference did not reach statistical significance, there was a great deal of variability observed in the rates of the PD speakers. For example, two patients spoke at 69.6 and 70.2 WPM, respectively, and another patient spoke at 249.6 WPM. Similar findings were reported for number of pauses, mean pause length, mean phrase length, and mean syllable duration (i.e., no significant group differences, but wider variability in the PD group). Canter's

(1963) findings suggested that although PD speakers as a group do not differ from normal speakers in terms of rate, there are some PD speakers who deviate markedly and for whom a reduced or excessive rate may be an important aspect of their speech deficits.

Metter and Hanson (1986) obtained acoustic and perceptual speech measures from ten Parkinson's disease patients during a reading task. Acoustic measures included speaking rate and phonation time. Perceptual ratings of intelligibility, dysphonia, articulation, prosody, and hypernasality were summed to produce an index of dysarthria severity. The control speakers' rates ranged from 118-186 WPM, while the PD speakers' range of 77-263 WPM revealed wide variability. Levels of statistical significance, however, were not reported. Speech rate did not relate significantly to either disease severity or dysarthria severity. However, normal speech rates were not observed in speakers with either severe Parkinson's disease or severe dysarthria. Mild to moderate dysarthria severity appeared to be associated with relatively normal rates, which either increased or decreased with increasing dysarthria severity. The authors recommended that the variability in individual performance be carefully considered during treatment (Metter & Hanson, 1986).

Spontaneous Speech

Illes, Metter, Hanson, and Iritani (1988) instructed ten speakers with Parkinson's disease and ten control speakers to produce several minutes of decontextualized spontaneous speech about familiar topics (e.g., their occupations). For the spontaneous speech sample, investigators measured word rate (in WPM) and verbal rate (i.e., the number of words minus total pause time). No significant group difference was observed for verbal rate. However, the Parkinson's disease group did exhibit a significantly slower mean word rate, suggesting that excessive pause time resulted in slower overall rate. Also, the PD group produced a significantly greater number of pauses per minute, as well as a significantly greater number of pauses exceeding two seconds in duration. These hesitations were more prevalent at sentence initial position, suggesting possible voicing initiation problems (Illes et al, 1988).

Tjaden (2000) observed that both articulation time and pause time seem to contribute to listeners' impressions of speaking rate. For example, speech with many long pauses is often perceived to be slower than speech with fewer, shorter pauses. Similarly, speech produced with a rapid articulatory rate is perceived as faster than speech with a slower articulatory rate. In this investigation, Tjaden (2000) analyzed speech samples (i.e., monologues about home, family, or work) without pauses based on previous findings suggesting that the characteristics of "speech runs" are most influential in determining perceptual impressions of speech rate (e.g., Grosjean & Lane, 1976). Results revealed habitual reading rates of 4.2 syllables per second (SPS) for the nine PD speakers, and 3.8 SPS for the ten control speakers. Spontaneous speech rates were 4.7 SPS for the PD group, and 4.5 SPS for the control group (Tjaden, 2000).

Thus, the Parkinson's disease speakers performed both tasks somewhat faster then the unimpaired speakers, but remained within one standard deviation unit of normative mean. Because pauses were removed from the analyzed samples, their impact on the overall speech rates of the Parkinson's disease speakers could not be determined. Tjaden (2000) inferred, however, that pause characteristics may have increased overall rates, citing studies reporting relatively short pauses in the speech of Parkinson's disease speakers (e.g., Hammen & Yorkston, 1996). It is also possible, however, that more frequent and/or longer pauses may have been evident due to voice initiation problems, as found by Illes et al. (1988). Such pause characteristics may have actually reduced overall rates produced by the Parkinson's disease speakers.

Summary of Connected Speech Studies

Consistent with his findings from syllable repetition tasks, Canter (1963) observed normal reading rates and pause characteristics, but much wider variability in the Parkinson's disease group. Metter and Hanson (1986) also reported marked variability among PD speakers, as well as a greater percentage of pause time for a given speech rate. However, group means and levels of statistical significance were not reported. Illes et al. (1988) found no significant group difference for articulation rate during spontaneous speech production. However, the PD group did exhibit a significantly slower mean word rate, suggesting greater pause time then the normal speakers. Tjaden (2000) measured rates of reading and spontaneous speech samples without pauses. Her participants with Parkinson's disease performed both tasks somewhat faster, but did so within one standard deviation unit of the mean.

Summary and Implications

In general, results of the speech rate studies detailed in the preceding sections support the conclusion by Darley et al. (1975) that most Parkinson's disease patients speak at a rate which is at least "somewhat deviant." Methodological differences notwithstanding, the investigations reviewed give the overall impression of marked variability (both inter-subject and intra-subject) of the speech rate characteristics of these patients. Several participant and experimenter variables potentially contributing to this variability will be delineated in this section.

First, physiological evidence presented by Hirose et al. (1981) revealed disturbances in the firing patterns of articulatory muscles of Parkinson's disease patients. Antagonistic muscle pairs, normally firing in sequence to maintain the level of muscle tone necessary for production of a particular speech sound, appear to discharge simultaneously in Parkinson's disease patients. This abnormality, possibly causing muscle rigidity, results in unpredictable levels of muscle contraction. In addition to yielding variable movement times, this phenomenon also appears to result in articulatory "undershoot," This, in turn, leads to the perception of imprecise consonant articulation as well as the perception of increased speaking rate (Hirose et al., 1981; Netsell et al., 1975).

Perhaps due to this impairment in neuromuscular responding, many Parkinson’s disease patients speak with a "festinating" pattern, characterized by a rapid acceleration of articulatory movements (Adams, 1997; Netsell et al., 1975; Yorkston et al., 2000). This speech pattern is analogous to the gait of some patients, wherein walking is initially slow and laborious but becomes increasingly rapid and uncoordinated. This phenomenon may account for findings of slow isolated syllable productions but normal or fast syllable repetition rates (e.g., Connor et al., 1989). It may also help explain findings of rapid articulation rates among Parkinson’s diease speakers in several studies (e.g., Tjaden, 2000; Volkmann et al., 1992).

Also related to muscle rigidity is the difficulty initiating voicing experienced by some patients. For example, Logemann et al. (1978) reported that 89% of 200 Parkinson’s disease patients assessed exhibited voice disorders, and 20% used excessive pauses. These observations suggest disturbances in the laryngeal musculature resulting in difficulty initiating phonation or timing phonation with articulatory movements. Several studies reported deviant, albeit variable, pause characteristics in the speech of PD speakers (e.g., Illes et al., 1988; Metter & Hanson, 1986), perhaps reflecting difficulty initiating phonation. Other findings of slower repetition rates of vowels than of stop consonants (Kreul, 1972), as well as the detection of incomplete vocal fold closure (Kegl et al., 1999), provided further evidence of phonatory deficits.

Interestingly, Fraile and Cohen (1999) observed a significant reduction of voiceless periods in sentences, possibly resulting from difficulty inhibiting laryngeal activity. This may have served as a compensatory strategy to maintain a normal overall speech rate by decreasing pause time (Fraile & Cohen, 1999). Alternatively, the strategy may have been used by speakers to avoid reinitiating phonation. Similar results were observed during syllable repetition tasks (Kegl et al., 1999). That is, incomplete vocal closure may have been used to avoid the difficulty of initiating phonation by maintaining a continuous level of vocal fold activity (i.e., an "undershooting" of the vocal folds). The use of such compensatory strategies is certainly plausible, given the fact that "continuous phonation" is actually a "fluency-enhancing behavior" often taught to developmental stutterers exhibiting severe laryngeal blocks (Bloodstein, 1995).

Additional variability in the speech rates of Parkinson's disease patients may be attributed to differences in disease severity and/or dysarthria severity. Several studies reported significant correlations between speech measures and Parkinson's disease or dysarthria severity. For example, Gurd et al. (1998) found syllable repetition rates to be correlated with disease severity, supporting Canter's (1965) documented correlation coefficient of 0.75 between diadochokinetic rates and "over-all speech adequacy" (which often deteriorates as the disease progresses; Adams, 1997). Dworkin and Aronson (1986) also reported moderate but statistically significant correlations between alternating motion rates and intelligibility ratings. That is, speakers with slower rates exhibited poorer intelligibility than those who produced more appropriate rates. Lastly, Metter and Hanson (1986) reported that normal speech rates were not observed in speakers with either severe Parkinson's disease or severe dysarthria, although correlations were not statistically significant.

Finally, the inconsistent findings among many speech rate investigations may be partially attributed to the fact many the majority of the studies utilized group difference designs. That is, mean speech rate (for example) of a group of Parkinson disease patients were compared to mean rate of a group of unimpaired speakers. Inferential statistics were then employed to determine the probability that the observed difference in rate was simply due to random sampling error, rather than to group membership. The fact that many authors were compelled to report the performance of individual participants within groups of Parkinson's disease speakers underscores one of the shortcomings of the group difference design. That is, group designs often misrepresent individual participant behavior (Christensen, 1988). This was evident in the results of many studies discussed, as normal mean speech rates for groups of Parkinson's disease patients obscured the fact that individual speakers often spoke at significantly faster or slower rates (e.g., Ackermann et al., 1995; Canter, 1963; 1965; Gurd et al., 1998; Ludlow et al., 1987).

A Rationale for Rate Control for Dysarthric Speakers

The published literature presented seems to confirm the long-standing clinical observation that Parkinson's disease patients exhibit wide variability in speech rate (both intra- and inter-subject), a high prevalence of articulatory imprecision (e.g., Darley et al., 1975; Logemann et al., 1978), and difficulty modifying their speech rates when necessary (e.g., Ludlow et al., 1987). These findings provide ample justification for attempting rate control strategies in an effort to not only reduce overall speech rate, but also improve intelligibility and speech naturalness.

As mentioned in the previous chapter, rate control offers several benefits as a treatment for dysarthric speech. Such strategies improve intelligibility by increasing articulatory precision, help to coordinate various speech processes, and, in some cases, minimize the need to reinitiate vocal fold activity. Lastly, reduced speaking rate allows the listener more processing time to "fill in the gaps" when attempting to interpret a distorted speech signal. Listeners often perceive rate to be excessive because of articulatory distortions (i.e., "blurring") present in dysarthric speech. When the listener's perception of phonemes becomes difficult due to imprecise articulation, speech rate is often judged to be faster than it actually is (Yorkston et al., 2000). Additionally, some rate control techniques (e.g., alphabet boards) provide the listener with visual information to aid in comprehension of the message (Beukelman & Yorkston, 1977; Crow & Enderby, 1989).

Thus, speech rate is generally thought to be "excessive" for a particular speaker when it is beyond the capabilities of that person's neuromuscular control system. For example, a Parkinson' disease patient may actually be speaking more slowly than unimpaired speakers, but may still be speaking at an excessive rate given his or her neuromotor impairment. Appropriate intervention may result in a further rate reduction (Yorkston et al., 2000). In such cases, the primary goal is not "normal" rate, but "compensated intelligibility." In other words, the key question is not how the speaker's rate compares to the normative value, but whether his or her speech can be made more intelligible and/or more "natural" by modifying rate (Yorkston et al., 1988). Several interventions used to accomplish these objectives will be discussed in the following sections.

Rate Control Interventions for Dysarthric Speech

The purpose of this second major division of the present chapter is to provide a critical analysis of the published rate control intervention efficacy research. Interventions discussed represent a hierarchy from "rigid" strategies which impose maximal rate control (e.g., pacing boards, alphabet boards) to techniques allowing for greater speech naturalness and independent rate control (e.g., rhythmic cueing). All treatment procedures will be critiqued with respect to effectiveness in reducing speech rate, impact on intelligibility and prosody, cost, training requirements, specific alterations made to speech rate (e.g., articulation time, pause time), and other relevant dimensions.

Pacing Boards

Helm (1979) documented the management of palilalia using a pacing board. Palilalia is a speech disorder in which a word, phrase, or sentence is repeated with increasing rapidity, in some cases becoming almost inaudible. This behavior is thought to be analogous to the "festinating gait" often seen in Parkinson's disease patients, in which they have difficulty initiating walking, but walk in an increasingly rapid and uncontrolled manner once they get started (Duffy, 1995). Helm (1979) observed that many of these patients have no difficulty walking up and down stairs or across lines painted at intervals on the floor, because these tasks substitute reactive movements for automatic movements (Helm, 1979).

The participant in this investigation was a 54-year-old male with a "parkinsonian syndrome," exhibiting palilalia of such severity that he was essentially noncommunicative. However, this patient did not exhibit palilalia during categorical naming tasks, during which he spoke in a "one-syllable-at-a-time" manner. Therefore, Helm (1979) attempted to improve this patient's communicative effectiveness by using a "pacing board." This apparatus was 13" by 2," with eight colored segments separated by wooden dividers. While tapping his finger on the board from left to right, segment to segment, the participant spoke syllable-by-syllable without exhibiting palilalia. However, no empirical data on any speech-related behaviors (e.g., rate, intelligibility, repetitions per minutes, etc.) were reported.

Lang and Fishbein (1983) documented the use of a similar pacing board to remediate speech deficits in addition to palilalia. The participant was a 53-year-old male Parkinson’s disease patient exhibiting rapid speech, palilalia, and frequent hesitations averaging six seconds in duration. These rate and fluency deficits resulted in an overall fluent speech rate which was 30% of normal rate, with a marked reduction in intelligibility. The authors attempted to use a pacing board to produce syllabic speech (i.e., equal duration alotted to each syllable). While using the board, the patient's rate of "coherent speech" increased to 63% of normal rate, and the disfluent behaviors were “virtually eliminated” (although no data regarding this reduction were reported). In addition, neither percentage of intelligibility nor follow-up data were reported. Lang and Fishbein (1983) concluded by recommending a trial use of the pacing board before attempting to use other rate control strategies because of its relatively low cost, ease of use, and minimal training requirements.

Alphabet Board Supplementation

In a report by Beukelman and Yorkston (1977), two dysarthric patients who previously spelled out entire messages on an alphabet board were taught to use a system whereby they pointed to the first letter of each word as they spoke. The first participant (P1) was a 61-year-old male with severe speech deficits secondary to a brain stem cerebral vascular accident. He exhibited 10-15% intelligibility during conversational speech, and communicated primarily by spelling out entire messages on a spelling board. This system yielded a rate of two to four words per minute, which apparently impaired listeners’ ability to retain sequences of letters and words (Beukelman & Yorkston, 1977).

The second participant (P2) was a 17-year-old male who sustained a brain stem injury during a motor vehicle accident. He progressed through a series of communication systems including a "yes/no" signal system, a picture-word board, and a spelling board allowing him to spell out four to six words per minute. His habitual speech was nearly unintelligible, but he exhibited normal auditory comprehension, vocabulary recognition, and sentence construction abilities. The investigators sought to design a system for this participant that would be more rapid than spelling board, but just as intelligible (Beukelman & Yorkston, 1977).

They devised a communication system consisting of oral speech supplemented by identification of the initial letter of each spoken word on an alphabet board. The listener repeated each spoken word after the speaker. When repeated incorrectly, the speaker shook his head negatively and repeated the word in question. If the word was still not comprehended after this repetition, the speaker spelled out the entire word. Instructions designed to resolve communication breakdowns included four phrases: “END OF SENTENCE,” “END OF WORD,” “REPEAT,” and “START AGAIN.” The speaker pointed to these phrases whenever he felt it necessary to enhance communication efficiency. Instructions to unfamiliar listeners explaining speaker and listener roles in the interaction were mounted on reverse side of the alphabet board.

Listening judges viewed videotaped samples of the speakers producing 20 single words and six unrelated sentences. Data were obtained on speech rate in WPM and the percentage of words correctly identified by judges. The three speaking conditions compared were unaided speech, aided speech, and “aided and concealed” (i.e., the portion of video monitor showing the alphabet board was hidden from the judges).

Results revealed that P1 exhibited an unaided rate of 39 WPM, an aided rate of 18 WPM, and four WPM using the original spelling method. Participant 2 produced 86 WPM unaided, 28 WPM aided, and six WPM with the spelling method. Results for intelligibility measures indicated that single words were generally less intelligible than words produced in a sentence context, suggesting that contextual cues in the form of grammatically complete sentences increased the intelligibility of both speakers (Beukelman & Yorkston, 1977). However, percent intelligibility for single words was not reported for either participant.

Participant 1's sentence intelligibility was 16% unaided, 60% aided, and 19% in the "aided and concealed" condition. This suggested that merely reducing P1's speech rate had little effect on his intelligibility. The observed increases in intelligibility were apparently due to the additional information provided by the alphabet board, rather than rate reduction per se. For P2, sentence intelligibility was 33% unaided, 66% aided, and 52% "aided and concealed." In his case, rate reduction did appear to contribute to the increased intelligibility provided by the alphabet board (Beukelman & Yorkston, 1977).

It should be noted that even with the use of the alphabet board, neither subjects' sentence intelligibility ever exceeded 75%. However, the examiners observed (anecdotally) that both speakers were nearly 100% intelligible during conversation, presumably due to increased contextual information and their ability to resolve communication breakdowns by repeating or spelling entire words (Beukelman & Yorkston, 1977). This communication system attempted to bridge the gap between a spelling system and functional oral speech. It allowed the speakers to attempt functional speech earlier in treatment than their level of intelligibility would have permitted without the use of an external device (Beukelman & Yorkston, 1977).

In a similar study, Crow and Enderby (1989) sought to determine whether auditory characteristics of speech are altered when dysarthric speakers point to the initial letter of a word on an alphabet board as they speak. Subjects were six dysarthric speakers, only one of whom exhibited hypokinetic dysarthria secondary to Parkinson's disease. Speaking tasks included a single-word task (i.e., describing 20 pictures each with one word), predictable picture description (i.e., describing six pictures each with one sentence; these pictures were designed to elicit predictable sentences), and a conversational task (i.e., one-sentence responses to common conversational sentences). Half of the stimuli were recorded while speakers used the alphabet board (i.e., the "aided" condition), while half were recorded while participants spoke without use of the alphabet board (i.e., the "unaided" conditions). For each task, percentage of words correctly transcribed by listeners was calculated to obtain intelligibility measures. Phonetic transcriptions were also completed for all words and sentences produced by all speakers. Speech rate was computed in words per minute, or WPM (Crow & Enderby, 1989).

Results of intelligibility measures yielded a significant main effect for task (i.e., single words were least intelligible, predictable sentences were most intelligible), and a significant main effect for condition (i.e., “aided” was more intelligible than “unaided”). Mean intelligibility scores for the three tasks in the unaided condition were 31.8% (single words), 59.3% (predictable sentences), and 43.7% (conversational sentences). Aided intelligibility scores were 42.7%, 74.5%, and 63.0%, respectively. Although statistical significance for the rate measures was not reported, mean speech rates were 101.7 WPM (unaided) and 35.2 WPM (aided). Lastly, phonetic transcriptions revealed that across speakers, twice as many target sounds were produced in an appropriate manner with the alphabet board than without it (Crow & Enderby, 1989).

The authors concluded that because judges only listened to audiotapes without actually viewing the alphabet board, improvements in intelligibility were solely attributable to rate reduction. Such reductions may have resulted from listener variables, as well as speaker variables. For example, more time was available for the listeners to process the information provided by the speaker and comprehend the message. Also, pauses inserted into sentences may have provided the listener with more well-defined word boundaries to aid in segmenting the messages. As for the speakers, insertion of pauses, as well as increased articulation time, presumably allowed more time to plan and execute the neuromotor activities necessary for speech production (Crow & Enderby, 1989).

Visual and Auditory Feedback

Speech therapy for dysarthric speakers generally relies upon the clinician's perceptual judgments of the patient's speech production. However, it is often more beneficial for patients to monitor and modify their own speech behaviors as efficiently as possible. The use of biofeedback allowing a speaker to receive immediate and continuous information about behavior may be the most desirable method for shaping that behavior toward a desired goal (Berry & Goshorn, 1983). One such technique that was hypothesized to minimize a patient's dependency on the clinician involved using immediate visual feedback of speech events. The goal of this approach was for the speaker to visualize and judge the adequacy of a speech response according to predetermined criteria (Berry & Goshorn, 1983).

The development of electronic visual storage units in recent years has provided further treatment options for speech-language pathologists. In an investigation by Berry and Goshorn (1983), a single-subject design was used to illustrate the use of immediate oscilloscopic feedback of vocal intensity and speech rate in the treatment of a severely dysarthric individual (Berry &

Goshorn, 1983). The participant was a 60-year-old male exhibiting severe dysarthria secondary to multiple cerebral vascular accidents. His speech was characterized by irregular articulatory imprecision, rapid/variable rate, harsh/breathy phonation, excessive loudness, and reduced intelligibility. This speaker exhibited a tendency to “overdrive” his poorly coordinated speech system by speaking too rapidly and too loudly. Immediate visual feedback of intensity and rate was the treatment selected.

A total of 40 sentences (20 high and 20 low predictability items) were used to test intelligibility prior to treatment, after five weeks of treatment, and at two weeks post-treatment. Treatment was administered twice a week during 45-minute sessions. While reading or repeating sentences, the participant viewed a storage oscilloscope preset to a five-second display, and each production was channeled through an acoustic analysis system to provide immediate visual information about his speech intensity and rate (Berry & Goshorn, 1983).

Prior to each sentence production by the participant, the clinician recorded a model production in one of four colors available for tracing. A second color line was preset at a standard distance above the first to identify an upper limit of intensity. The speaker was instructed to keep his loudness level below this line, and to speak slowly enough to “fill up” more than half of the screen's horizontal (i.e., time) display. The resulting sentence production was displayed by a third color line, with the loudness limit depicted in a fourth color. The participant was then asked to judge his rate and loudness in relation to the clinician's model, although specific speech rates trained were not reported. When the speaker met the duration criteria (also not reported), a "good production" was stored on the oscilloscope. He then produced that same sentence several more times, and these productions were displayed in other colors. This allowed the speaker to visually compare his output with his own model, a technique used to promote consistency of production (Berry & Goshorn, 1983).

Listeners were presented with audiotapes of the sentences and were instructed to fill in the word most likely to occur at end of the sentence (i.e., the “key word”) and then to write down the word that was perceived. A percentage of intelligibility score (i.e., percentage of all phonemes correctly perceived by the listeners) was then calculated. Rate measurements taken were overall sentence duration, key word duration, and total pause time for each sentence (Berry & Goshorn, 1983).

Results revealed significant increases from pre-therapy to post-therapy for overall intelligibility, low predictability sentence intelligibility scores, and high predictability sentence intelligibility scores. However, overall and low predictability intelligibility scores decreased significantly during the two weeks following the end of therapy (i.e., regression was observed within two weeks of termination of therapy). Similar results were observed for overall sentence duration and total pause time. Key word duration showed no significant differences over time. There was no significant difference for average pause time for low versus high predictability sentences. There were, however, significantly longer pauses produced during low predictability sentences at post-therapy and at two weeks post-therapy than at baseline.

Results of this study suggested that although statistically significant gains were made during treatment, the patient appeared to regress somewhat within two weeks. All scores were still significantly higher than baseline scores, but were also significantly lower than measures taken immediately post-treatment (Berry & Goshorn, 1983). As the authors pointed out, no specific rate reduction strategies were taught. The participant was simply instructed to “go slower," and was given immediate visual confirmation of success or failure. The authors concluded that the speaker evidently utilized one or several components of the tasks to alter his rate. He produced key words with roughly the same mean duration, but increased the length of pauses between words. In addition, this speech containing longer pauses was more intelligible (Berry & Goshorn, 1983).

However, close inspection of the data revealed that between pre-therapy and post-therapy, mean sentence duration increased from approximately 2.9 seconds to approximately 3.8 seconds. Pause time, however, only increased from about .1 seconds to about .4 seconds (i.e., about a .3 seconds increase). Therefore, the participant must have also increased articulation time somewhat, as mean sentence duration increased by almost one second. In other words, the contribution of increased pause time to this speaker's rate reduction may have been overestimated by the authors.

Results also revealed longer pauses in sentences with fewer semantic cues (i.e., low predictability), even though the participant had no knowledge that low versus high predictability sentences were being used. Berry and Goshorn (1983) speculated that increasing the length of his pauses either allowed more time to prepare for articulatory movements, and/or allowed listeners more time to process the auditory information.

Unfortunately, because verbal clinician models were used throughout treatment, the observed reduction in speech rate cannot be attributed solely to the visual feedback provided by the oscilloscope. With respect to the oscilloscopic feedback technique itself, one significant drawback is that there does not appear to be any way to fade this visual feedback, as is possible with auditory feedback (e.g., delayed auditory feedback can be attenuated by reducing the intensity of the delayed signal). This limitation makes independent home-practice impossible (unless the patient invests in an oscilloscope). Lack of fading capability also inhibits the transfer of newly-acquired speech skills to "outside" situations (i.e., speaking without the apparatus).

These limitations notwithstanding, the use of feedback systems to monitor rate does show potential for improving speech. The Berry and Goshorn (1983) study suggested that some patients may benefit from treatment programs which provide feedback to one or more of the anatomic subsystems within the speech mechanism, specifically feedback related to prosodic variables such as duration and intensity. In a related investigation, Caligiuri and Murry (1983) compared the effectiveness of visual feedback and nonvisual feedback (Caligiuri & Murry, 1983). Treatment efficacy was based on assessments of articulatory precision, rate, prosody, and overall severity of dysarthria.

The sole participant who exhibited excessive speech rate was a 75-year-old male with dysarthria secondary to bilateral CVAs. His speech was characterized by articulatory imprecision, excessive speech rate, and reduced variability of loudness and pitch. During all feedback phases of treatment, a modeled response was provided by the clinician and stored on the upper half of an oscilloscope. The participant's responses were displayed on the lower half of the scope (Caligiuri & Murry, 1983).

The participant received four three-week treatment phases (three using visual feedback and one with no visual feedback) and one three-week "no-treatment phase." The first nine weeks of the study consisted of three visual feedback treatment phases (word duration, vocal intensity, and intraoral air pressure associated with target stress). Each phase consisted of six 40-minute sessions (i.e., two sessions per week). There were a total of 18 treatment sessions, with the no-treatment phase preceding the final treatment phase. The non-visual feedback phase did not utilize visual feedback, but used the auditory modality to determine accuracy of the speaker's responses. However, the specific manner in which this was accomplished was not delineated in the report (Caligiuri & Murry, 1983).

Treatment stimuli progressed from CV nonsense syllables to sentences. Measurements were taken six times (baseline, after each of the four phases, and post-treatment) using a reading passage and a list of 15 phrases from a contrastive stress drill. Listeners judged articulatory precision, rate, prosody, and severity. The participant achieved a score that represented the percentage of listeners selecting the post-treatment sample as more "normal" than the pre-treatment samples. According to the authors, percentage scores greater than 50% indicated that more than half the listeners judged the post-treatment sample as the "more normal sample" along the four perceptual categories (Caligiuri & Murry, 1983).

Results indicated that the participant failed to score over 50% after the no-visual feedback condition for any of the categories (i.e., articulatory precision, rate, prosody, or overall severity). After the visual feedback condition, he scored 78% for rate, 50% for prosody, 25% for articulatory precision, 25% for severity. Visual feedback percentages were based on the combined effects of the three phases (i.e., word duration, vocal intensity, and intraoral air pressure).

The authors astutely pointed out that because the participant received nine weeks of visual feedback before the non-visual feedback phase, improvement may have reflected the amount of time spent in treatment rather than the type of treatment used (Caligiuri & Murry, 1983). While no attempt was made to combine visual and auditory feedback, the authors felt it likely that the benefit of auditory monitoring was present through all treatments. Most treatment gains were observed after nine weeks of treatment (i.e., 18 sessions). In contrast, Berry and Goshorn's (1983) participant demonstrated improved rate control after ten sessions. However, inter-listener reliability was relatively low in the Caligiuri and Murry (1983) study, suggesting that the perceptual ratings employed were either too stringent or too subjective.

Also, the dependent measures were taken from a reading passage and contrastive stress drills. These tasks were likely at a different level of complexity for the speaker (both motorically and linguistically) than the tasks used in treatment (i.e., CV nonsense syllables and sentences). Thus, these measures may not have been accurate indicators of gains made in therapy. Other limitations of Caligiuri and Murry's (1983) design included an absence of objective rate and intelligibility measures, and the inclusion of three visual feedback phases but only one non-visual feedback phase. In addition, insertion of the no-treatment phase before the non-visual treatment phase may have resulted in potential confounds such as history or maturation effects (Barlow & Hersen, 1984), or a deterioration of skills acquired during the previous treatment phases.

Based on results suggesting that visual biofeedback may be useful in treating prosodic disorders in selected patients (e.g., Berry & Goshorn; Caligiuri & Murry, 1983), LeDorze, Dionne, Ryalls, Julien, and Ouellet (1992) investigated the use of computer-assisted auditory and visual feedback to treat prosodic deficits. They utilized a single-subject multiple baseline design across behaviors with a 74-year-old woman exhibiting hypokinetic dysarthria secondary to Parkinson's disease. This patient's speech was characterized by a reduced pitch range, inappropriate pitch level, and rapid rate. This rate resulted in poor articulation and speech that was perceived as “moderately unintelligible” (LeDorze et al., 1992).

Baseline measures of three behaviors (i.e., intonation, mean fundamental frequency, and rate) were taken throughout study, and the behaviors were treated sequentially. These dependent measures were obtained with the IBM Speech Viewer, a computerized speech analysis system which provided on-line measures of acoustic parameters. The participant produced 40 pairs of declarative and interrogative sentences, each sentence consisting of five to seven syllables.

During treatment, the patient produced various words, phrases, and sentences. She received visual and auditory feedback on the computer screen following each production. In addition, feedback pertaining to the adequacy of each production was provided the clinician. By using the Speech Viewer, the clinician was able to model and record the desired behavior in the top half of screen, while the patient's speech productions were recorded in bottom half for comparison. Audio playback of the productions was also possible with this apparatus. Traditional therapy techniques that facilitated production of each behavior were employed (e.g., increasing expiratory muscle force). Two to three 60-minute sessions were conducted each week for nine weeks. Treatment objectives were gradually increased until the pre-specified criteria (which were not described in detail) were reached (LeDorze et al., 1992).

Results indicated that speech rate for declarative sentences ranged from 3.8-4.7 SPS during the extended baseline. The criterion for rate was fixed at 3.8 SPS (i.e., two standard deviations below the subject's mean of 4.3 SPS during baseline). After three sessions, there was reportedly a "substantial decrease" in rate. Follow-up measures taken ten weeks post-therapy revealed a rate of 3.9 SPS (LeDorze et al., 1992). This rate was slightly faster than the best results obtained during treatment, but slower than the mean rate recorded prior to therapy. Also observed was a statistically significant improvement in word intelligibility in sentences from 86% (baseline) to 96% (post-therapy). However, no intelligibility measures were taken during the follow-up session.

The authors concluded that their treatment caused improvement when attention was given to a specific behavior. There was a total of 25 sessions, and measurable improvement was observed after ten weeks (i.e., comparable to results obtained by Caligiuri and Murry, 1983). On-line measures with the Speech Viewer were used to guide treatment, as well as document its effectiveness. Results suggested that immediate visual and auditory feedback may be effective in improving prosody (LeDorze et al., 1992). As in the studies described above (i.e., Berry & Goshorn, 1983; Caligiuri & Murry, 1983), however, the relative effects of the visual and auditory feedback were not demonstrated experimentally.

Cueing/Pacing Strategies

Yorkston and Beukelman (1981) evaluated several treatment options for dysarthric speakers designed to improve intelligibility and prosody. One such technique was rhythmic cueing, a "behavioral" rate control method often used as a "transition" between rigid rate control techniques (e.g., the pacing board) and self-monitoring of speech rate (Yorkston & Beukelman, 1981). By pointing to words to be read by the speaker, the clinician paced the reading of the passage by imposing a slow rate with "appropriate" pausing and phrasing. This resulted in more natural prosody than the "one-word-at-a-time" quality of the pacing board, which had been shown to allot equal duration to all syllables and yield relatively long interword pause times (Helm, 1979; Lang & Fishbein, 1983). To facilitate natural prosody, the clinician cued stressed syllables more slowly than unstressed syllables, and gave greater emphasis to more "prominent" words (Yorkston & Beukelman, 1981).

Participants were instructed to follow the imposed rhythm, and were permitted to lag behind but not "get ahead" of the clinician. As participants became more proficient at controlling their rates, the cueing gestures were "faded by gradually diminishing and then eliminating them" (Yorkston & Beukelman, 1981). However, specific fading procedures were not described, making replication of this intervention difficult.

One participant, for example, read at a rate of 137 WPM prior to therapy, well below the normal rate of 160-170 WPM for adults (Fairbanks, 1960). However, this rate was still too rapid for this patient's neuromotor speech system, as his speech was characterized by limited articulatory movement and poor intelligibility. Therefore, rhythmic cueing was selected to reduce his speech rate. After four weeks of treatment, the participant maintained a rate of 80 WPM, and achieved articulatory targets adequately. Following seven months of treatment, his speaking rate increased to 134 WPM, yielding a 99% intelligibility score (Yorkston & Beukelman, 1981). The principles described were drawn from clinical experience, but the authors conceded that further research was needed to verify and refine such clinical cueing/pacing procedures (Yorkston & Beukelman, 1981).

A computerized version of this cueing strategy was utilized by Yorkston, Hammen, Beukelman, and Traynor (1990). The speaking rates of four speakers with hypokinetic dysarthria and four control speakers were reduced to 60% and 80% of their habitual rates using four different pacing strategies. The effects of these various strategies on sentence intelligibility and speech naturalness were examined experimentally (Yorkston et al., 1990). Sentence intelligibility was measured with eleven sentences, and was defined as the percentage of words correctly produced. For the speech naturalness measure, a three-sentence sample extracted from each reading passage was judged for intonation, voice quality, rate, rhythm, and intensity using a seven-point interval scale (i.e., 1 = most natural, 7 = least natural) (Darley, Aronson, & Brown, 1975).

Reading rates were controlled using a computer software program called PACER, which allowed the clinician to enter reading passages into the computer and select desired target rates. Each participant read under nine different conditions (i.e., habitual rate and four rate control strategies at two rates each). Presentation style (i.e., additive and cued) and timing relationships (i.e., metered and rhythmic) were manipulated. Additive pacing, considered the most rigid style, involved presentation of the reading passage on the computer screen one word at a time. Cued pacing, a less rigid rate control method, involved the entire passage appearing on the screen, with a cursor automatically cueing each word according to the target speaking rate selected by the clinician. During the metered pacing conditions, each word was given equal duration (similar to metronome pacing). In contrast, rhythmic pacing more closely simulated "natural" speech, as stressed syllables more were allotted more time than unstressed syllables (similar to what clinicians typically do during "finger-cueing;" Yorkston & Beukelman, 1981).

During the Additive-Metered Condition (AM), the reading passage was presented on the screen one word at a time, with each word alloted equal duration. In the Additive-Rhythmic Condition (AR), timing patterns simulated normal speech, as the computer program assigned a relative durational value to each word by estimating the number of syllables in a word. In the Cued-Metered Condition (CM), the entire reading passage was presented on the screen. Activation of a switch initiated underlining of each word with equal duration at a rate selected by examiner. Lastly, the Cued-Rhythmic Condition (CR) was similar to AR, except that the entire passage was presented on the computer screen (Yorkston et al., 1990).

Results obtained included mean habitual rates of 201 WPM for the dysarthric speakers and 190 WPM for the control group. Under the rate control conditions, target rates were achieved within 10%. During the naturalness task, mean habitual rates were 205 WPM for the dysarthric speakers, and 190 WPM for the control group. Again, rate control reduced speech rates to target rates within 10%. Thus, the PACER software effectively controlled speech rate for both groups of speakers in a relatively short period of time (Yorkston, Hammen, Beukelman, & Traynor, 1990).

Results for sentence intelligibility revealed that the dysarthric speakers increased their intelligibility from 60.7% at their habitual rates to 81.2% at while speaking at 60% of their habitual rates. This suggested a strong rate effect on sentence intelligibility. Next, the differential effects of the various rate control strategies on intelligibility were assessed. Results revealed that the metered conditions produced higher mean sentence intelligibility scores for both groups of participants than the rhythmic conditions (Yorkston, Hammen, Beukelman, & Traynor, 1990). Sentence intelligibility scores were ranked across the four strategies according to the proportion of time that each strategy produced the highest sentence intelligibility: CM (54%), AM (31%), AR (15%), and CR (0%). In sum, the pacing strategy that placed the entire reading passage on the computer screen and allotted the same amount of time for production of each word (i.e., CM) yielded the greatest intelligibility.

Results for speech naturalness indicated that the mean naturalness ratings for the control group decreased from 1.8 (at habitual rate) to 2.7 (at 60% of habitual rate). Ratings for the dysarthric speakers decreased only slightly from 4.3 (habitual rate) to 4.5 (60% rate). This suggested that the habitual speech of the dysarthric speakers was perceived as quite unnatural, and rate reduction did not result in substantial further deterioration. Normal speakers, however, were judged as less natural-sounding when they slowed their rates. For both groups, the metered strategies yielded the lowest naturalness scores, but this trend was most marked for the control speakers. Interestingly, the rhythmic conditions resulted in almost identical naturalness scores as habitual rate for dysarthric speakers. This was averaged across rates (i.e., 60% and 80%) and presentation style (i.e., cued and additive) (Yorkston, Hammen, Beukelman, & Traynor, 1990).

In a related experiment, the speech rates of normal speakers and dysarthric speakers were reduced with the PACER software at various rates using a variety of presentation strategies (Hammen, Yorkston, & Beukelman, 1989). The primary goal of this phase of the project was to determine specifically how speakers achieved reduced rates. This particular study sought to determine whether normal speakers and dysarthric speakers exhibit similar durational characteristics at habitual rate, and what specific adjustments they make in order to reduce rates. The impact of the type of rate control strategy used upon duration characteristics (i.e., pause time versus articulation time) was also investigated (Hammen, Yorkston, & Beukelman, 1989).

Four dysarthric speakers and four normal speakers read a 60-word, 77-syllable portion of a paragraph under nine different conditions: habitual rate, then Cued-Metered (CM), Additive-Metered (AM), Cued-Rhythmic (CR), and Additive-Rhythmic (AR) at both 80% and 60% of habitual rate. Measures of speech duration, pause duration, and number of pauses were obtained from a three-sentence sample extracted from the middle of the paragraph.

Results indicated that at habitual rate, the control group achieved a mean overall rate of 189 syllables per minute (SPM), 280 SPM without pauses, 78% speech duration (i.e., articulation time), 22% pause duration, and 2.5 pauses in the sample. The dysarthric speakers demonstrated a mean overall rate of 200 SPM, 325 SPM without pauses, 65% speech duration, 35% pause duration, and 2.7 pauses. Therefore, the dysarthric speakers demonstrated greater articulation rate as well as faster overall rate. These results confirmed the perception of excessively rapid speech rates in patients exhibiting hypokinetic dysarthria (Darley et al., 1975; Duffy, 1995; Netsell et al., 1975; Yorkston et al., 1995; Yorkston et al., 2000). The dysarthric speakers reached the target rate within four percent during the 80% condition, and within one percent for the 60% condition. In other words, the PACER program was again effective in controlling speech rate at targeted levels (Hammen, Yorkston, & Beukelman, 1989).

In order to examine the specific adjustments made by speakers when they reduced their rates, data were averaged across pacing strategies. At 80% of their habitual rate, the control group exhibited a 19% increase in speech duration. At 60% of their habitual rate, these participants exhibited a 48% increase in speech duration, a 28% increase in pause duration, and a 30% increase in the number of pauses. In other words, at the 80% rate, speakers increased rate almost exclusively by increasing the duration of the speech segments. At the 60% rate, however, they exhibited a marked increase in speech duration, and moderate increases in both pause duration and number of pauses (Hammen, Yorkston, & Beukelman, 1989).

During the 80% conditions, the dysarthric speakers achieved a 22% increase in speech duration, a 13% increase in pause duration, and a 2% increase in the number of pauses. During the 60% condition, speech duration was increased by 44%, pause duration by 56%, and number of pauses by 26%. These data suggested that speech duration was "elastic" enough to achieve the target rate when a small change was required (i.e., 80% of habitual rate). Only at 60% of habitual rate was the number of pauses increased significantly by both groups of speakers (Hammen, Yorkston, & Beukelman, 1989).

Results of the effects of specific pacing strategy on speech and pause duration revealed that rhythmic pacing had its greatest impact on pause duration. During the rhythmic conditions, the normal speakers increased speech duration by 19%, pause duration by 41%, and number of pauses by 10%. In the metered conditions, however, these speakers increased speech duration by 41%, pause duration by 19%, and number of pauses by 20% (Hammen, Yorkston, & Beukelman, 1989). During the rhythmic conditions, the dysarthric speakers increased speech duration by 24%, pause duration by 49%, and number of pauses by 4%. In the metered conditions, these speakers increased speech duration by 42%, pause duration by 26%, and number of pauses by 13% (Hammen, Yorkston, & Beukelman, 1989).

Thus, for both groups of speakers, the metered strategies produced greater increases in speech duration. Neither group were observed to use a "one-word-at-a-time" pattern, as the authors emphasized that this would have resulted in substantial increases in number of pauses (although both groups did increase number of pauses; controls by 20%, and dysarthric speakers by 13%). The authors observed that because the metered cueing condition presented each word with equal duration, relatively short words (such as articles) were allotted the same duration as multi-syllable words. This may have prompted speakers to extend the shorter words to accommodate the pacing program, thus inflating speech duration measures for metered conditions (Hammen, Yorkston, & Beukelman, 1989).

The findings of Hammen et al. (1989) demonstrated that the dysarthric speakers achieved near-target rates using the PACER program with minimal training. Thus, the software was shown to be useful for assessment and training, as well as for evaluating the effects of different speech rates on intelligibility and speech naturalness (Hammen, Yorkston, & Beukelman, 1989).

However, there remains a need for studies to verify the maintenance of rates after pacing is removed. Long-term effects of pacing procedures were not investigated by Hammen et al. (1989).

Hammen and Yorkston (1996) further investigated speech duration and pause duration changes following computer-assisted pacing. Changes in pause structure (i.e., mean pause duration, interpause phrase length, pause location) resulting from rate reduction were also investigated. The authors hypothesized that inserting frequent pauses may increase intelligibility by giving the listener more time to "decode" the distorted speech signal. However, the influence of pause location was also expected to contribute to intelligibility level. For example, inserting pauses in unexpected locations (e.g., within a noun phrase) may actually reduce intelligibility (Hammen & Yorkston, 1996).

Six Parkinson's disease patients with hypokinetic dysarthria and six normal speakers read a passage during habitual and paced reading conditions. The PACER software was utilized once again, and 60% of habitual rate was used throughout the study as the target rate. As mentioned above, Yorkston et al. (1990) suggested that the largest gains in intelligibility occurred at this rate. Dependent measures taken were speech duration (in ms), total pause duration (in ms), mean pause duration (in ms), interpause phrase length (i.e., number of words occurring between pauses), and pause location (i.e., syntactically appropriate or inappropriate).

Results indicated that mean habitual rate was 268 SPM for the Parkinson's disease group, and 216 SPM for the control group. All participants read within seven percent of the targeted rate during the paced condition, confirming the effectiveness of the PACER software in controlling reading rate. This finding was consistent with previous studies (Hammen, Yorkston, & Beukelman, 1989; Yorkston et al., 1990).

At habitual rate, speech duration was 32.41 seconds for PD group, and 41.23 seconds for the control group. Total pause duration was 8.33 sec. for the PD group, and 6.75 sec. for the control group. During paced reading, speech duration was 42.31 sec. for the PD group, and 57.75 seconds for the control group. Pause duration increased to 21.36 seconds for PD, and 20.92 for the control speakers. This yielded significant main effects for condition (i.e., habitual versus pacing) and group (i.e., Parkinson's disease versus control) on both speech duration and pause duration. In other words, the speakers with Parkinson's disease spent more time on pauses habitually than did the normal speakers, but both groups increased pause time significantly at 60% of their habitual rates.

Thus, the speakers with Parkinson's disease increased their speech duration by 28% and pause duration by 156%. The normal speakers increased speech duration by 40%, and pause duration by 209% (Hammen & Yorkston, 1996). Interestingly, during the paced condition, speech duration for the PD speakers (41.64 seconds) was nearly identical to that of the control speakers at habitual rate (41.21 seconds). In others, the PD speakers read at nearly normal rates when they slowed their habitual rates to 60%!

The two groups of speakers did not differ significantly in terms of mean pause duration or interpause phrase length. Similarly, reading condition (i.e., habitual versus paced) failed to yield significantly different mean pause durations. There was, however, a significant main effect for condition on percentage of syntactically appropriate pauses. At habitual rates, both groups placed a majority of their pauses at primary and secondary boundaries. However, the Parkinson's disease speakers inserted 28.5% of their pauses within a phrase or clause, compared to 14% for the control speakers (Hammen & Yorkston, 1996). During pacing, both groups exhibited significant decreases in the percentage of pauses in syntactically appropriate locations.

This most likely reflected an increase in total number of pauses during paced reading. In other words, both groups achieved rate reduction by using more frequent pauses rather than increasing the duration of their pauses.

These findings were consistent with observations of faster than normal rates in speakers with Parkinson's disease (e.g., Canter, 1965; Hammen et al., 1989; Hanson & Metter, 1983). When paced to 60% of their habitual rates, the PD speakers increased their speech durations toward the normative value. The authors observed that the PD speakers with the shortest speech durations at habitual rates increased it more than they increased pause duration when paced. Likewise, participants with more normal speech duration times increased pause time more when paced (Hammen & Yorkston, 1996). This suggested that during treatment, responses to pacing may depend on the durational characteristics of the individual's habitual speech.

The authors recommended that when using pacing with Parkinson's disease patients, cues for pausing at primary and/or secondary locations should be incorporated into therapy (as the PD speakers placed a greater proportion of their pauses within clauses/phrases than the normal speakers did). However, the impact of shifting pause location on intelligibility needs to be examined in future studies. For example, it would be interesting to determine whether dividing a reading passage into smaller units with more logical boundaries would increase intelligibility without changing any articulatory characteristics of the sample (Hammen & Yorkston, 1996).

Summary and Conclusions

The use of rigid rate control techniques such as pacing boards and alphabet boards has been effective in reducing rate and improve intelligibility in cases of severe dysarthria (Beukelman & Yorkston, 1977; Crow & Enderby, 1989; Helm, 1979; Lang & Fishbein, 1983;). As discussed above, these techniques offer relatively little expense, ease of use, minimal training requirements, and the option of home practice. Alphabet board supplementation offers the additional advantage of visual cues to aid the listener in comprehension of the message (Beukelman & Yorkston, 1977).

It should be noted, however, that such external devices may be considered cosmetically unacceptable, require manual dexterity (not available to all persons with Parkinson's disease), may require normal vision and adequate spelling ability (e.g., the alphabet board), and may result in adaptation or overlearning of the required movement (Yorkston et al., 1988). These strategies also tend to disrupt prosody by imposing a "one-word-at-a-time" speech pattern with pauses between words. However, they are often effective when other interventions fail, allowing severely dysarthric individuals to use oral speech earlier in treatment than would have otherwise been possible (Beukelman & Yorkston, 1977).

Rate control strategies that preserve prosody (e.g., oscilloscopic feedback, IBM Speech Viewer, pacing) require significantly more speaker training, relatively intact cognitive abilities, and ample time and motivation to master new motor skills (Yorkston et al., 1988). This may pose a difficulty for sub-groups of Parkinson's disease patients who exhibit dementia (Levin, Tomer, & Rey, 1992) or other cognitive deficits (Saint-Cyr, Taylor, & Lang, 1988). For appropriate speakers, however, visual and/or auditory feedback may be useful for training these individuals to monitor and modify their own speech behaviors within nine or ten weeks of treatment (Caligiuri & Murry, 1983; LeDorze et al., 1992).

In addition to the relatively high cost of the systems discussed, they present the challenge of gradually fading the visual feedback provided by the oscilloscope or computer screen. This limitation impedes the transfer of skills acquired in the clinic to "real world" speaking situations. Also, the relative controlling effects of the visual and auditory feedback in the studies reviewed were not clearly demonstrated (Berry & Goshorn, 1983; Caligiuri & Murry, 1983; LeDorze et al., 1992). Studies designed to accomplish this (e.g., alternating-treatment design, A-B-A-B design, etc.) could potentially lead to improved treatment efficiency by identifying the most effective component(s) of a particular intervention (Barlow & Hersen, 1984).

Other "behavioral" rate control methods such as various cueing and pacing strategies were recommended as a transition between rigid techniques and self-monitoring of speech rate (Yorkston & Beukelman, 1981). These strategies typically result in more natural prosody and re-introduce normal rhythmic elements into the patient's speech pattern. For example, Yorkston and Beukelman (1981) gradually increased the rate of one patient’s speech from 80 WPM to 134 WPM while maintaining 99% intelligibility (Yorkston & Beukelman, 1981). However, the seven months of treatment needed to obtain such dramatic gains underscores the relatively taxing training requirements of such behavioral interventions.

Computerized pacing programs (i.e., PACER) offer the ability to select precise speaking rates (not possible with "finger-pacing"), as well as the added benefits of home practice (provided that the patient has access to a computer and the software). The PACER program was been shown to effectively pace speaking rate within a relatively short training period (Yorkston et al., 1990). In addition, naturalness of speech was kept relatively intact, particularly during rhythmic pacing (Hammen et al., 1989). Rate reduction via PACER evidently resulted primarily from increased articulation time during metered presentation and from increased total pause time during rhythmic presentation. However, both parameters were increased when speakers reduced their rates to 60% of habitual rate. Because the computerized pacing yielded significant increases in total pause time but not in mean pause duration, both PD and control groups evidently increased total pause time by adding more frequent pauses rather than producing longer pauses (Hammen et al., 1996). This absence of excessively long pauses may have contributed to preserved prosody during pacing.

It is widely believed that for many dysarthric speakers, intelligibility must take priority over speech rate and naturalness. For example, Yorkston et al. (1988) recommended that when intelligibility reaches 90%, improvements in rate and prosody should be attempted. The target rate should continue to increase as long as intelligibility is maintained. Thus, the primary treatment goal should be to use the least intrusive rate control technique that provides adequate rate reduction, while optimizing intelligibility and speech naturalness. If substantial improvement is not observed, however, rate control may not be appropriate for that individual. In such cases, other management approaches should be considered (Yorkston et al., 2000).

Implications for Future Research

As mentioned throughout the preceding sections, several of the treatment efficacy studies discussed presented methodological limitations. Future studies examining the effects of rate control procedures on dysarthric speech would benefit from attention to several important design principles. First, clinical procedures (i.e., length of treatment, clinician instructions, fading procedures, dependent measures, etc.) must be delineated in a manner that allows for accurate replication. For example, measures such as syllables per second, percentage of intelligible words, and percentage of disfluency are more objective than rating scales such as those used by Darley et al. (1975). The use of objective measures facilitates comparison between various studies, as well as replication of the clinical procedures.

Secondly, speech tasks used for pre- and post-treatment comparisons of speech parameters should be similar to tasks used during treatment. This allows for a more accurate demonstration of therapeutic gains, as different tasks (e.g., reading, conversation, picture description, etc.) vary considerably in terms of linguistic, cognitive, and motor demands imposed upon the speaker (Norris et al., 1998). Such variables must be given consideration when providing treatment for individuals with neuromotor impairments such as Parkinson's disease.

Lastly, studies using single-subjects designs are needed in order to experimentally demonstrate the controlling effects of specific treatment variables on speech behaviors (Ingham, 1984; Kadzin, 1982). For example, the A-B-A-B design and the alternating-treatments design are particularly well suited for evaluating the relative effectiveness of two or more treatments, or treatment versus "no treatment" conditions (Barlow & Hersen, 1984). Single-subject designs can also be used to provide follow-up data by simply adding an extended "no treatment" phase after the final treatment phase, or by taking periodic generalization probes. Also, by including a "no treatment" condition during each treatment session, a "running baseline" is available throughout the study. This feature is useful for measuring generalization of treatment gains (i.e., "carry-over") across time. These and other methodological issues were given due consideration in the present study.

The Use of Delayed Auditory Feedback for Rate Reduction

The purpose of the final section of this chapter is to provide a critical review of the literature related to delayed auditory feedback (DAF). Following the successful use of DAF to reduce rate and simplify motor speech production in stutterers, several researchers examined its use with dysarthric speakers (e.g., Adams, 1994; Dagenais et al., 1998; Downie et al., 1981; Hanson & Metter, 1980; 1983; Yorkston et al., 1988). In general, results were mixed, but suggested positive effects on several speech parameters for appropriate individuals.

Singh and Schlanger (1969)

In an early investigation of delayed auditory feedback, Singh and Schlanger (1969) examined its impact on speech characteristics of dysarthric, aphasic, and mentally retarded individuals. Specifically, the authors sought to determine the effects of DAF on duration, intensity, and frequency of phonemic errors of "kernel" sentences and various transformations (i.e., negative, query, and negative-query). Each kernel sentence represented a different level of "grammaticalness" (i.e., meaningful, less meaningful, and least meaningful) (Singh & Schlanger, 1969).

The dysarthric speakers exhibited various types of dysarthria, with only one speaker exhibiting hypokinetic dysarthria secondary to Parkinson's disease. All speakers read or repeated the 12 sentences (i.e., three sentences, each with four different structures). The three kernel sentences used were *"The boy hit the ball," "The ball kus the ground," "The tis tas the fuv."* A delay interval of 180 ms was used due to its documented effects on the speech of normal speakers (Black, 1951; Lee, 1951). Each participant produced the sentences without DAF, and then again with DAF.

Results for sentence duration yielded a significant main effect of DAF on sentence duration (i.e., DAF resulted in longer durations, or slower rates), a significant main effect of group (i.e., dysarthic speakers exhibited a longer mean duration than aphasic speakers, but shorter durations than the mentally retarded speakers), and a significant main effect of meaningfulness (i.e., the less "meaningful" the sentence, the longer its duration). Thus, lack of semantic relevance appeared to negatively impact speech production (Singh & Schlanger, 1969). In addition, a significant main effect of syntactic structure on duration was observed (i.e., the kernel sentences were produced significantly more rapidly than any of the three transformations).

Results for vocal intensity (in sound pressure level) revealed that delayed auditory feedback significantly increased intensity. Results for phonemic errors yielded a significant main effect of group (i.e., the dysarthric speakers produced significantly more errors per sentence than did the other two groups). Also, the less meaningful the sentences were, the more phonemic errors were elicited. Specific types of errors produced were not described in detail, although some substitutions were reported (e.g., from "fuv" to "fuzz"). Unfortunately, the effects of DAF on the frequency and types of phonemic errors produced were not discussed. Likewise, repetitions, omissions, or distortions of speech segments were not reported.

Critique of Singh and Schlanger (1969)

This was the first investigation of the effects of delayed auditory feedback on speech features of dysarthric individuals, demonstrating that DAF induced these patients to increase speech intensity and sentence duration (i.e., to reduce their speech rates). Because only one of the participants exhibited hypokinetic dysarthria, however, these findings are of limited clinical value. As hypokinetic dysarthria is the only subtype in which rapid speech rates are often observed (Duffy, 1995), patients presenting most other types of dysarthria are not as likely to benefit from an intervention designed to reduce speech rate.

An alternative research strategy in such a case would be to utilize a single-subject design (Barlow & Hersen, 1984; Christensen, 1988; Ingham, 1997; Kadzin, 1982; Young, 1994). This would allow a treatment variable, such as DAF, to be systematically presented and withdrawn in order to determine any controlling effects on speech behavior (e.g., sentence duration). Any findings from such a study using a single individual exhibiting hypokinetic dysarthria would be no more difficult to generalize to similar speakers than would findings from a group difference study with only one participant with hypokinetic dysarthria (e.g., Singh & Schlanger, 1969).

Downie, Low, and Lindsay (1981)

Downie, Low, and Lindsay (1981) documented the use of delayed auditory feedback by two Parkinson's disease patients. Patient 1 exhibited speech characterized by poor intelligibility, frequent hesitations, syllable repetitions, short rushes of speech, and excessive rate. After other interventions were shown to be ineffective, a trial with 50 ms DAF resulted in a "dramatic improvement" in intelligibility and reduced speech rate. After three months of "home use," however, the original festinating speech pattern re-emerged. Following one year of disuse of the DAF unit, the patient obtained "intermittent benefit" with delay setting of 150 to 200 ms The authors posited that deterioration of motor functioning due to the disease necessitated a substantial increase in delay interval (Downie, Low, & Lindsay, 1981).

Patient 2 also exhibited accelerating speech with weak intensity and poor intelligibility. With the aid of 50 ms DAF, his speech became slower, louder, and "completely fluent." This patient continued to wear the portable DAF unit for two years, with persistent improvement in intelligibility whenever the unit was in use (Downie, Low, & Lindsay, 1981).

Thus, delayed auditory feedback was judged by the authors to be applicable primarily to cases of festinating speech, an accelerating speech pattern reminiscent of the gait of many Parknison's disease patients (Duffy, 1995). The DAF unit's impact upon the speech of the two patients reported was "dramatic" (and enduring in the second case). The investigators noted, however, that these patients were selected from several hundred seen for treatment in a Parkinson's disease clinic. There was no indication that DAF produced any persisting effects on speech rate when the unit was not in use (i.e., no carry-over). Thus, the authors likened the unit to "a pair of spectacles," concluding that it must be used continuously to be effective (Downie, Low, & Lindsay, 1981).

Critique of Downie et al. (1981)

One of the first documented case studies using DAF with Parkinson's disease patients, this report suggested clinically significant effects on speech rate and intelligibility. However, no objective speech measures of any kind were included, making it difficult to determine exactly how much improvement was observed (as well as the nature of the improvement). Also, because no baseline measures were taken, the specific effects of DAF on the speech of these two patients were not clearly demonstrated.

Another limitation was the fact that only "home use" of DAF was reported. Therefore, exactly when, where, how, and how often the DAF units were used was not documented. As no instructions were evidently given, the actual tasks for the speakers (e.g., to prolong vowels) were not specified. Despite the conclusion that DAF held no usefulness when not worn by the speaker, no fading or generalization procedures were not attempted. This case study, therefore, provided limited evidence of the potential benefits of DAF as a rate control strategy, but did serve to generate further interest in its use with Parkinson's disease patients.

Hanson and Metter (1980)

Hanson and Metter (1980) utilized a portable DAF unit to reduce speech rate and improve intelligibility in one dysarthric patient with progressive supranuclear palsy. This is a progressive neurological disorder often associated with "parkinsonian" symptoms such as akinesia, postural instability, and hypokinetic dysarthria (Duffy, 1995; Yorkston et al., 2000). This patient's speech was characterized by rapid acceleration, weak intensity, limited pitch range, imprecise consonant articulation, and poor intelligibility. After eight months of unsuccessful speech therapy focusing on rate reduction and self-monitoring of speech, delayed auditory feedback was observed to effectively reduce his rate and increase his intensity. Therefore, this individual began to wear a portable DAF unit as a permanent speech prosthesis (Hanson & Metter, 1980).

Measurements of rate, intensity, and intelligibility were taken both with and without DAF. Reading was selected as the speech task in order to provide a more uniform speech sample for series measurements (Hanson & Metter, 1980). During each of the two recording sessions, the participant read a passage ten times, with DAF being introduced during trials 4 and 8 only. A delay interval of 100 ms was selected because of its "positive effect" on the patient's speech (Hanson & Metter, 1980). Dependent measures were taken at beginning of therapy (i.e., Session 1) and three months later, following daily "home use" of the DAF unit (i.e., Session 2). Speech rate was measured in words per minute (WPM), vocal intensity was measured in dB SPL, and intelligibility was judged on a seven-point scale (i.e., 1 = normal intelligibility, 7 = "severe deviation from normal speakers").

Documented reading rates were 255 WPM pre-therapy and 311 WPM post-therapy without DAF, and 116 WPM pre-therapy and 104 WPM post-therapy with DAF. Thus, DAF yielded significantly lower rates than the median normative value of 177.6 WPM (Canter, 1963). Results for intensity revealed that all measurements, both with and without DAF, were within the normal range of 72.0 dB to 85.9 dB SPL (Canter, 1963). Intelligibility scores were 5.75 pre-therapy and 6.88 post-therapy without DAF, and 1.00 with DAF (both pre- and post-therapy).

The authors interpreted the findings as evidence of the usefulness of DAF for improving intelligibility in patients with a progressive neurological disease and severe hypokinetic dysarthria. The DAF unit was not used as an adjunct to therapy, but as a permanent speech prosthesis. The reduction of speech rate was evidently responsible for the improved intelligibility. This subject's family stated that his speech was much improved when using DAF, and his verbal output increased due to greater willingness to participate in conversations (Hanson & Metter, 1980).

Critique of Hanson and Metter (1980)

This study benefited from the inclusion of objective measures of speech rate and intensity (both with and without DAF), but used a subjective rating scale to measure intelligibility. Calculating the percent of intelligible syllables or words provides a more objective and easily replicated measure of intelligibility. As a supplement to the objective data provided, family members' comments were included, highlighting the clinical significance of treatment gains. This was an example of "subjective evaluation," a type of therapeutic criterion sometimes used to assess whether treatment has led to qualitative differences in how others view the participant (Christensen, 1988).

Because the investigators obtained only one pre-therapy and one post-therapy measurement, this study would be categorized as a one-group before-after design (Christensen, 1988). This presents inherent limitations, as any single-subject study requires some type of time-series design (i.e., repeated measures of a dependent variable taken both before and after treatment is introduced) to detect any effect produced by the treatment variable. This is necessary because of the absence of a control group in a single-subject experiment. When only one pre- and one post-response measurement are taken, the result is a one-group before-after design, which has disadvantages (Christensen, 1988). These include the possibility of confounding variables such as maturation (e.g., age, learning, fatigue, fluctuation of blood levels of medication, etc.) and history effects (e.g., a change in medication, surgery, etc.).

To overcome these potential confounds, it is necessary to obtain multiple measures of the dependent variable. The resulting design would be considered a time-series design, which provides a continuous record of responses during the course of the experiment. This is considered an "experimental" design because a planned intervention (i.e., DAF) is presented, and its effects on some behavior (e.g., speech rate) are then evaluated (Christensen, 1988). In a subsequent study, Hanson and Metter (1983) attempted to obtain more frequent response measurements in order to control for the potential confounding variables described.

<u>Hanson and Metter (1983)</u>

Following successful prosthetic use of delayed auditory feedback with a dysarthric speaker with progressive supranuclear palsy, Hanson and Metter (1983) assessed its effects on the speech of two Parkinson's disease patients. Patient A was a 58-year-old male with speech characterized by poor intelligibility, weak intensity, rapid rate, and reduced variability of pitch and loudness. He participated in speech therapy using various rate control strategies for nine months. Although some success in the clinic was noted, no carry-over was observed. Patient B was a 56-year-old woman who presented rapid speech rate, limited pitch variability, weak intensity, imprecise consonants, and mildly impaired intelligibility (Hanson & Metter, 1983).

Measures of speech rate, intensity, fundamental frequency, and intelligibility were taken on four occasions (i.e., during baseline and at one-month intervals thereafter for three months). Speech rate for both reading and conversation was measured in words per minute (WPM) without pauses (i.e., sentence rates). Both patients wore portable DAF units "as needed" for three months. A delay interval of 150 ms was selected because it reportedly produced the greatest degree of rate reduction with the least disruption of "speech flow," and because both patients "tolerated it well" (Hanson & Metter, 1983).

During all four recordings, Patient A's reading rate exceeded the normal range of 140-219 WPM (Canter, 1963), while DAF reduced his rate to slightly below the normal range (i.e., 122-139 WPM). Home use of the unit did not result in any noticeable carry-over of treatment gains, as reading rates without DAF remained high throughout the study. During conversation, this subject's speech rate without DAF could not be measured due to poor differentiation of individual words. However, his mean conversational rate with DAF of 166 WPM was within the normative range of 150-250 WPM (Goldman-Eisler, 1968).

In addition, Patient A's reading intensity increased significantly from 66.3 dB without DAF to 77.3 dB with DAF, within the normative range of 72.0-85.9 dB (Canter, 1963). Similar increases were also observed during conversation. No statistically significant increases in fundamental frequency were observed with DAF during reading or conversation. Lastly, and most importantly, this speaker's intelligibility was significantly improved with the use of DAF. Judged on a seven-point scale (Hanson & Metter, 1980), his mean reading intelligibility rating improved from 5.75 without DAF to 2.50 with DAF. Likewise, his conversational intelligibility improved from 6.50 without DAF to 3.00 with DAF (Hanson & Metter, 1983).

Patient B's mean reading rate without DAF was 183.3 WPM, exceeding the median normative value of 177.6 (Canter, 1963). The use of DAF reduced her reading rate to 137 WPM, and reduced her conversational rate from 238.8 WPM to 166.8 WPM. Her speech intensity was significantly higher with DAF, but only during reading. However, mean peak intensities for both tasks were within the normal range of 72.0-89.5 dB (Canter, 1963), both with and without DAF. Patient B's fundamental frequency increased significantly with DAF during reading, but not during conversation. Lastly, her mean intelligibility rating for reading improved from 2.25 without DAF to 1.50 with DAF, and her mean intelligibility rating for conversation improved from 3.50 without DAF to 2.25 with DAF (Hanson & Metter, 1983).

An acoustic analysis of selected phrases from the reading passages revealed that both speakers increased duration of the speech segments (i.e., articulation time) as well as between-segment pauses (i.e., pause time). These increases were relatively proportional (Hanson & Metter, 1983). In general, findings suggested that both speakers increased "physiological effort" while using DAF (e.g., increased intensity), although this did not seem to generalize to their speech without DAF. The authors hypothesized that the force of articulatory contact may have increased as a result of this added effort. Therefore, they recommended the DAF unit as a "compensatory speech aid" to be used with or without other forms of therapy (Hanson & Metter, 1983).

Critique of Hanson and Metter (1983)

Significant treatment gains were made by both patients, particularly in speech rate and intelligibility. Changes in intensity and fundamental frequency were not as marked or consistent. The acoustic analysis provided additional information about specific rate changes resulting from use of delayed auditory feedback (i.e., proportional increases of articulation time and pause time). This was the first investigation to demonstrate such acoustic changes resulting from the use of DAF. Such information has important clinical implications, as the relative duration of articulation time and pause time play a key role in perceived speech rate, as well as speech naturalness (Tjaden, 2000; Yorkston et al., 1988).

Although more frequent measurements were taken than in their previous study (Hanson & Metter, 1980), only one baseline measurement was made before the independent variable (i.e., DAF) was introduced. This made the controlling effects of DAF on speech parameters somewhat ambiguous (Barlow & Hersen, 1984). Likewise, obtaining dependent measures more frequently than once a month would have helped to rule out rival hypotheses more effectively.

Additionally, this investigation presented some of the same limitations as the previous study (i.e., Hanson & Metter, 1980). For example, the process of selecting the "best" delay interval for the speaker was not delineated. Also, because "therapy" was limited to home use of the DAF unit, no replicable clinical procedures (e.g., practice schedule, speech tasks used, clinician feedback, etc.) were made available for use by other clinicians or researchers. Lastly, the authors recommended gradually "weaning" patients from DAF, but attempted no such fading procedures in this or any subsequent investigation.

Yorkston, Beukelman, and Bell (1988)

Yorkston, Beukelman, and Bell (1988) documented the use of delayed auditory feedback with a 72-year-old male Parkinson's disease patient whose habitual reading rate was 262 words per minute (WPM) (i.e., 138% of normal rate), with 67% intelligibility. A trial with computerized pacing reduced his rate to 137 WPM and increased intelligibility to 94%. In an attempt to transition from controlled conditions to "real" communication situations, the investigators chose to use DAF based on the prediction that, if effective, it would require the least amount of training (Yorkston et al., 1988).

The patient was recorded reading a passage at various delay settings. Speech rate was reduced as the delay interval was increased from 0 ms to 100 ms, and again from 100 ms to 150 ms However, no further rate reduction was observed when the interval was increased from

150 ms to 200 ms This confirmed the effect of DAF and allowed selection of the delay that produced the greatest rate reduction (Yorkston et al., 1988). At 150 ms, the speaker's reading rate was 135 WPM, with 97% intelligibility.

Thus, DAF produced slightly better speech performance than computerized pacing with much less training. Perceptually, reducing this speaker's rate reportedly improved speech "naturalness," which was not operationally defined. The short rushes of speech were reportedly eliminated, and breath group patterns and intonational contours were preserved. The authors also performed an acoustic analysis which revealed that DAF increased articulation time as well as pause time. This may have been responsible for the preserved naturalness of speech (Yorkston et al., 1988). These findings were consistent with those of Hanson and Metter (1983).

The authors conceded, however, that DAF was not as effective during conversational speech. Because the subject's utterances were relatively short, no "DAF effect" was observed. To bring conversational speech under more control with DAF, therefore, investigators attempted to train the participant to allow DAF to become a more effective "speech pacer." Specifically, the patient was instructed to prolong the initial word of each utterance with a "relatively strong intensity," speak in full phrases, and speak slowly enough to avoid "overdriving" the DAF unit (Yorkston et al., 1988). Although the authors acknowledged that some patients may need to be instructed to "allow" DAF to slow their speech, guidelines for accomplishing this (i.e., matching the delayed signal) were not described.

Critique of Yorkston et al. (1988)

While resembling a quasi-experimental design (i.e., repeated measurements were made neither before nor after introduction of DAF), this was the first report to graphically depict the effects of gradually increasing delay interval on speech rate. Doing so helped to delineate the process of selecting the optimal delay interval for a particular speaker. For example, the fact that speech rate did not decrease when the delay interval was increased from 150 ms to 200 ms suggested that the speaker must not have been precisely matching the delayed signal. Inclusion of such information provides valuable insight into exactly what individuals are doing (or not doing) while speaking with delayed auditory feedback.

The authors offered some useful suggestions for training speakers to use DAF more effectively, information not included in most other DAF studies (e.g., Hanson & Metter, 1980; 1983). These strategies included prolonging initial words, increasing vocal intensity, speaking in full phrases, and not speaking rapidly enough to "overdrive" the DAF unit (Yorkston et al., 1988). This latter suggestion alluded to the need for speakers to precisely match the delayed signal in order to achieve maximal rate reduction at a given delay interval. Although the authors acknowledged that some patients require overt instruction to effectively reduce their rates with DAF, they did not endeavor to evaluate the effects of such clinician instruction experimentally.

<u>Adams (1994)</u>

In an innovative study, Adams (1994) assessed the effects of DAF using phonetic, acoustic, and kinematic analyses, as opposed to clinician impressions (e.g., Downie et al., 1981), rating scales (e.g., Hanson & Metter, 1983), or global measures of severity (e.g., Yorkston et al., 1988). The purpose of the investigation was to provide a more thorough understanding of the nature of “accelerating speech,” as well as a more adequate explanation of the effects of DAF.

The participant was a 78-year-old male with hypokinetic dysarthria secondary to progressive supranuclear palsy. His conversational speech rate was 375 WPM (without interphrase pauses), will 54% intelligibility (Adams, 1994). Speech tasks included isolated words, short conversational samples, and words embedded in carrier phrases produced three times in succession. This latter repetition task permitted a more complete evaluation of accelerating speech. In addition, the speaker produced two multi-syllabic utterances three times consecutively (e.g., "sapapple-sapapple-sapapple"). He produced all stimuli both with and without 80 ms DAF (Adams, 1994).

Results of perceptual and acoustic analyses revealed that the speaker's conversational rate was reduced from 350-400 WPM during baseline to 150-200 WPM with DAF. This latter rate was within the normative range of 150-250 WPM (Goldman-Eisler, 1968). Sentence intelligibility increased from 55% during baseline to 95% with DAF. Phonetic errors made during baseline included voicing errors on initial consonants, substitutions of stops for affricates and fricatives, final consonant deletion, and cluster reduction. These were all "virtually eliminated" by the use of DAF (Adams, 1994).

Spectrographic analysis revealed a reduction of many acoustic features of speech. For example, the word "wax" was misperceived as "wack," likely due to reduced duration of the /ks/ segment, as well as reduced intensity of frication noise and the absence of a stop gap during the /ks/ segment. While using DAF, however, these phonetic features were restored and, as a result, were generally perceived correctly. Production of /ks/, for example, showed a clear stop gap and burst associated with the /k/ segment, and a relatively intense period of frication noise associated with the following /s/ (Adams, 1994).

Kinematic analysis revealed reduced amplitudes of lower lip and jaw movements with repeated productions of the same utterance. During use of DAF, however, lip and jaw movements had significantly larger displacements and were produced with significantly longer movement times. Mean peak velocity for lip and jaw movements were not significantly different from baseline to the DAF condition (Adams, 1994). Although not stated by the author, the fact that the speaker increased both displacement amplitude and movement time most likely accounted for the relatively stable velocity (i.e., distance per unit time).

Many of the phonetic errors made were related to a simplification of or reduction in the number of phonetic features transmitted. The use of DAF resulted in a marked decrease in the frequency of such errors. Spectrographic analysis revealed that the speaker's poor intelligibility was not simply due to the rapid rate of speech, but rather the reduction in or absence of specific acoustic features. The use of DAF restored most of the expected phonetic and acoustic features, resulting in greatly improved intelligibility (Adams, 1994). Thus, delayed auditory feedback was shown to be a practical, effective, and "relatively long-term solution" for this individual.

Critique of Adams (1994)

The primary strengths of this investigation were the inclusion of objective speech measures and the description of specific phonemic errors produced. In addition, kinematic analysis confirmed previous findings of reduced displacement amplitude, or "articulatory undershoot" in speakers exhibiting hypokinetic dysarthria (Hirose et al., 1981; Netsell et al., 1975). This was the first study to include such an analysis both with and without DAF. The author attributed the subject's poor intelligibility to the reduction of acoustic features rather than to rapid rate. According to other studies (Hirose et al., 1981), however, reduced movement amplitude itself resulted from speech increased rate. In other words, speakers may compensate for slow individual articulatory movements by reducing amplitude of those movements, thus giving the perception of normal or excessive speech rate (Netsell, et al., 1975).

Results indicated that 80 ms DAF yielded a 50% reduction in speech rate and a 40% increase in intelligibility (Adams, 1994). However, the author did not report how or why this delay was selected, or how long it took to find this "optimal delay." Also, no follow-up data were provided, despite the conclusion that DAF was a "relatively long-term solution" for this individual. For example, monthly follow-up measurements (or generalization probes) provide a relatively easy method of evaluating long-terms treatment effects (Ingham, 1984).

<u>Dagenais, Southwood, and Lee (1998)</u>

Dagenais, Southwood, and Lee (1998) evaluated the efficacy of a DAF-based rate control protocol with three Parkinson's disease patients using an experimental single-subject design. The authors hypothesized that if a "slow speech response" could be induced with DAF, then speech rate could be gradually increased and shaped into more natural-sounding speech. This study also compared the relative effectiveness of various treatment strategies (i.e., DAF, "traditional" therapy, and prolonged speech). Dependent measures obtained were speech rate (in syllables per minute, or SPM) and percent intelligibility. A multiple-baseline, changing-criterion design was employed, with separate baselines taken for the three speaking tasks used (i.e., reading, picture description, and spontaneous speech). In addition, sentence intelligibility was assessed pre-therapy, post-therapy, and during a four-month follow-up session (Dagenais et al., 1998).

During Speaker 1's first treatment phase (i.e., B phase), different delay intervals were tested to determine the "optimal delay" (i.e., the delay that consistently produced the highest intelligibility). This delay interval was used at the beginning of the C phase, which combined DAF with clinician instruction for the reading task (e.g., oral-motor exercises, feedback about unintelligible and/or slurred words, practice with difficult words). Speaker 1 spoke at each delay setting for at least three one-minute intervals. If intelligibility improved by at least 10%, the length of the delay interval was decreased. This procedure was continued until intelligibility was maintained without DAF. If the criterion was not met at a particular delay interval, the previous interval was reinstated to re-establish stability. Once stability was established for all three tasks, the next shortest delay interval was attempted.

During the D phase, delayed auditory feedback was combined with prolonged speech (Ingham et al., 1974). The targeted speech rate began at 70 SPM and was increased in 30 SPM increments when rate and intelligibility stabilized. Speaker 1 was trained to use prolonged speech via recorded samples and clinician modeling/feedback. When his rate reached 170 SPM, the DAF unit was removed and a final baseline phase (i.e., "follow-up") was initiated to detect any maintenance of treatment gains.

Results for reading indicated that during baseline, Speaker 1's rate stabilized to about 160 SPM with about 95% intelligibility. During phase B, intelligibility varied between 82-100%, while no specific rate coincided with the greatest intelligibility. During phase C, rate varied from 120-160 SPM, and intelligibility from 90-98%. During the D phase, prolonged speech was used to initially reduce reading rate to 60-80 SPM, while intelligibility stabilized to above 98%. With clinician modeling and systematic decreases in the DAF interval, rate was gradually increased to 195 SPM, while intelligibility remained at 100%. These rate and intelligibility gains were maintained during the final baseline phase.

During the picture description task, baseline performance varied widely for both rate (i.e., 75-158 SPM) and intelligibility (i.e., 72-98%). This pattern continued during phase B, as no specific delay interval appeared to significantly affect rate or intelligibility. During the C phase, both rate and intelligibility decreased slightly, as the speaker exhibited marked word retrieval difficulties. During the D phase, however, intelligibility stabilized above 97% and was maintained as rate was gradually increased from 75 to 130 SPM. As with the reading task, these gains were maintained during the final baseline phase.

During the spontaneous speech task, stable baselines were quickly established at about 140 SPM and 95% intelligibility (results from the B phase were not reported). During phase C, rate varied from 82-120 SPM, and intelligibility increased to about 95%. During phase D, rate initially decreased to 90-95 SPM, then was gradually increased and maintained at about 145 SPM, while intelligibility stabilized at over 98%. Again, these gains were maintained during the final baseline phase. Overall, Speaker 1's intelligibility improved from 87.5% (pre-therapy), to 95.4% (post-therapy), to 95.5% (4-months post-therapy). The pre-therapy score was significantly different from the other two scores, which did not differ from significantly from each other. It should be noted, however, that 95% intelligibility for reading was achieved during the baseline phase, making these intelligibility gains appear less clinically significant.

Because Speaker 2 exhibited attentional deficits during therapy, the C phase was eliminated, as was the spontaneous speech task. During reading, baseline rate stabilized near 70 SPM, while intelligibility gradually increased to above 90%. During the B phase, rate varied from 100-180 SPM, while intelligibility varied from 65-95% and overlapped with baseline values. During the D phase, rate reduced to 40-60 SPM with 95-100% intelligibility. However, this intelligibility level was not maintained and varied from 78-100%. Because adjusting the DAF setting was ineffective in stabilizing rate and intelligibility, the final baseline phase was initiated. Rate varied from 100-150 SPM, while intelligibility decreased from 96% to 88%.

For the picture description task, baseline rate stabilized at about 120 SPM, with 75% intelligibility. No delay interval had any consistent effects on rate or intelligibility during phase B, as intelligibility fluctuated from 74-93%. Results during D phase were similar to those for the reading task. For example, when rate was reduced to 70-110 SPM, intelligibility improved to 96-100%. However, Speaker 2 was apparently unable to increase his rate while maintaining intelligibility. Overall intelligibility scores were 66.2% pre-therapy and 72.7% post-therapy (i.e., not a statistically significant difference).

Reading was the sole task performed by Speaker 3, as he reportedly became "confused" and complained about the use of DAF during picture description and spontaneous speech. During baseline, rate was 195-220 SPM and intelligibility was 88-94%. During phases B and C, results were sporadic for both rate and intelligibility. For example, a delay interval of 231 ms resulted in intelligibility decreasing to 81%, although rate did not decrease significantly. Because discontinuing DAF did not significantly alter rate or intelligibility, prolonged speech alone was used during phase D. Reading rate decreased to 142 SPM and then fluctuated between 171 and 195 SPM (i.e., only slightly slower than during C phase). Intelligibility was generally above 95%. Because Speaker 3 seemed unable to respond to either delayed auditory feedback or prolonged speech, treatment was terminated. The final baseline phase yielded speech rates from 177-190 SPM and intelligibility from 96-100%. Overall intelligibility scores increased significantly from 74.6% pre-therapy to 93.1% post-therapy, although reading intelligibility was as high as 94-95% during the initial baseline.

The authors concluded that none of the speakers were "responsive" to DAF, as continued exposure to DAF alone did affect rate or intelligibility markedly or consistently (Dagenais et al., 1998). In general, changes in speech rate did not correspond to any specific delay intervals.

Although the participants reportedly heard themselves speaking, their responses suggested that they did not "process" the delayed auditory input. The authors attributed this to a potential "resource allocation" failure, or a reduction of available resources for both a speaking task and an auditory monitoring task. Thus, it was concluded that Parkinson's disease patients may not know how to respond to DAF, and may not have the skills needed to overcome the delay by prolonging their speech (Dagenais et al., 1998).

Critique of Dagenais et al. (1998)

As the first experimental single-subject investigation of the use of delayed auditory feedback with Parkinson's disease patients, this innovative study holds particular significance. It represented the first published attempt to gradually fade the delay interval using a changing-criterion design (Barlow & Hersen, 1984). Similar studies are needed in order to demonstrate the usefulness of DAF as a behavioral rate control intervention rather than simply a prosthetic device. To the extent that Parkinson's disease patients are capable of transferring treatment gains achieved with any rate control method, it is certainly reasonable to attempt generalization procedures using a DAF unit. This study also made use of objective speech measures and utilized time series measurements before, during, and after the administration of DAF. Such a procedure is necessary in order to clearly demonstrate the controlling effects of a treatment variable on some dependent measure (Barlow & Hersen, 1984).

Unfortunately, the use of multiple treatments simultaneously (e.g., DAF + traditional therapy, DAF + prolonged speech) made it difficult to evaluate the specific effects of DAF. Likewise, the authors' conclusion that prolonged speech was most likely responsible for rate control exhibited by Speaker 1 is speculative, as the use of prolonged speech alone was not evaluated. Speakers 2 and 3 did not seem to benefit from any strategy, including prolonged speech (Dagenais et al., 1998).

In addition to potential speaker variables (e.g., age, cognitive abilities, disease severity), characteristics of the tasks used may have impeded optimal performance with DAF. First, all three participants exhibited difficulty during the spontaneous speech tasks, confirming previous findings (e.g., Rosenbek et al., 1978; Yorkston et al., 1988) that DAF is more effective during reading than spontaneous speech. This is certainly not unexpected, as spontaneous speech typically places increased motor, linguistic, cognitive, and social demands on the speaker (Norris et al., 1998).

Reading also facilitates a more rhythmic speech pattern with relatively equal duration between stressed syllables, or "isochrony" (Starkweather, 1987). Clinical evidence suggests that this enhances the use of the DAF signal to predict when the next syllable should be produced (Bloodstein, 1995; Kehoe, 1998). Based on these observations, future investigators should consider using reading as the sole speech task. Any positive findings obtained should then with attempted with other tasks (e.g., picture description, monologue, etc.) by conducting systematic replications of the initial experiment (Barlow & Hersen, 1984).

Also, the lack of specific instructions on how to respond to DAF may help explain the variability of responding in Dagenais et al. (1998). As the authors stated, the speakers did not seem to "process" the delayed auditory input, despite being able to hear it. Although clinician instruction and modeling was reportedly a component of the traditional therapy and prolonged speech protocols, no instructions on how to match the DAF signal were described in the report.

Close examination of the data suggested that the speakers did not accurately match, or "speak along with the cadence of the delay time," as recommended by other authors (e.g., Goldiamond, 1965; Lotzmann, 1961; Yorkston et al., 1988). Altering the delay interval, even dramatically, did not produce any systematic rate changes. For example, adjusting Speaker 3's delay interval from 196 ms to 231 ms and then to 0 ms (i.e., no DAF) inexplicably resulted in virtually no change in speech rate. When precisely matching the signal, however, increases in the delay interval should produce further reductions in speech rate. For example, a syllable must be prolonged for a much longer duration before the perception of a 200 ms delay than before a 50 ms delay. Unfortunately, the inability of any of the speakers to exhibit stable rates while using DAF prevented the gradual fading of the delay, which was one of the primary purposes of the study.

The authors concluded that persons with Parkinson’s disease may not know how to respond or may not have same skills to overcome the delay by prolonging their speech. The authors cited differences in age and possible cognitive deficits as alternative explanations for the speakers’ lack of responding to the DAF (Dagenais et al., 1998). However, without further studies to evaluate the impact of task variables such as speaker training and clinician instruction, attributing these results to speaker variables may be premature.

Conclusions and Implications

In general, findings from this limited number of published studies confirmed clinical impressions of delayed auditory feedback as an effective rate control strategy for some speakers with hypokinetic dysarthria (e.g., Adams, 1994; Downie et al., 1981). Effects on speech intensity and pitch were also reported, although these were not as consistent or as dramatic (Hanson & Metter, 1983). Improvements in rate and intelligibility were apparently related to increased articulation time, as well as increased pause time (Adams, 1994; Yorkston et al., 1988). In addition, kinematic analyses suggested that DAF may improve intelligibility by preventing "articulatory undershoot," or the failure of speech articulators to reach their target positions (Adams, 1994).

Studies have generally shown DAF to be most effective in reducing reading rate, as opposed to spontaneous speech rate (e.g., Dagenais et al., 1998; Yorkston et al., 1988). As discussed above, this may be due to the reduced linguistic and motor demands of reading (Norris et al., 1998), and is consistent with findings of the effects of DAF on stutterers (Bloodstein, 1995; Ingham, 1984).

Delay intervals ranging from 50 ms (e.g., Downie et al., 1981) to 150 ms (e.g., Hanson & Metter, 1983) were used effectively with dysarthric speakers, while intervals exceeding 150 ms were reported to yield no further gains in rate or intelligibility (Yorkston et al., 1988). In fact, such delays intervals have reportedly produced "disastrous" effects on the speech of some speakers (Dagenais et al., 1998; Rosenbek et al., 1978).

Such reactions to relatively long delay times are commonly observed during clinical use of DAF, and likely result from improper matching of the delayed signal. For example, a delay interval of 150 ms produces a relatively long time lag between production of a syllable and its perception. Unless the speaker continues to prolong the syllable until the delayed auditory signal is perceived, this signal is not completely "canceled out." This results in a salient and potentially aversive "echo" which may limit the rate reduction benefits of DAF, as well as elicit speech disfluencies (e.g., syllable repetitions). Such behaviors have been observed in stutterers (Goldiamond, 1965), dysarthric speakers (Rosenbek et al., 1978; Dagenais et al., 1998), as well as unimpaired speakers (Black, 1951; Lee, 1951; Soderberg, 1968).

To facilitate optimal use of DAF, therefore, clinicians must provide instruction, modeling, and feedback. Clinician instruction is frequently used in speech-language therapy with persons exhibiting neuromotor impairments, but unfortunately has not been reported during use of delayed auditory feedback. As stated above, DAF has been primarily used with these speakers as a prosthetic device, with carry-over of speech gains rarely expected (or attempted). However, it may be difficult for a patient with a degenerative neurological disease to generalize a behavior when he or she is not informed of what that behavior actually is. In other words, simply instructing the patient to wear a DAF unit and "begin talking" does not provide any guidelines for properly matching the delayed signal in order to obtain maximal improvements in rate and intelligibility.

As highlighted by Duffy (1995), overt instruction improves performance, as most patients do not simply improve by talking. The ability to alter speech with instruction is taken as a positive prognostic indicator, although this assumption has not been tested formally (Duffy, 1995). Feedback is essential to motor learning, especially in early stages, and should be immediate and precise relative to the treatment goals (Schmidt & Lee, 1999; Yorkston et al., 1988). Such feedback should be specific, and can be instrumental or administered by the clinician. Rosenbek and LaPointe (1978) further asserted that the clinician should be as active in DAF training as in any other form of treatment because carry-over can only be achieved if the clinician provides feedback regarding the speaker's performance.

Unfortunately, most reports of delayed auditory feedback interventions have not clearly delineated clinician instructions for purposes of replication. What is currently lacking in the literature are studies which demonstrate the effects of simple, consistent, and replicable feedback pertaining specifically to how precisely speakers match the delayed signal. For example, by wearing a headphone/microphone assembly, the clinicians can determine how precisely the speaker is matching the signal. Verbal feedback and demonstrations of accurate matching would then be possible. The effects of such instruction on speech rate and intelligibility could be evaluated experimentally by using an A-B-A-B single-subject design (Barlow & Hersen, 1984). For example, speakers would receive DAF alone during the A phases, and DAF + clinician instruction during the B phases. Comparison of performance during the two conditions would then be used to evaluate the relative contributions of the clinician instruction.

These and other aspects of DAF-based rate control protocols need to be evaluated using experimental single-subject designs to determine the effects of task variables on speaker performance. The primary goal is this line of inquiry is not to demonstrate that DAF benefits some speakers under some conditions, but rather which task parameters (e.g., clinician instructions, delay interval, etc.) contribute to its success or failure. Such information could then be used to "fine-tune" the DAF procedure to maximize its efficacy. Factors such as age, cognitive abilities, and pre-morbid speech characteristics may, in part, determine whether or not DAF is an appropriate technique for a particular patient (Dagenais et al., 1998). However, without further studies to evaluate the impact of procedural variables, attributing any lack of success of a DAF intervention to speaker variables may be premature.

Therefore, the primary purpose of the present study was to evaluate the impact of clinician instruction on the effectiveness of delayed auditory feedback in improving speech rate, intelligibility, and fluency in dysarthric speakers with Parkinson's disease. A related purpose was to compare the effects of different delay intervals on these speech behaviors. It was hypothesized that administering feedback during DAF training would improve performance with all delay intervals used during training. While each individual speaker may still find one particular interval "optimal," extended training with several intervals may increase proficiency with the remaining intervals. That is, interactions between delay interval and clinician instruction may be demonstrated.

For example, a delay interval of 50 ms may be relatively easy to match, but may not provide sufficient rate reduction for a particular speaker. Conversely, an interval of 150 ms may be more difficult to match, but would yield a much slower speech rate. With further practice and clinician feedback, the speaker may develop the ability to match this longer delay more precisely. Therefore, a longer delay interval may ultimately prove to be more beneficial than the interval which was initially deemed "optimal."

Alternately, 50 ms DAF may yield five percent disfluency immediately, but produce no further gains with clinician instruction. However, 100 ms DAF may yield ten percent disfluency without instruction (i.e., without being accurately matched by the speaker), but one percent disfluency when supplemented by clinician instruction. Such findings would suggest that the initial stages of a DAF intervention may not be the best time to determine an individual speaker's “optimal delay,” as is often done clinically and in the published literature (e.g., Adams, 1994; Hanson & Metter, 1980; 1983).

Specific Questions of the Present Study

As stated above, the present study was conducted in order to obtain information that could later be used to maximize the efficacy and efficiency of delayed auditory feedback. Toward that goal, the purpose of the study was to evaluate the relative contributions of clinician instruction and delay interval on the effectiveness of delayed auditory feedback in treating speech rate, intelligibility, and fluency deficits in adults with dysarthria secondary to Parkinson's disease. Specific research questions were as follows:

1) Does delayed auditory feedback reduce reading rate in speakers with Parkinson’s disease?
2) Does delayed auditory feedback improve intelligibility and/or fluency?
3) Are there differential effects of various delay intervals on speech behaviors?
4) Are there differential effects of clinician instruction on speech behaviors?
5) Does extended use of DAF result in generalization of speech improvements?

METHOD

Experimental Design

The present study utilized an A-B-A-B single-subject design for each of the three participants (Barlow & Hersen, 1984). The A phases (four sessions each) consisted of a sentence reading task using DAF alone, while the B phases (four sessions each) incorporated experimenter instruction/modeling into the DAF protocol. In addition, the study also included elements of an alternating-treatments design (Barlow & Hersen, 1984). That is, during each of the 16 experimental sessions, speakers were exposed to four different DAF intervals. The order of presentation of the delay intervals was randomized to control for sequence effects. Each of the three participants received exactly the same experimental protocol, making the study essentially a single-subject experiment with two simultaneous, direct replications (Barlow & Hersen, 1984).

Participants

Three adult males with Parkinson's disease and an associated dysarthria participated in the study. Participants were recruited from the Baton Rouge Parkinson's Disease Support Group and the Louisiana State University (LSU) Speech and Hearing Clinic. These particular individuals were invited to participate based on the presence of Parkinson’s disease (as diagnosed by a neurologist); the presence of dysarthria (confirmed by the principal investigator); a presenting complaint of a communicative impairment related to speech rate, intelligibility, and/or fluency; and sufficient hearing, vision, and cognitive abilities to complete the experimental tasks. All participants met the following inclusion criteria:

1) A neurologist's diagnosis of Parkinson's disease.

2) Disease severity of at least Stage 1 level on the Hoehn and Yahr severity scale (Hoehn & Yahr, 1967) to characteristic motor involvement associated with Parkinson’s disease.

3) A passing score of 24/30 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) to rule out the presence of dementia.

4) Self-reported native speakers of English.

5) Normal or corrected vision.

6) Pure-tone hearing thresholds at or below 50 dB HL for 0.5, 1.0, and 2.0 kHz.

7) Presenting complaint of two or more of the following speech symptoms: excessive speech rate, imprecise articulation, poor intelligibility, disfluencies (e.g., sound, syllable, word, or phrase repetitions; interjections; revisions).

8) No history of reading difficulties.

Relevant characteristics of the three participants are summarized below in Table 1.

Table 1. Descriptive characteristics of speakers with Parkinson's disease.

	Speaker 1	**Speaker 2**	**Speaker 3**
Age in years	64	36	74
Years since diagnosis	23	7	16
Overt physical signs	Shuffling gait, resting hand tremor, involuntary arm movements	Festinating gait, postural instability, use of walker	Non-ambulatory, ridigity in limbs, limited arm and hand movement
Speech characteristics	Rapid rate, imprecise consonant articulation, disfluencies	Rapid rate, imprecise consonant articulation, frequent disfluencies	Variable rate, soft intensity, fatigue of oral musculature, vowel distortions, imprecise consonant articulation, difficulty initiating phonation
Primary types of disfluencies	Sound and syllable repetitions	Sound repetitions, word revisions	Interjections (e.g., extraneous vocalizations), phrase repetitions
Medication	Sinemet	Sinemet, Mirapex	Sinemet CR, Tasmar, Mirapex, Eldepryl

Settings

Experimental sessions were conducted at the participants' residences (Speakers 1 and 2), and at the LSU Speech and Hearing Clinic (Speaker 3). Speakers 1 and 2 requested that sessions be held at their residences due to transportation difficulties. At each location, the experimenter and participant were seated facing each other at a table in a quiet room. Sessions were held two to four times per week, for a total of 16 sessions per participant (i.e., four sessions each during each of the four treatment phases). The length of each session varied from 25-45 minutes. All sessions for a particular speaker were scheduled at approximately the same time of day, coinciding with the time of optimal effectiveness of each speaker's medication.

Stimuli

A sentence-reading task was used throughout the study in all experimental conditions and during all phases. Sentences were obtained from the Speech Perception in Noise (SPIN) test (Kalikow, Stevens, & Elliot, 1977), and consisted of six to nine syllables each. The sentences were typed out in relatively large font (i.e., 16-point Times New Roman style) and presented to speakers on sheets of typing paper for reading ease.

As a generalization probe, participants also read a paragraph from a short story during each session (following the sentence reading task). Stories were obtained from a collection of classic literary works, and included such tales as *Huckleberry Finn, Jane Eyre, Black Beauty*, and *The Rocking-Horse Winner*. A one-minute segment was extracted from each paragraph read for data analysis.

Pre-test Measures

Prior to commencement of the experimental sessions, the following assessment battery was administered to each speaker: Mini Mental State Exam (Folstein, Folstein, & McHugh, 1975) to rule out the presence of dementia, the Hoehn and Yahr severity scale (1967) to categorize motor severity involvement, and a dysarthria checklist (see APPENDIX B) to verify the presence of dysarthria.

Instrumentation

Delayed auditory feedback (DAF) was generated using the Pocket Fluency System (Casa Futura Technologies), a portable unit capable of producing delay intervals of up to 250 ms in duration. All speakers wore a head-mounted microphone/headphone assembly (Labtec, model C-324). This assembly was connected to the DAF unit, and an additional microphone was clipped onto the speaker's shirt and connected to a portable cassette tape recorder (Sony, model WM-D6C). This procedure permitted audio recordings that were later used for reliability checks. All sessions were recorded onto TDK D60 audiocassette tapes.

The experimenter also wore a microphone/headphone assembly (Labtec, model C-324), attached to a second pair of jacks on the DAF unit, in order to hear the speaker's delayed speech signal. This allowed the experimenter to evaluate how precisely the speaker "matched" the delayed signal, as well as provide modeling of accurate matching. For each speaker, delay intervals of 0 ms, 50 ms, 100 ms, and 150 ms were presented in a randomized sequence during each of the 16 sessions. Intensity levels were set at comfortable listening levels for each speaker.

Data Collection

The principle investigator served as experimenter during all 16 sessions. The three dependent variables measured throughout the study were speech rate (in syllables per second), intelligibility (i.e., percentage of intelligible syllables), and percent disfluencies (i.e., the number of disfluent events per hundred syllables). Unintelligible syllables were defined as those that the experimenter was unable to identify. Disfluencies tallied included sound, syllable, word, and phrase repetitions, interjections (e.g., “um,” “uh,” as well as extraneous vocalizations), and revisions (e.g., “She went to *he went to* the store.”).

Following each session, reading rate, intelligibility, and disfluency were calculated for each 20 sentence DAF condition (i.e., 0 ms, 50 ms, 100 ms, and 150 ms). Rate was calculated by dividing the total number of syllables in each sentence by the total number of seconds elapsed during production of that sentence. Dividing the number of intelligible syllables in each sentence by the total number of syllables in that sentence, and multiplying by 100 calculated intelligibility. Dividing the total number of disfluent events in each sentence by total syllables in that sentence, and multiplying by 100 calculated disfluency. Mean values for all three dependent measures were computed for each interval condition in every session. For each of the 16 sessions, reading rate, intelligibility, and disfluency were plotted for each of the interval conditions (i.e., 0 ms, 50 ms, 100 ms, and 150 ms) on three separate graphs for each speaker (see Figures 1-9). Thus, each speaker had 12 data points per session for the sentence task, for a total of 192 data points during the experiment (i.e., 64 for each dependent variable).

Following each session, reading rate, intelligibility, and disfluency were also calculated for each one-minute paragraph segment read at the conclusion of the session (i.e., the generalization probe). Reading rate was calculated by dividing the total number of syllables spoken during each segment by the total number of seconds elapsed. Dividing the number of intelligible syllables in each segment by the total number of syllables, and multiplying by 100 calculated intelligibility. Dividing the total number of disfluent events in each segment by total syllables, and multiplying by 100 calculated disfluency. For each of the 16 sessions, reading rate, intelligibility, and disfluency for all three speakers were plotted on three separate graphs (see Figures 10-12). Thus, each speaker had three data points per session for the paragraph task, for a total of 48 data points during the experiment (i.e., 16 for each dependent variable).

Procedures

As described above, the present study utilized an A-B-A-B single-subject design for each of the three participants (Barlow & Hersen, 1984). The A phases (four sessions each) consisted of a sentence reading task using DAF alone, while the B phases (four sessions each) incorporated experimenter instruction/modeling into the DAF protocol. During each of the 16 experimental sessions, speakers were exposed to four different DAF intervals (i.e., 0 ms, 50 ms, 100 ms, and 150 ms). The order of presentation of the delay intervals was randomized to control for sequence effects. Each participant performed exactly the same experimental protocol.

A Phases

During each of the two A phases (i.e., DAF alone), each speaker read 20 sentences using each of four DAF intervals, for a total of 80 sentences per session. The speaker wore the microphone/headphone assembly throughout the entire session, including the 0 ms DAF condition (for ease of randomization of conditions). The volume of the delayed feedback was adjusted to a comfortable listening level. During each condition, the speaker read the sentences from sheets of paper placed in front of him. After 20 sentences were read, the experimenter adjusted the delay setting on the DAF unit (e.g., from 50 ms to 150 ms), and began the next delay interval condition.

Following completion of all four interval conditions, the paragraph reading task was presented as a generalization probe. The participant read a paragraph approximately 400 syllables in length without the use of DAF. The purpose of this task was to identify any potential “carry-over” of speech benefits gained through use of DAF to a more linguistically demanding and ecologically valid speech task (Norris et al., 1998). Data from this task were useful in determining whether extended use of DAF resulted in generalization of speech benefits (i.e., the fifth research question of the present study). All three participants read the same paragraphs, in the same sequence.

B Phases

During each of the two B phases (i.e., DAF + instruction), procedures were similar to those followed during the A phases. However, following each sentence production by the speaker, the experimenter provided verbal feedback specifically pertaining to how precisely the speaker matched the delayed signal throughout production of the sentence. "Matching" the delayed signal was defined as prolonging the duration of each spoken syllable until the delayed signal presented via headphones was auditorily perceived, and then beginning production of the next syllable in the sentence. It was expected that this manner of speech production, when performed accurately, would result in the elimination of an audible repetition of the syllable (or an "echo"). In effect, the speaker would be allowing the delayed signal to "catch up," temporally, to his production of the syllable before proceeding with production of the next syllable. This typically results in a "synchronization" of the speaker's direct speech signal with the delayed signal, preventing a potentially distracting and aversive auditory stimulus. Precise matching of the delay also ensures maximal speech rate reduction from that particular delay interval.

As described above, the experimenter listened to each sentence production through headphones in order to monitor matching accuracy. Following each sentence production, the experimenter provided the speaker with verbal feedback about how precisely he matched the delayed signal. Whenever deemed necessary (i.e., when audible echoes were perceived), the experimenter briefly instructed the speaker on how to improve matching accuracy (e.g., "Wait until you hear the syllable through the headphones before you start the next syllable," or "Stretch out your syllables a little longer, I'm still hearing an echo.").

Following this verbal feedback, the experimenter demonstrated precise matching by orally producing the same sentence at the appropriate rate with each syllable adequately elongated. Following this demonstration, the experimenter prompted the speaker to read the next sentence on the list while matching as precisely as possible. For production of sentences judged to be accurately matched, the experimenter responded with verbal praise (e.g., "Good.") and instructed the speaker to proceed with the next sentence in the list. This procedure was followed for every session during each of the two B phases. As in the A phases, the generalization probe (i.e., paragraph reading) was conducted following completion of the sentence reading task.

Data Analysis

For the sentence reading data, the three dependent variables (i.e., reading rate, intelligibility, and disfluency) were plotted on separate graphs for each speaker following each of the 16 sessions. Descriptive statistics computed included mean values for each of the four delay settings (i.e., 0 ms, 50 ms, 100 ms, 150 ms) during the A phases (i.e., A1 + A2) and B phases (i.e., B1 + B2), as well as across all four phases. Likewise, mean values for the A and B phases were calculated across interval conditions. Standard deviation (SD) was used as the measure of variability.

Visual inspection of these data was supplemented with statistical analysis. For each speaker, three 2x4 analyses of variance (ANOVAs) were performed (one on each of the three dependent variables) to test for significant effects of DAF interval and experimental phase (i.e., DAF vs. DAF + instruction), as well as significant interactions between these two factors. Following all significant main effects of DAF interval, Bonferroni tests were used to make pair-wise comparisons among the four DAF interval conditions across experimental phases.

For the paragraph reading data, the three dependent variables (i.e., reading rate, intelligibility, and disfluency) were plotted on separate graphs for all three speakers following each of the 16 sessions. Descriptive statistics computed included mean values for each speaker across all 16 sessions. Standard deviation (SD) was used as the measure of variability. As with the sentence task, visual inspection of these data was supplemented with statistical analysis. For each speaker, three Pearson product moment correlations were used to examine overall relationships between each of the speech variables and number of experimental sessions (i.e., the length of exposure to DAF).

Intrajudge Reliability

For the sentence data, agreement between the experimenter's calculations of each of the three dependent variables was computed using five percent of the sentences produced by each speaker during each session (i.e., 64 sentences per each speaker, for a total of 192 sentences). Intrajudge reliability was calculated using paired *t*-tests to test for significant differences between the two sets of values assigned by the experimenter (i.e., TIME 1 and TIME 2). Additionally, Pearson product moment correlations were used to evaluate the relationships between the two sets of values (i.e., TIME 1 and TIME 2) for each dependent variable.

For the paragraph data, agreement between the experimenter's calculations of speech rate, intelligibility, and disfluency was calculated speakers using 25% of the paragraph segments produced by each speaker (i.e., one paragraph from each of the four experimental phases for each speaker, for a total of 12 paragraphs). For each paragraph segment, values were calculated for reading rate, intelligibility, and disfluency. Intrajudge reliability was calculated using paired *t*-tests to test for significant differences between the two sets of values assigned by the experimenter (i.e., TIME 1 and TIME 2). Additionally, Pearson product moment correlations were used to evaluate the relationships between the two sets of values (i.e., TIME 1 and TIME 2) for each of the three dependent variables. Table 2 provides a summary of the intrajudge reliability data.

Table 2. Summary of intrajudge reliability data for the sentence and paragraph tasks (NS = nonsignificant).

	Mean and SD for TIME 1	**Mean and SD for TIME 2**	**Correlation and significance**	**Significance of *t*-test**
Sentence Task				
Reading rate in syllables per second	2.31 (.88)	2.34 (.89)	r = .981 p = .000	p = .011
Percent intelligible syllables	96.55 (10.63)	97.77 (8.94)	r = .617 p = .000	NS
Percent disfluency	2.58 (6.27)	3.01 (6.91)	r = .891 p = .000	NS
Paragraph Task				
Reading rate in syllables per second	2.61 (1.00)	2.61 (.98)	r = .998 p = .000	NS
Percent intelligible syllables	84.67 (17.99)	85.50 (16.6)	r = .986 p = .000	NS
Percent disfluency	4.76 (3.91)	4.62 (3.94)	r = .963 p = .000	NS

As indicated in Table 2, intrajudge reliability was generally high for the sentence data as well as the paragraph data. All correlations between the two separate calculations (i.e., TIME 1 and TIME 2) were positive, at least moderately strong, and statistically significant. In addition, none of the pairs of data sets were significantly different from each other, with the exception of the reading rate data for the sentence task. Despite similar mean rate values for TIME 1 and TIME 2 (i.e., 2.31 syllables per second and 2.34 syllables per second, respectively), these two sets of values were statistically different from each other ($p = .011$). This may be due, in part, to the strong correlation between the two sets of values. That is, such an *r* value (i.e., $r = .981$) results in a lower error term obtained during the *t*-test, as twice the value of the correlation (i.e., $2r$) is subtracted from the error term. Because the error term is the denominator in a *t*-test, this may have increased the likelihood of obtaining a significant *t* value. The fact that the *t*-test was also based on a large number of data points (i.e., 192) may have also increased the likelihood of detecting a significant difference between the two sets of values.

Interjudge Reliability

A graduate student in the Department of Communication Sciences and Disorders at LSU served as reliability judge for the sentence data (for all three participants). Following a brief training period, she calculated reading rate, intelligibility, and disfluency for five percent of the sentences produced by each speaker during each session (i.e., 64 sentences for each speaker, for a total of 192 sentences). Interjudge reliability was calculated using paired *t*-tests to detect any significant differences between values assigned by the reliability judge (i.e., JUDGE 2) and those assigned by the experimenter (i.e., JUDGE 1). Additionally, Pearson product moment correlations were used to evaluate the relationships between the two sets of values for each dependent variable.

A faculty member in the Department of Communication Sciences and Disorders at LSU served as reliability judge for the paragraph data (for all three speakers). Following a brief training period, he calculated speech rate, intelligibility, and disfluency for 25% of the paragraph segments produced by each speaker (i.e., one paragraph from each of the four experimental phases for each speaker, for a total of 12 paragraphs). For each paragraph segment, values were calculated for reading rate, intelligibility, and disfluency. Interjudge reliability was calculated using paired *t*-tests to detect any significant differences between values assigned by the reliability judge (i.e., JUDGE 2) and those assigned by the experimenter (i.e., JUDGE 1). Additionally, Pearson product moment correlations were used to evaluate the relationships between the two sets of values for each dependent variable. Table 3 provides a summary of the interjudge reliability data.

Table 3. Summary of interjudge reliability data for the sentence and paragraph tasks.

	Mean and SD for JUDGE 1	**Mean and SD for JUDGE 2**	**Correlation and significance**	**Significance of *t*-test**
Sentence Task				
Reading rate in syllables per second	2.31 (.88)	2.50 (1.07)	r = .982 p = .000	p = .000
Percent intelligible syllables	96.55 (10.63)	94.98 (14.01)	r = .303 p = .000	NS
Percent disfluency	2.58 (6.27)	4.90 (7.22)	r = .512 p = .000	p = .000
Paragraph Task				
Reading rate in syllables per second	2.61 (1.00)	2.58 (.95)	r = .988 p = .000	NS
Percent intelligible syllables	84.67 (17.99)	60.44 (28.60)	r = .853 p = .000	p = .000
Percent disfluency	4.76 (3.91)	2.97 (2.70)	r = .942 p = .000	p = .000

As indicated in Table 3, interjudge reliability was generally high for the sentence data, although specific values warrant further explanation. First, although JUDGE 1 and JUDGE 2 calculated similar mean rate values (i.e., 2.31 syllables per second and 2.50 syllables per second, respectively), these two sets of values were statistically different from each other (p = .000). As discussed in the preceding section, this may be due to statistical factors such as the strong correlation between the two sets of values (i.e., r = .982) and the large number of data points (i.e., 192) used to calculate the *t*-test.

Secondly, intelligibility values assigned by the two judges were not significantly different, indicating high agreement. However, the relatively low correlation between these two sets of values (r = .303) suggests the presence of a ceiling effect for intelligibility during sentence reading. That is, because of the restricted range of values for this measure (i.e., speakers were generally intelligible during this task), values varied only slightly either above or below the mean. For example, JUDGE 2's calculation for a particular sentence was typically slightly higher or slightly lower than JUDGE 1's calculation for that same sentence (hence, a relatively low correlation between the two sets of values).

Lastly, disfluency values assigned by the two judges were significantly different, (p = .000), although characterized by a significant moderate correlation (r = .512). That is, although mean values assigned by the judges were significantly different, there was a tendency for JUDGE 1 and JUDGE 2 to detect similar changes in disfluency from sentence to sentence. The significant difference between the two sets of values may be due, in part, to the difficulty for an unfamiliar listener in differentiating some of the rapid and distorted disfluencies produced by the speakers.

Examination of the values presented in Table 2 reveals that, for the paragraph data, interjudge reliability was high for the reading rate, but somewhat lower for intelligibility and disfluency. Although intelligibility and disfluency values assigned by JUDGE 1 and JUDGE 2 showed strong, positive correlations (.853 and .942, respectively), the significantly different means illustrate the difficulty in differentiating between disfluent syllables and unintelligible syllables produced by speakers who exhibit dysarthria. That is, rapid and “blurred” syllables may be judged as repetitions by some listeners, but as simply unintelligible by other listeners.

For example, Table 3 indicates that JUDGE 2 assigned significantly lower mean values for both intelligibility and disfluency than did JUDGE 1. That is, although JUDGE 2 scored more syllables as being unintelligible than did JUDGE 1, he also tallied fewer syllables as disfluencies. However, the strong positive relationships between values assigned by the two listening judges (for all three dependent variables) demonstrate similarly consistent changes in scoring from paragraph to paragraph. That is, when JUDGE 1 calculated more disfluent events in one paragraph than in the previous paragraph (for example), JUDGE 2 exhibited a strong tendency to follow suit.

RESULTS

As discussed in the second chapter, the primary research questions of the present study were as follows:

1) Does delayed auditory feedback reduce reading rate in dysarthric speakers with Parkinson's disease?
2) Are any rate reductions accompanied by improvements in intelligibility and fluency?
3) Are there differential effects of various delay intervals on speech behaviors?
4) Are there differential effects of clinician instruction on speech behaviors?
5) Does extended use of DAF result in generalization of speech improvements?

Sentence Data

Because the sentence reading task (using four different DAF conditions during each session) was of primary interest in answering these research questions, performance on this task will be examined first, followed by the paragraph reading data. Due to the idiosyncratic patterns of responding observed across participants, each participant's data will be presented individually. For each speaker, changes in each of the three dependent variables (i.e., speech rate, percent intelligibility, and percent disfluency) will be discussed separately. Data for all three participants were evaluated using both visual inspection and statistical analysis.

Speaker 1

Figures 1-3 display Speaker 1's performance on each of the three dependent measures (plotted on the y-axes) across the 16 experimental sessions (plotted on the x-axes). The three graphs depict data for speech rate (Figure 1), intelligibility (Figure 2), and disfluency (Figure 3). The four lines plotted on each graph represent the four DAF conditions utilized during each session (i.e., 0 ms, 50 ms, 100 ms, and 150 ms). Each graph is divided into four sections, which display data for the four phases of the experiment (i.e., A1, B1, A2, and B2). During each A phase, the participants read the sentences while using DAF without instruction from the experimenter. The experimenter provided instruction in conjunction with the use of DAF during the two B phases.

Speech Rate

Figure 1 displays Speaker 1's speech rate (in syllables per second) across all 16 sessions. A 2x4 Analysis of Variance (ANOVA) yielded significant main effects for phase [F (1, 63) = 51.766, p = .000] and interval [F (3, 63) = 5.720, p = .000], but no significant interaction effect [F (3, 63) = 2.013, p = .123]. In addition, a one-way ANOVA yielded a significant main effect of phase for the 0 ms condition [F (1, 15) = 5.756, p = .031].

A Bonferroni test was performed to determine the differential effects of the four delay intervals on speech rate. Results indicated that Speaker 1's reading rate during the 0 ms DAF condition was significantly higher than during each of the three remaining DAF conditions (p = .000), and that 50 ms DAF yielded a significantly higher rate than did 100 ms DAF (p = .000) or 150 ms DAF (p = .000). However, 100 ms DAF and 150 ms DAF did not produce significantly different speech rates (p = .089). In sum, statistical analyses revealed that Speaker 1's speech rate was significantly reduced during the B phases (i.e., DAF + instruction), including during the 0 ms (i.e., no DAF) condition. Also, with the exception of 150 ms, each DAF interval produced a significantly lower rate than the next shortest delay interval across phases.

These statistical results are highlighted by visual inspection of the data (see Figure 1). The no DAF condition consistently yielded the highest speaking rates (M = 4.04 SPS, SD = .25), with no overlap with values for any of the three DAF settings. In fact, there were no overlapping

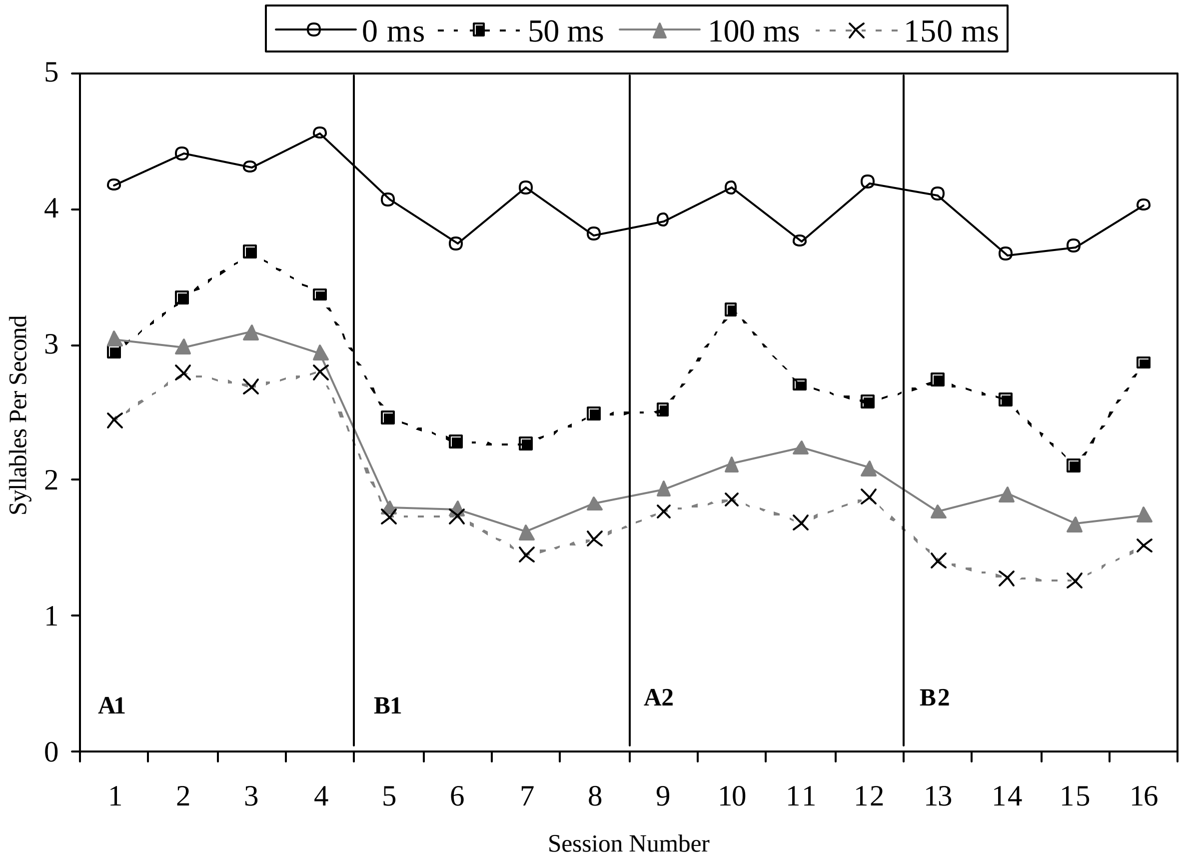

Figure 1. Reading rate (syllables per second) across sessions during sentence reading for Speaker 1.

values among any of the DAF conditions. As expected, 150 ms DAF yielded the lowest speech rates in every session (M = 1.87 SPS, SD = .52), most markedly during the second B phase. As stated above, however, the mean difference in speech rate between this condition and the 100 ms DAF condition (M = 2.16 SPS, SD = .53) across the four phases was not statistically significant.

These results clearly demonstrate that each successive increase in the delay interval resulted in a further decrease in Speaker 1's reading rate. By the final session, he read at a rate of over four syllables per second without the use of DAF but approximately 1.5 syllables per second with 150 ms DAF, confirming the effectiveness of the intervention (i.e., the use of DAF with experimenter instruction) in reducing reading rate.

In an ideal A-B-A-B experiment, each of the measurements of speech rate would have declined from the first A phase to the first B phase, and then risen from the first B phase to the second A phase (Barlow & Hersen, 1984). Examination of changes in speech rate between the four phases of the experiment reveals an immediate downward shift in rate for all four intervals at the beginning of the first B phase (i.e., session 5). This change in level during phase B1 was much greater in magnitude for the three levels of DAF than for the no DAF condition (i.e., 0 ms DAF), and illustrates the effectiveness of clinician instruction in increasing the efficacy of DAF as a rate control intervention. The beginning of phase A2 (i.e., withdrawal of experimenter instruction) resulted in an immediate increase in rate during all interval conditions (including the 0 ms DAF condition), as well as a slight upward trend for 100 ms DAF.

Re-instating the experimenter instruction at phase B2 (session 13) resulted in immediate downward shift in speech rate for all conditions with the exception of 50 ms DAF, which also produced a rate decrease by session 15. Throughout the remainder of this last phase (i.e., B2), performance stabilized during use of the two longest delay intervals (i.e., 100 ms and 150 ms), but showed slightly more variability without the use of DAF (i.e., 0 ms), as well as with the use of 50 ms DAF. In general, these results demonstrate that Speaker 1 experienced the most dramatic (and consistent) rate reductions by using the two longest delay intervals, particularly in conjunction with matching instruction from the experimenter. However, speech rate without the use of DAF was also significantly lower during the B phases (i.e., DAF + instruction) than during the A phases (DAF alone), suggesting within-session generalization of DAF effects.

Intelligibility

Figure 2 displays Speaker 1's percentage of intelligible syllables across sessions. A 2x4 Analysis of Variance (ANOVA) failed to reveal significant main effects for phase [F (1, 63) = 2.936, p = .092] or DAF interval [F (3, 63) = .434, p = .729], or a significant interaction effect [F (3, 63) = 1.304, p = .282]. Thus, Speaker 1's intelligibility was not significantly increased by any of the DAF intervals, whether presented alone or in conjunction with experimenter instruction. This finding is confirmed by visual inspection (see Figure 2), which shows that even when reading without the use of DAF, Speaker 1's intelligibility never decreased below 97.5%. Thus, intelligibility during sentence reading was evidently not a significant deficit in this individual's speech. The restricted range of intelligibility values for this speaker (i.e., a ceiling effect) was likely responsible for the results obtained throughout the study.

Disfluency

Figure 3 displays Speaker 1's percentage of disfluency across sessions. A 2x4 Analysis of Variance (ANOVA) yielded significant main effects for phase [F (1, 63) = 12.469, p = .001] and interval [F (3, 63) = 5.720, p < .002], but no significant interaction effect [F (3, 63) = .673, p = .572]. In addition, a one-way ANOVA failed to yield a significant main effect of phase for the 0 ms condition [F (1, 15) = 1.937, p = .186].

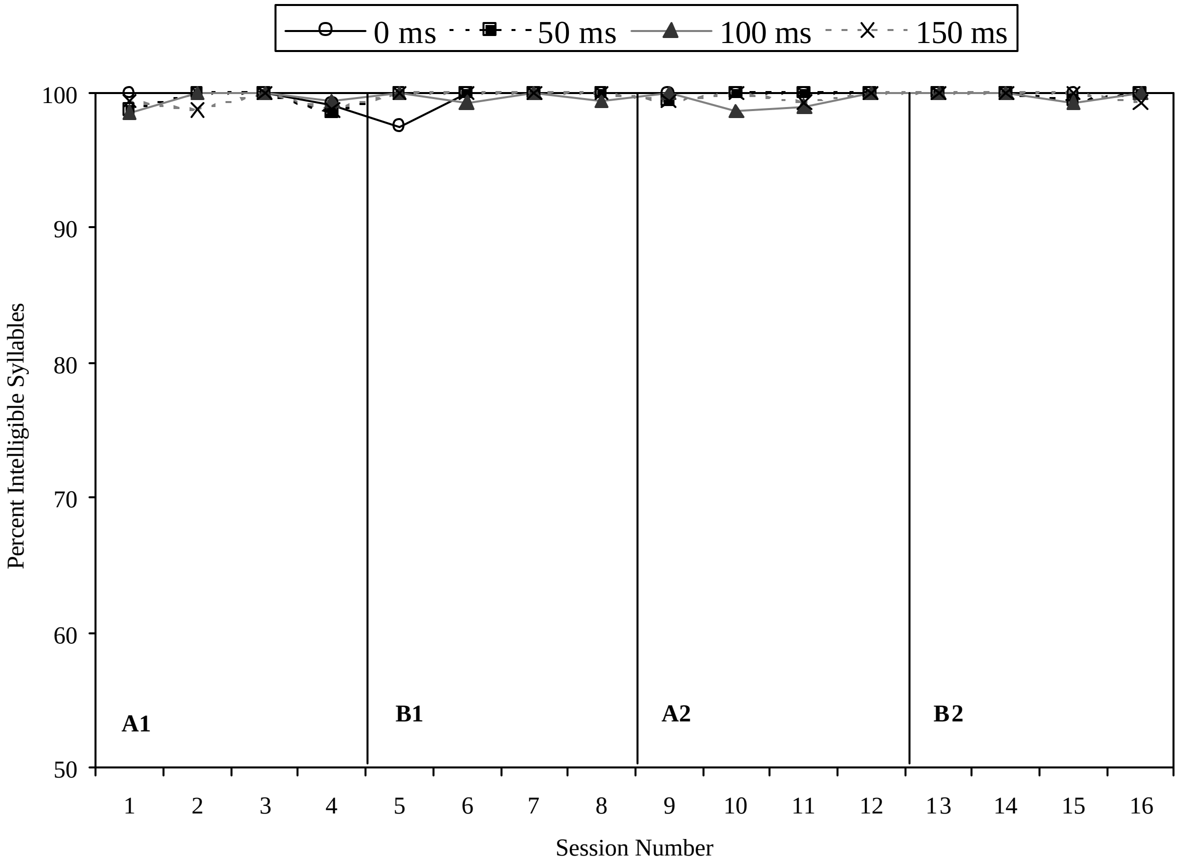

Figure 2. Percent intelligible syllables across sessions during sentence reading for Speaker 1.

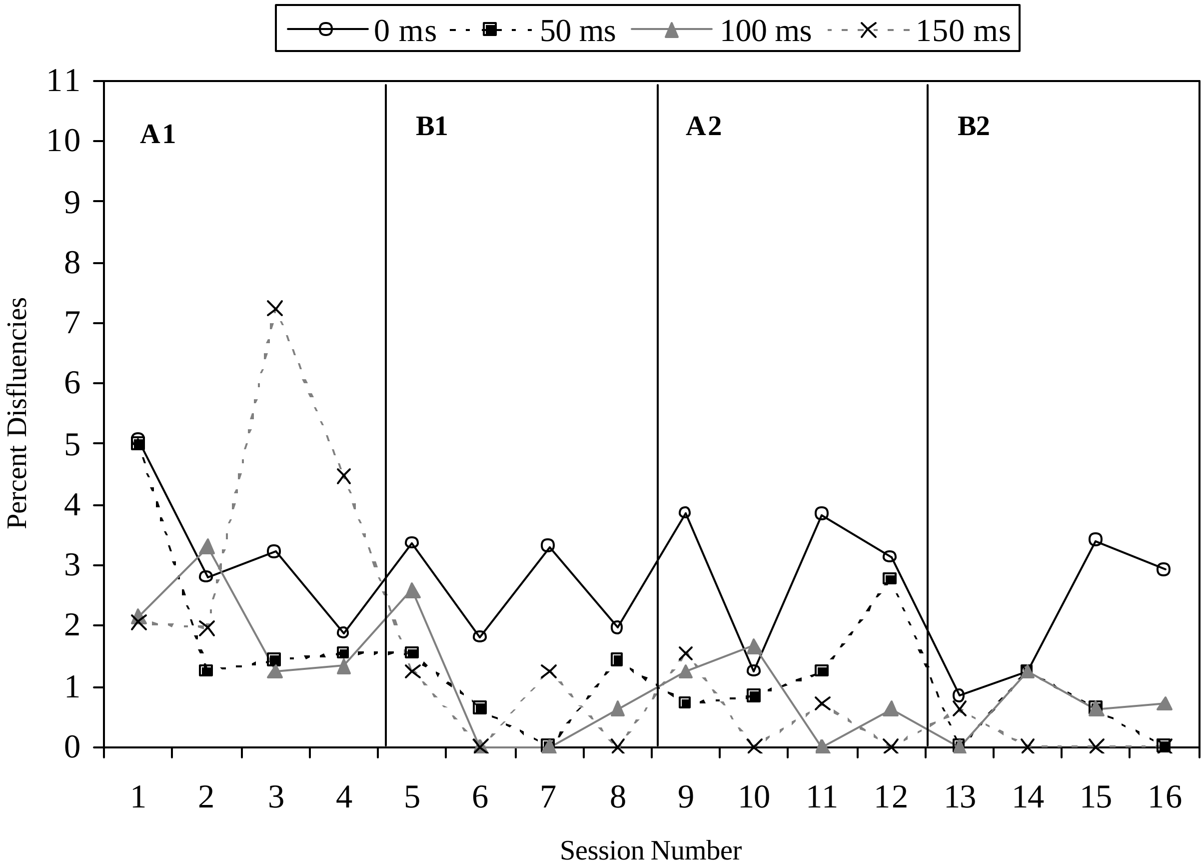

Figure 3. Percent disfluencies (i.e., number of disfluent events per hundred syllables) across sessions during sentence reading for Speaker 1.

A Bonferroni test was performed to evaluate the differential effects of the four delay intervals on Speaker 1's disfluency level. Results indicated that his percentage of disfluency during the no DAF condition was significantly higher than with each of the three DAF settings ($p = .011$, $p = .003$, $p = .016$), none of which yielded significantly different results from one another. Thus, statistical analyses revealed that Speaker 1's percentage of disfluency was significantly reduced during the B phases (i.e., DAF + instruction) relative to the A phases (i.e., DAF alone), but not during the 0 ms condition. Also, all three DAF settings (i.e., 50 ms, 100 ms, and 150 ms) significantly reduced percentage of disfluency (as compared to no DAF).

Visual inspection of these data reveals some interesting patterns not readily apparent through statistical evaluation (see Figure 3). Throughout most of the experiment, the 0 ms DAF condition yielded the highest percentages of disfluency ($M = 2.74\%$, $SD = 1.15$), with little overlap with values for either the 50 ms DAF ($M = 1.27\%$, $SD = 1.23$) or 100 ms DAF conditions ($M = 1.09\%$, $SD = .98$). During the first phase, however, the highest disfluency levels (which exceeded seven percent) resulted from use of 150 ms DAF (see data points for sessions 3 and 4).

However, immediately following the introduction of experimenter instruction (session 5), disfluency during the use 150 ms DAF decreased dramatically to less than one percent. From that point on, this delay interval produced relatively low disfluency rates ($M = 1.32\%$, $SD = 1.98$) comparable to those produced by 50 ms and 100 ms DAF. Speaker 1 evidently responded well to 150 ms DAF, but only after the introduction of matching instruction from the experimenter. It is also noteworthy that 50 ms DAF produced consistent, albeit slight, upward trends during both

A phases which were quickly reversed during the B phases. In general, results illustrated that after some initial instruction in matching the delay (during phase B1), all three settings of DAF were effective in decreasing Speaker 1's frequency of disfluent events.

Summary of Sentence Data for Speaker 1

In general, results revealed that the use of delayed auditory feedback led to significant improvements in Speaker 1's reading rate and fluency, and that these effects were significantly greater in magnitude when supplemented by clinician instruction. Reading rate without the use of DAF (i.e., 0 ms) was also significantly slower during the DAF + instruction phases, suggesting generalization of the DAF-induced speech pattern. However, percent disfluency during the 0 ms condition was not significantly reduced by the addition of instruction to the intervention.

Although no particular delay interval proved optimal in reducing the frequency of disfluent events, 150 ms DAF provided maximal rate reduction (although not statistically greater than 100 ms DAF). Similar to findings regarding the effects of DAF on the speech of normal speakers (Bloodstein, 1995), Speaker 1 actually exhibited more frequent repetitions while using 150 ms DAF during phase A1. However, these disfluencies were significantly reduced in frequency when clinician instruction was added to the DAF intervention. Lastly, the use of DAF, either alone or with instruction, had no significant effects on Speaker 1's intelligibility. This was most likely due to the limited range of values for this measure (i.e., a ceiling effect). That is, Speaker 1's intelligibility was consistently high during the sentence reading task, with or without the aid of delayed auditory feedback.

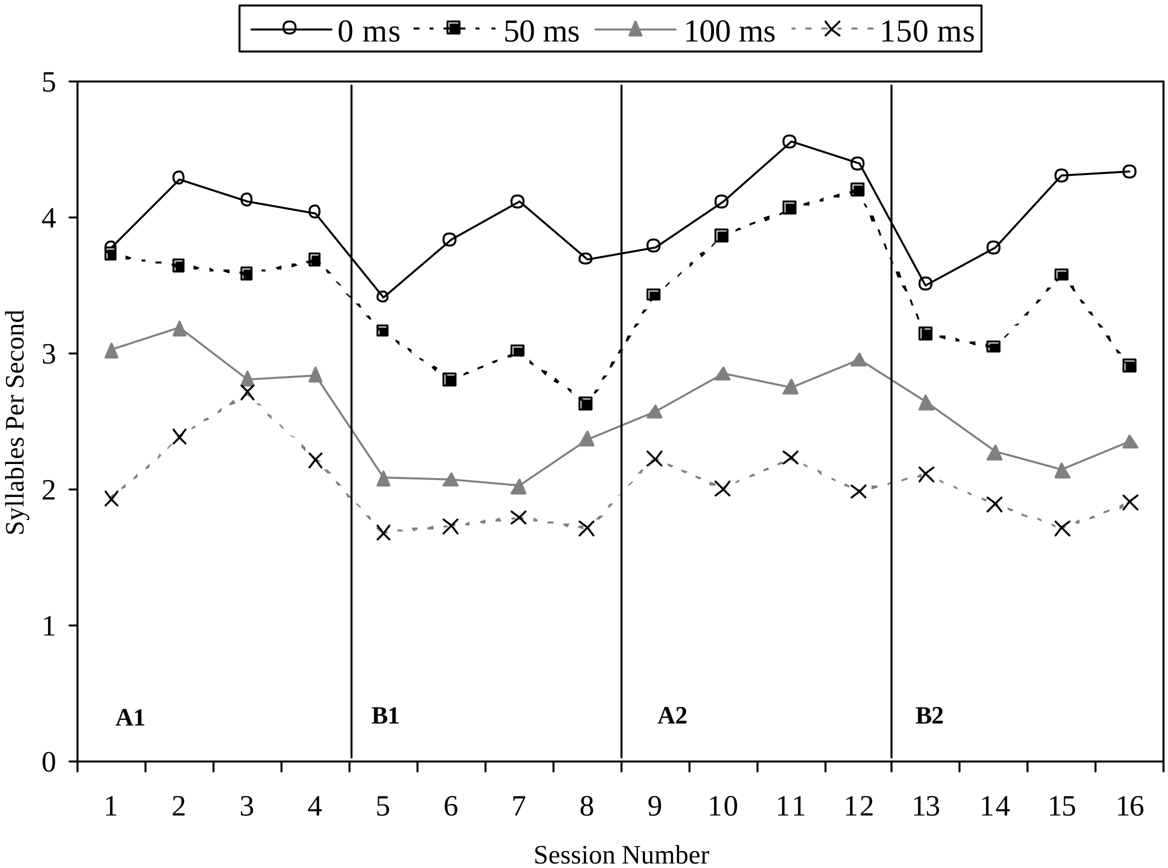

Figure 4. Reading rate (syllables per second) across sessions during sentence reading for Speaker 2.

Speaker 2

Figures 4-6 display Speaker 2's performance on each of the three dependent measures across experimental sessions. The three graphs depict data for speech rate (Figure 4), intelligibility (Figure 5), and disfluency (Figure 6).

Speech Rate

Figure 4 displays Speaker 2's speech rate (in syllables per second) across all 16 sessions. A 2x4 Analysis of Variance (ANOVA) yielded significant main effects for phase [F (1, 63) = 64.752, p = .000] and interval [F (3, 63) = 196.708, p = .000], as well as a significant interaction effect [F (3, 63) = 2.013, p = .038]. In addition, a one-way ANOVA failed to yield a significant main effect of phase for the 0 ms condition [F (1, 15) = 2.778, p = .118].

A Bonferroni test was performed to determine the differential effects of the four DAF intervals on speech rate. Results revealed that all six pairs of intervals were significantly different in terms of their effects on reading rate (p = .000). That is, across the four phases of the experiment, each delay interval resulted in a significantly lower speech rate than the next shortest interval (e.g., 100 ms versus 50 ms). In sum, statistical analysis revealed that Speaker 2's reading rate was significantly reduced during the B phases (i.e., DAF + instruction), but not without the use of DAF (i.e., the 0 ms condition). Also, all six pairs of interval conditions produced significantly different speech rates across phases. Lastly, the significant interaction effect suggested that the impact of phase change (i.e., shifting from DAF alone to DAF + instruction) was more pronounced for particular DAF intervals.

This interaction effect becomes more evident through visual inspection of the data (see Figure 4). The separation between the data points and absence of overlapping values reveals the differences in speech rate produced by the four DAF intervals, regardless of phase (i.e., whether

DAF was used alone or supplemented by instruction). However, the relative differences in speech rate among the four intervals were somewhat idiosyncratic. That is, performance at each delay interval was affected somewhat differently by changes in phase (e.g., proceeding from the use of DAF alone to the use of DAF plus instruction).

Close examination of speech rate changes between the four phases of the experiment reveals an immediate downward shift in rate for all four interval conditions at the beginning of the first B phase (i.e., session 5). However, this change in level was maintained throughout phase B1 for all three levels of DAF, but not for the 0 ms DAF condition (i.e., no DAF). Reading rate at 0 ms DAF returned to baseline levels (i.e., with the use of DAF alone), confirming the effectiveness of adding experimenter instruction to the DAF intervention. Withdrawal of instruction at phase A2 resulted in an immediate increase in speech rate during all interval conditions, as well as a marked upward trend for the 50 ms DAF condition. It became clear by phase A2 that 50 ms DAF produced relatively little rate reduction (in comparison to no DAF) when used without the benefit of experimenter instruction.

Re-instating the instruction at phase B2 (session 13) resulted in another immediate downward shift in reading during all interval conditions. Again, this decrease in rate was maintained at all three levels of DAF, but not at 0 ms DAF. As in phase B1, reading rate without the use of DAF returned to baseline levels (i.e., with the use of DAF alone), confirming the effectiveness of adding instruction to the DAF intervention. Thus, all three DAF settings were more effective when experimenter instruction was added to the protocol. This was particularly evident for 50 ms DAF, which appeared to be most effective in reducing Speaker 2's rate when supplemented by verbal instruction and modeling.

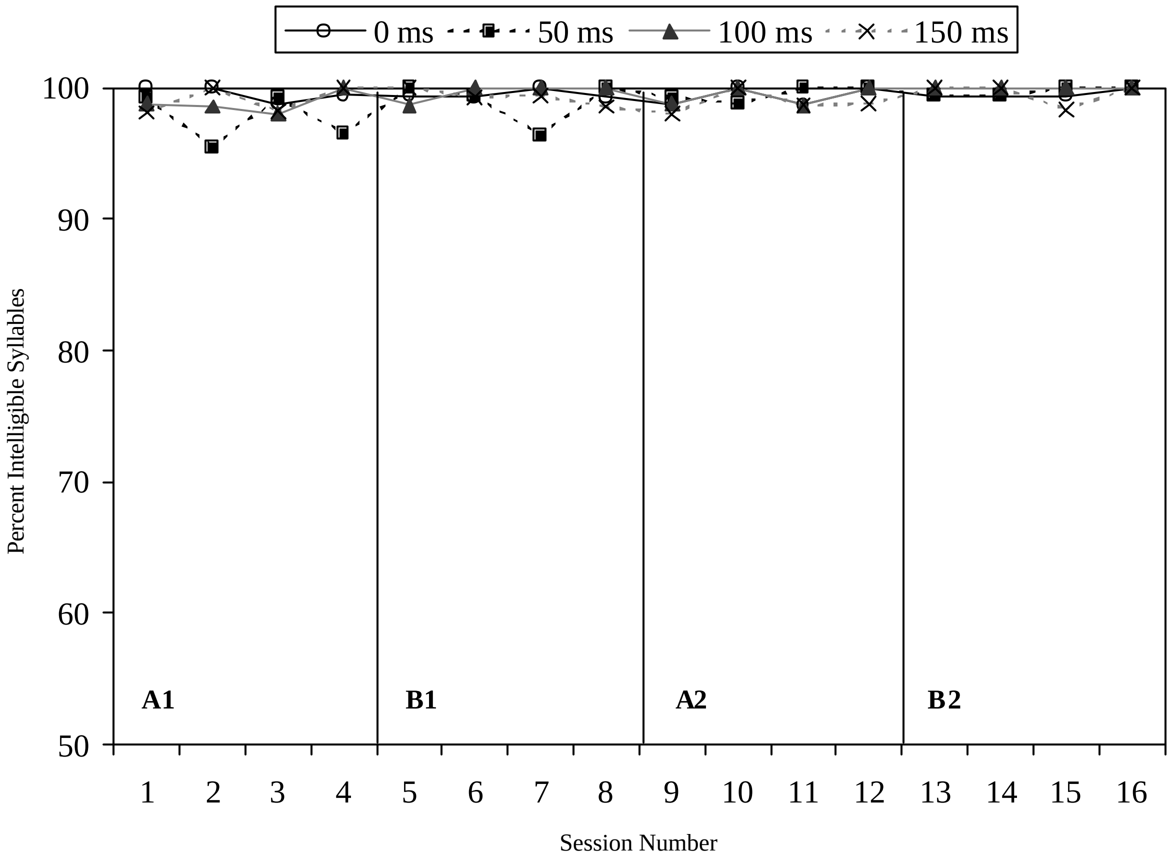

Figure 5. Percent intelligible syllables across sessions during sentence reading for Speaker 2.

Intelligibility

Figure 5 displays Speaker 2's percentage of intelligibility across sessions. A Between-Subjects Analysis of Variance (ANOVA) yielded a main effect for phase [$\underline{F}$ (1, 63) = 4.764, $\underline{p}$ = .033], but failed to reveal a significant main effect for interval [$\underline{F}$ (3, 63) = 1.183, $\underline{p}$ = .729] or a significant interaction effect [$\underline{F}$ (3, 63) = .476, $\underline{p}$ = .700]. Thus, Speaker 2's intelligibility was significantly higher during the B phases than the A phases, across all DAF interval conditions.

This is confirmed by visual inspection (see Figure 5), which shows that wide variability during 50 ms DAF during the first two phases seems to have accounted for the mean differences between the phases (i.e., both A phases versus both B phases). Beginning at session 9, however, intelligibility of 98% or higher was maintained throughout the remainder of the experiment, regardless of whether DAF and/or instruction was utilized. As was the case for Speaker 1, intelligibility during the sentence reading task was evidently not a primary clinical concern for Speaker 2. Again, the restricted range of intelligibility values for this speaker (i.e., a ceiling effect) was likely responsible for the results obtained.

Disfluency

Figure 6 displays Speaker 2's percentage of disfluency across sessions. A Between-Subjects Analysis of Variance (ANOVA) yielded significant main effects for phase [$\underline{F}$ (1, 63) = 25.517, $\underline{p}$ = .000] and interval [$\underline{F}$ (3, 63) = 8.843, $\underline{p}$ = .000], as well as a significant interaction effect [$\underline{F}$ (3, 63) = 2.995, $\underline{p}$ = .038]. In addition, a one-way ANOVA yielded a significant main effect of phase for the 0 ms condition [$\underline{F}$ (1, 15) = 12.233, $\underline{p}$ = .004], suggesting generalization of DAF effects to sentence reading without the use of DAF.

A Bonferroni test was utilized to evaluate the differential effects of the four delay intervals on Speaker 2's percentage of disfluency. Results indicated that his percentage of disfluency during the no DAF condition (M = 4.86%, SD = 2.85) was significantly higher than during each of the three remaining DAF intervals (p = .001, p = .001, p = .000), none of which yielded significantly different results from one another. Thus, statistical analysis indicated that Speaker 2's disfluency was significantly reduced during the B phases (i.e., DAF + instruction), including during reading without the use of DAF. Also, all three DAF settings significantly reduced disfluency (as compared to no DAF) across phases. Lastly, the significant interaction effect suggests that the significantly higher percentage of disfluency exhibited during the 0 ms DAF condition was more marked during the A phases than during the B phases.

This latter finding is confirmed by visual inspection of the data (see Figure 6). The separation between the data points and absence of overlapping values during both A phases illustrates the higher levels of disfluency exhibited without the use of DAF. However, during the B phases, percentage of disfluency during 0 ms DAF was at times lower than during the three DAF conditions, suggesting generalization of DAF-induced fluency improvements. Alternatively, this may be due, in part, to the relatively high standard deviations attained for percentage of disfluency both during the A phases (M = 4.11%, SD = 2.19) and the B phases (M = 2.12%, SD = 1.58) across all delay intervals. As discussed in the following chapter, it is also possible that certain types of disfluencies are not likely to be eliminated via rate reduction.

Examination of changes in disfluency between the four phases of the experiment reveals an immediate downward shift for all four interval conditions at the beginning of the first B phase (i.e., session 5). However, performance during phase B1 was marked by variability during three

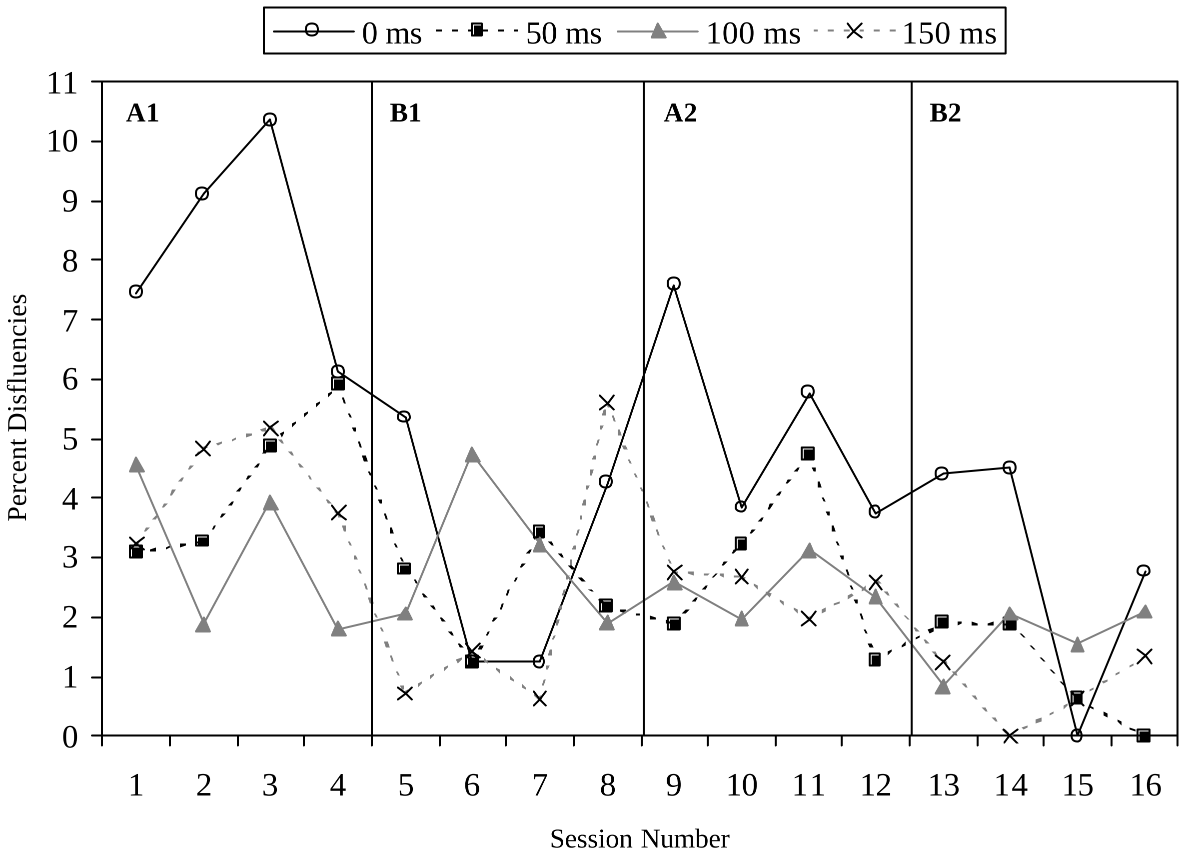

Figure 6. Percent disfluencies (i.e., number of disfluent events per hundred syllables) across sessions during sentence reading for Speaker 2.

of the four interval conditions (i.e., 0 ms, 100 ms, and 150 ms), with frequent overlap with baseline values (i.e., those obtained during phase A1, which used DAF alone). The 50 ms DAF condition, however, produced consistently fewer disfluent events during B1 than during A1, as was expected. Withdrawal of experimenter instruction at phase A2 resulted in an immediate increase in disfluency during the no DAF condition and an upward trend for the 50 ms DAF condition, which was reversed by session 12. This low percentage of disfluency at session 12 may have reflected Speaker 2's ability to accurately match 50 ms of DAF without feedback from the experimenter (i.e., a learning effect).

Interestingly, performance with 100 ms and 150 ms DAF stabilized to relatively low levels throughout phase A2, although values were at times higher than those obtained during phase B1 (particularly for 150 ms DAF). This stabilization would be expected, and confirms the particular effectiveness of these relatively long DAF intervals in reducing the frequency of speech disfluencies, particularly when supplemented by clinician instruction. That is, longer delay intervals usually result in slower speech rates, which were expected to increase speech fluency.

Re-instating the experimenter instruction during phase B2 resulted in observably lower mean disfluency values for all four interval conditions, though with varying latencies of change. This relatively low level of disfluency was maintained for all four interval conditions, including the 0 ms DAF condition. However, the reduced variability during phase B2 for the three DAF settings (i.e., 50 ms, 100 ms, and 150 ms) suggests not only the effectiveness of DAF in stabilizing speech fluency, but also Speaker 2's improved ability to consistently respond to the experimenter's matching instruction in order to maintain low levels of disfluency.

Summary of Sentence Data for Speaker 2

To summarize, results revealed that the use of DAF resulted in significant improvements in Speaker 2's reading rate and fluency, which were significantly greater in magnitude during the DAF + instruction phases. Percent disfluency without the use of DAF (i.e., 0 ms) was also significantly slower during the DAF + instruction phases, suggesting generalization of the DAF-induced speech pattern. However, reading rate during the 0 ms condition was not significantly reduced by the addition of instruction to the intervention.

Although no particular delay interval proved optimal for reducing the frequency of disfluent events, 150 ms DAF provided maximal rate reduction. Interestingly, the rate reducing effects of 50 ms DAF showed the greatest enhancement from clinician instruction DAF (although 150 ms DAF still yielded significantly slower speech rates). Lastly, the use of DAF produced no significant effects on Speaker 2's intelligibility, most likely due to the restricted range of values for this measure (i.e., a ceiling effect). However, his intelligibility was significantly higher during the B phases (i.e., DAF + instruction) than during the A phases (i.e., DAF alone), most likely due to variability in responding during the first half of the study (see Figure 5). Although this difference was statistically significant, as the lowest intelligibility values were approximately 96%, it holds little clinical significance.

Speaker 3

Figures 7-9 displays Speaker 3's performance on each of the three dependent measures (plotted on the y-axes) across sessions (plotted on the x-axes). The three graphs depict data for speech rate (Figure 7), intelligibility (Figure 8), and disfluency (Figure 9).

Speech Rate

Figure 7 displays Speaker 3's mean speech rate (in syllables per second) during each of the four conditions across the 16 sessions. A 2x4 Analysis of Variance (ANOVA) was performed to statistically evaluate the effects of phase and delay interval on speech rate. Results of the ANOVA yielded significant main effects for phase [F (1, 63) = 23.617, p < .000] and interval [F (3, 63) = 39.956, p < .000], but no significant phase-by-interval interaction [F (3, 63) = .195, p = .899]. In addition, a one-way ANOVA failed to yield a significant main effect of phase for the 0 ms condition [F (1, 15) = 3.446, p = .085].

Potential differences among the interval conditions were evaluated via a Bonferroni test. Results revealed that Speaker 3's rate during the 0 ms DAF condition was significantly higher than during each of the three remaining DAF conditions (p = .000), and that the 50 ms DAF condition yielded significantly higher speech rates than did the 150 ms DAF condition (p = .003). In sum, statistical analysis revealed that Speaker 3's reading rate was significantly reduced during the B phases (i.e., DAF + instruction), but not without the use of DAF (i.e., 0 ms). Also, all three DAF settings significantly reduced his speech rate (as compared with no DAF) across phases, while 150 ms DAF yielded a significantly slower rate than did 50 ms DAF.

These statistical results are corroborated by visual inspection of the data (see Figure 7). The no DAF condition consistently yielded the highest speaking rates (M = 2.34 SPS, SD = .39), with no overlap of values with any of the three DAF settings. Conversely, 150 ms DAF yielded the lowest speech rate in nearly every session (M = 1.43 SPS, SD = .26). As described above, however, the mean difference in speech rate between this condition and the 100 ms condition (M = 1.58 SPS, SD = .22) was not statistically significant.

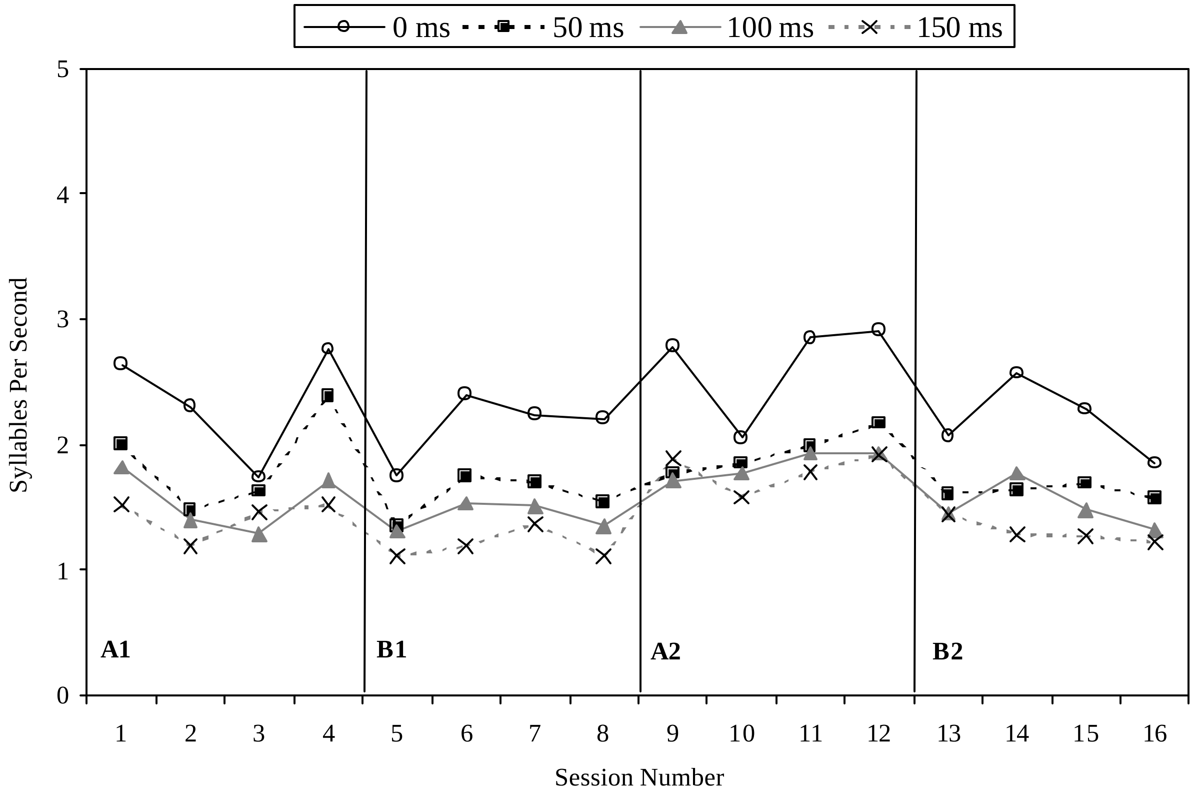

Figure 7. Reading rate (syllables per second) across sessions during sentence reading for Speaker 3.

Examination of changes in speech rate between the four phases of the experiment (see Figure 7) reveals an upward trend by the end of phase A1 (for all four conditions) that was immediately reversed at the beginning of the first B phase (i.e., session 5). This downward shift confirmed the hypothesis that the treatment applied in phase B1 (i.e., DAF + experimenter instruction) was effective in reducing reading rate. Rates during all interval conditions increased slightly at session 6 before stabilizing throughout phase B1.

The beginning of phase A2 (i.e., withdrawal of experimenter instruction) produced an immediate increase in speech rate during all interval conditions as well as a slight upward trend throughout the A phase for all conditions, again confirming the effectiveness of the experimenter instruction. Re-instating instruction in conjunction with DAF at phase B2 (session 13) resulted in a second immediate decrease in speech rate during all interval conditions. Throughout the remainder of this last phase (i.e., B2), performance stabilized during all DAF conditions with the exception of the 0 ms condition (i.e., no DAF), which produced less consistent reading rates.

Intelligibility

Figure 8 displays Speaker 3's percentage of intelligibility across all 16 sessions. A 2x4 Analysis of Variance (ANOVA) yielded significant main effects for phase [F (1, 63) = 24.396, p < .000] and interval [F (3, 63) = 4.614, p = .006], but no significant interaction effect [F (3, 63) = .075, p = .973]. In addition, a one-way ANOVA failed to yield a significant main effect of phase for the 0 ms condition [F (1, 15) = 3.919, p = .068].

A Bonferroni test was performed to determine the differential effects of the four DAF intervals on Speaker 3's intelligibility. Results revealed that intelligibility during the 0 ms (i.e., non-DAF) condition was significantly lower than during each of the three remaining intervals

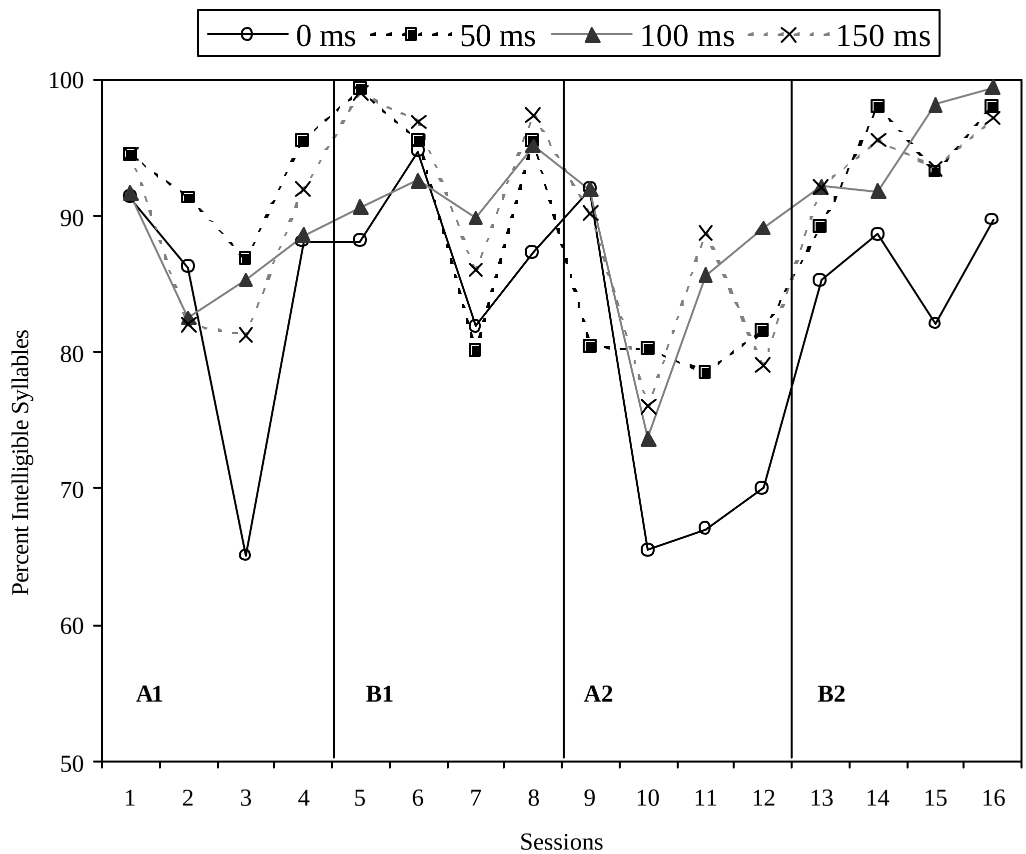

Figure 8. Percent intelligible syllables across sessions during sentence reading for Speaker 3.

conditions ($p = .024$, $p = .023$, $p = .018$), none of which differed significantly from one another. In sum, statistical analysis revealed that Speaker 3's percentage of intelligible syllables was significantly higher during the B phases (i.e., DAF + instruction) than during the A phases (i.e., DAF alone), but not without the use of DAF (i.e., 0 ms). Also, all three levels of the DAF significantly increased his intelligibility relative to 0 ms DAF (i.e., no DAF) across phases.

Visual inspection of Speaker 3's intelligibility data (Figure 8) illustrates the improved intelligibility that resulted from using either 50 ms (M = 89.83%, SD = 7.46), 100 ms (M = 89.86%, SD = 6.16), or 150 ms DAF (M = 90.06%, SD = 6.16), as opposed to no DAF (M = 82.66%, SD = 10.01). The standard deviation of 10.01% in the 0 ms DAF condition, compared to the range of standard deviations in the other three DAF conditions (i.e., 6.16-7.46%), highlights the variability in Speaker 3's intelligibility when reading without the use of DAF. Figure 8 indicates that while his intelligibility occasionally approached 100% with DAF (particularly during the second B phase), it deteriorated to less than 70% during both A phases without DAF (i.e., the 0 ms DAF condition). Although no DAF setting was clearly superior in improving Speaker 3's intelligibility, all three intervals yielded over 90% intelligibility throughout the final phase (i.e., B2), confirming the effectiveness of the DAF in improving the speech deficit.

Visual inspection of changes in intelligibility throughout the four experimental phases reveals that a slight upward trend at the end of phase A1 was extended during phase B1 for all DAF intervals except 0 ms. Thus, it is not clear that introduction of experimenter instruction in the first B phase was responsible for the observed increases in Speaker 3's intelligibility. With the exception of 100 ms DAF, performance at all delay intervals was characterized by variability during phase B1. However, withdrawal of instruction in session 9 produced an immediate downward trend (i.e., poorer intelligibility) during each delay condition except for 0 ms DAF. This shift suggests that the DAF + instruction was effective in increasing intelligibility (relative to DAF alone). In addition, re-instating the instruction at phase B2 (session 13) resulted in an immediate upward shift in performance during all four interval conditions, again indicating the effectiveness of the instruction. Throughout the remainder of this last phase (i.e., B2), performance stabilized during all interval conditions, but remained consistently lowest during the 0 ms DAF condition.

Disfluency

Figure 9 displays Speaker 3's percentage of disfluency (i.e., the number of disfluent events per 100 spoken syllables) across all 16 sessions. A 2x4 Analysis of Variance (ANOVA) revealed neither significant main effects for phase [F (1, 63) = .217, p = .643] nor interval [F (3, 63) = .366, p = .778], nor a significant interaction effect [F (3, 63) = .571, p = .636]. Thus, statistical analysis revealed that Speaker 3's percentage of disfluency was not significantly reduced by any of the DAF intervals, whether presented alone or in conjunction with instruction from the experimenter.

These inconsistent results become more evident through visual inspection of Speaker 3's disfluency data (see Figure 9). Throughout the four phases, percentage of disfluency showed marked variability in all DAF conditions, but relatively low means in both A phases (M = 1.67%, SD = 1.53), as well as both B phases (M = 1.51%, SD = 1.11). Although the highest percentage of disfluency occurred during the no DAF condition (in session 2), none of the three DAF settings were consistently effective in further reducing the frequency of Speaker 3's disfluencies. This is likely due to the low mean percentages of disfluency exhibited by this

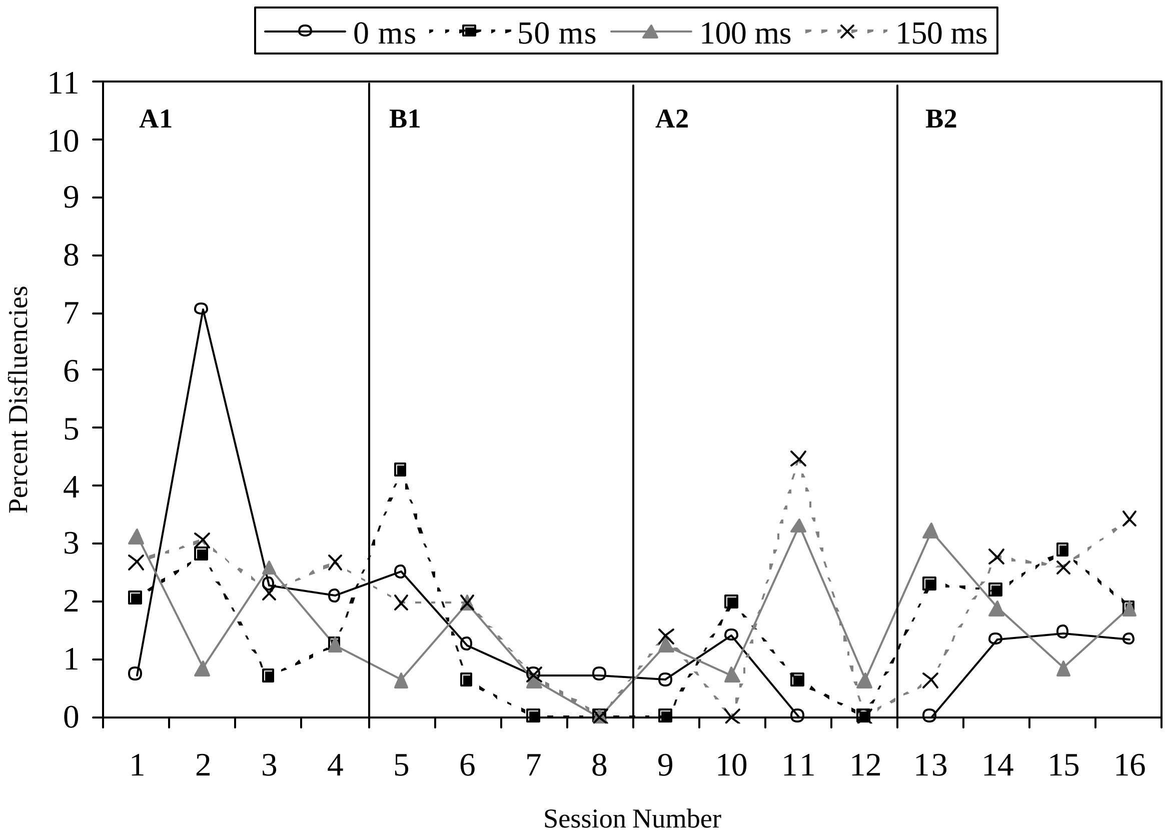

Figure 9. Percent disfluencies (i.e., number of disfluent events per hundred syllables) across sessions during sentence reading for Speaker 3.

speaker (i.e., a floor effect). Throughout the study, his percentages of disfluency ranged from 0.00% to 7.06%. This large variability may have resulted, in part, from the wide variety of disfluency types measured. As discussed in the following chapter, these various disfluencies may by indicative of different deficits (e.g., cognitive versus motor), and may not be equally responsive to a reduction in speech rate.

Summary of Sentence Data for Speaker 3

To summarize, results revealed that Speaker 3's use of delayed auditory feedback produced significantly slower rates of speech, and that the delay interval of 150 ms provided the greatest degree of rate reduction (although not statistically greater than 100 ms DAF). In addition, clinician instruction significantly improved the rate reducing effects of DAF across all delay intervals except for 0 ms (i.e., no DAF). The use of DAF also yielded improvements in intelligibility, which were significantly increased by clinician instruction, although no particular delay interval proved optimal. Lastly, the use of DAF, either alone or with instruction, had no significant effect on Speaker 1's frequency of speech disfluencies. This was most likely attributable to the limited range of values for this measure (i.e., a floor effect), as disfluency was evidently not the primary communicative impediment for this individual.

Paragraph Data

As discussed above, the paragraph reading task was included as a generalization probe. After each session (i.e., the sentence task), all participants read a paragraph approximately 400 syllables in length without the use of DAF. The purpose of this task was to identify any potential "carry-over" of speech benefits gained through use of DAF to a more linguistically demanding and ecologically valid speech task (Norris et al., 1998) performed without the use of DAF. Data from this task were helpful in determining whether extended use of DAF resulted in generalization of speech improvements (i.e., the fifth research question of the present study).

Figures 10-12 display performance of all three participants on each of the three dependent variables (plotted on the y-axes) across the 16 experimental sessions (plotted on the x-axes). The three graphs depict data for reading rate (Figure 10), intelligibility (Figure 11), and disfluency (Figure 12). As with the sentence task, paragraph data were evaluated using both visual inspection and statistical analysis. Pearson product moment correlations were used to examine overall relationships between each of the speech variables and number of experimental sessions (i.e., the length of exposure to DAF). Changes in each of the three dependent variables (i.e., speech rate, intelligibility, and disfluency) across time will be discussed separately.

Speech Rate

Figure 10 displays mean paragraph reading rate (in syllables per second) for each of the 16 sessions. Pearson product moment correlations between reading rate and number of sessions were non-significant for Speaker 1 (r = .207, p = .443), Speaker 2 (r = .018, p = .947), and Speaker 3 (r = .110, p = .685). Thus, none of the participants demonstrated significant decreases in reading rate across sessions without the use of delayed auditory feedback. Visual inspection of the data (see Figure 10) confirms this absence of a carry-over effect for any of the three participants, as well as remarkably stable responding throughout the study.

Intelligibility

Figure 11 displays mean intelligibility scores (i.e., percentage of intelligible syllables) for each of the 16 sessions. Pearson product moment correlations between intelligibility and number of sessions were not significant for Speaker 1 (r = .192, p = .476) or Speaker 2 (r = .087,

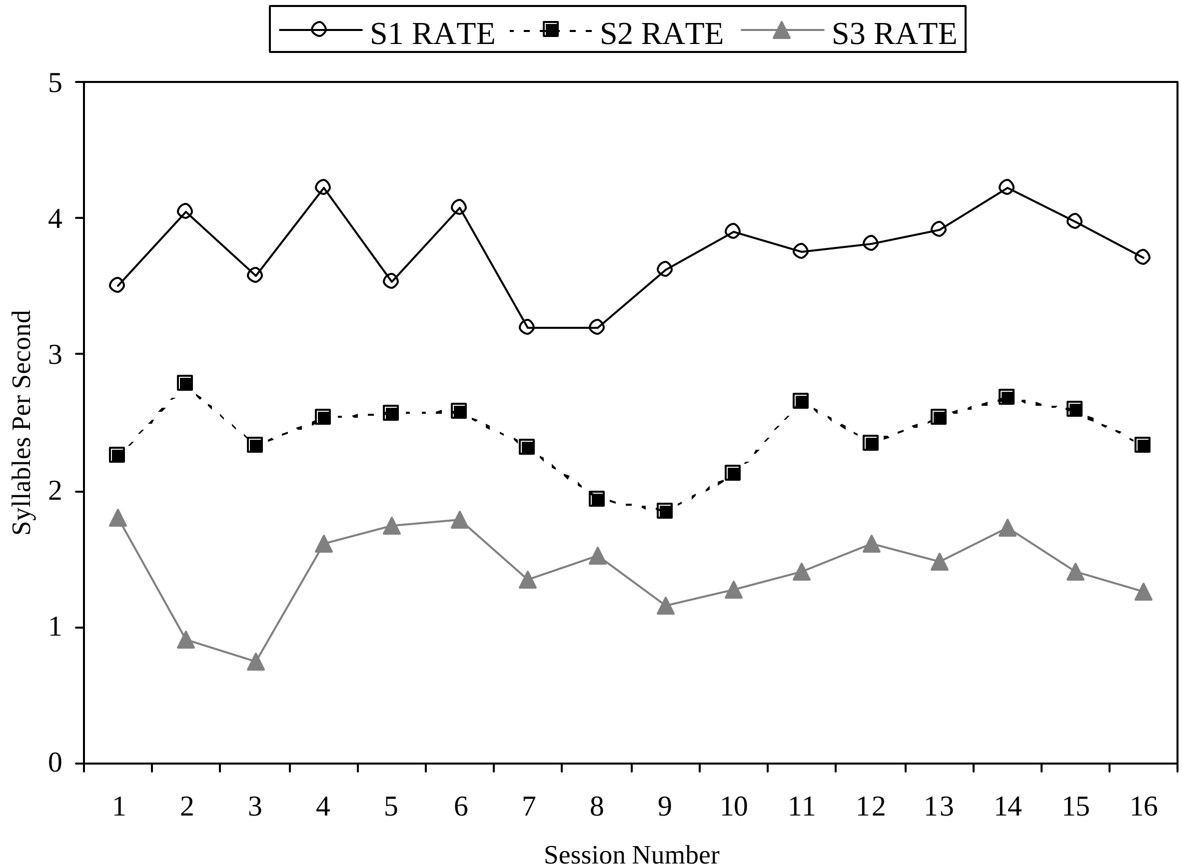

Figure 10. Reading rate (syllables per second) across sessions during paragraph reading for Speaker 1 (S1), Speaker 2 (S2), and Speaker 3 (S3).

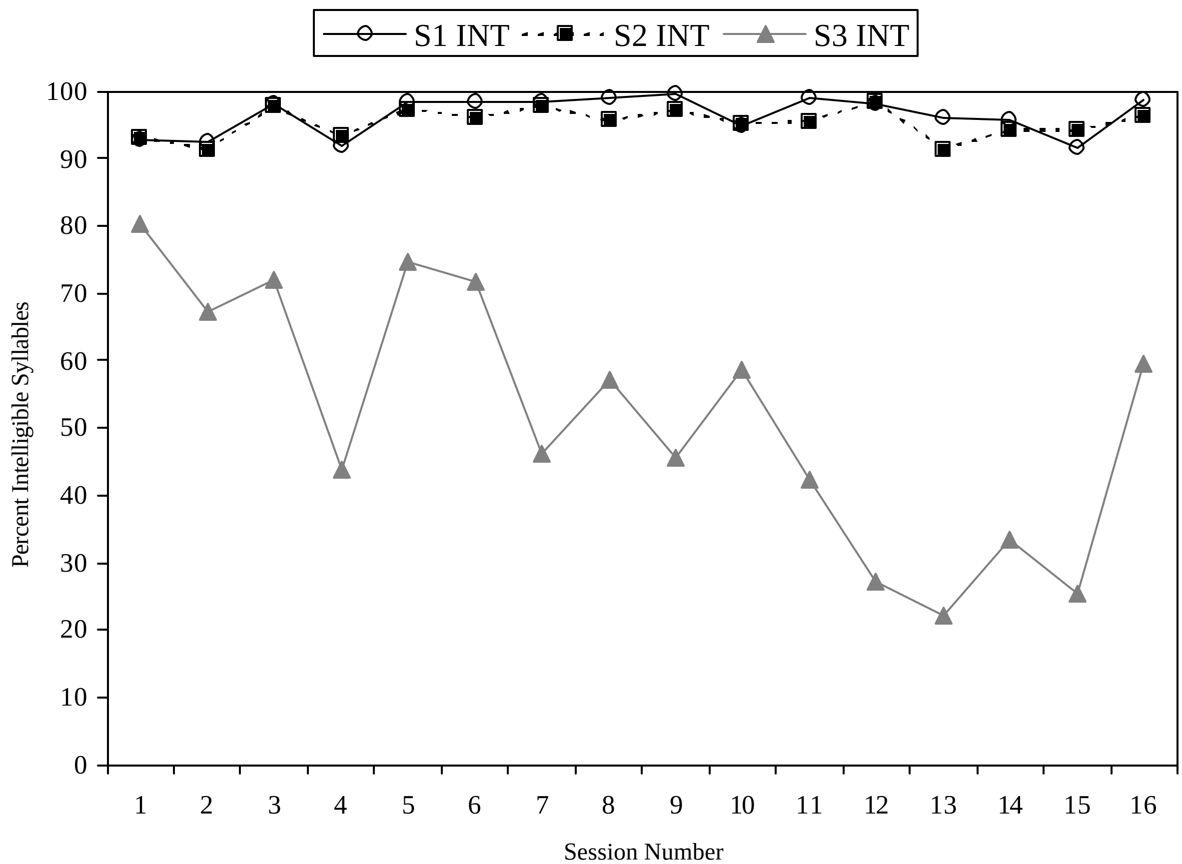

Figure 11. Percent intelligible syllables across sessions during paragraph reading for Speaker 1 (S1), Speaker 2 (S2), Speaker (S3).

p = .749), indicating no statistically significant increases in intelligibility across sessions (due to ceiling effects for both speakers). For Speaker 3, however, a strong negative correlation (r = -.722, p = .002) revealed significantly poorer intelligibility as the study progressed. That is, his intelligibility without intervention actually deteriorated over the course of the study. However, visual inspection of Speaker 3's data (see Figure 11) reveals considerable variability in responding (M = 51.70%, SD = 18.79), as well as a marked increase in intelligibility by the study's conclusion (i.e., session 16).

Disfluency

Figure 12 displays mean percentages of disfluency for each of the 16 sessions. Pearson product moment correlations between disfluency and number of sessions were not significant for Speaker 1 (r = .351, p = .182), Speaker 2 (r = -.189, p = .483), or Speaker 3 (r = -.345, p = .191), indicating no statistically significant decreases in the frequency of disfluent events across sessions. Visual inspection (Figure 12) reveals relatively low and stable percentages for Speaker 3 (M = .82%, SD = .75), while Speaker 1 exhibited consistently higher disfluency levels, less stable responding (M = 4.41%, SD = 1.16), and an upward trend during the final two sessions. That is, his fluency began to steadily deteriorate from sessions 14 to 16.

Speaker 2 consistently exhibited the highest percentages of disfluency throughout the experiment (M = 4.41%, SD = 1.16), although a slight downward trend was evident during the last two sessions. During session 9, his disfluency level rose dramatically to nearly 18%, but immediately returned to previous levels. This transient increase in disfluency was similar to that which occurred during the sentence task in the same session (see Figure 6).

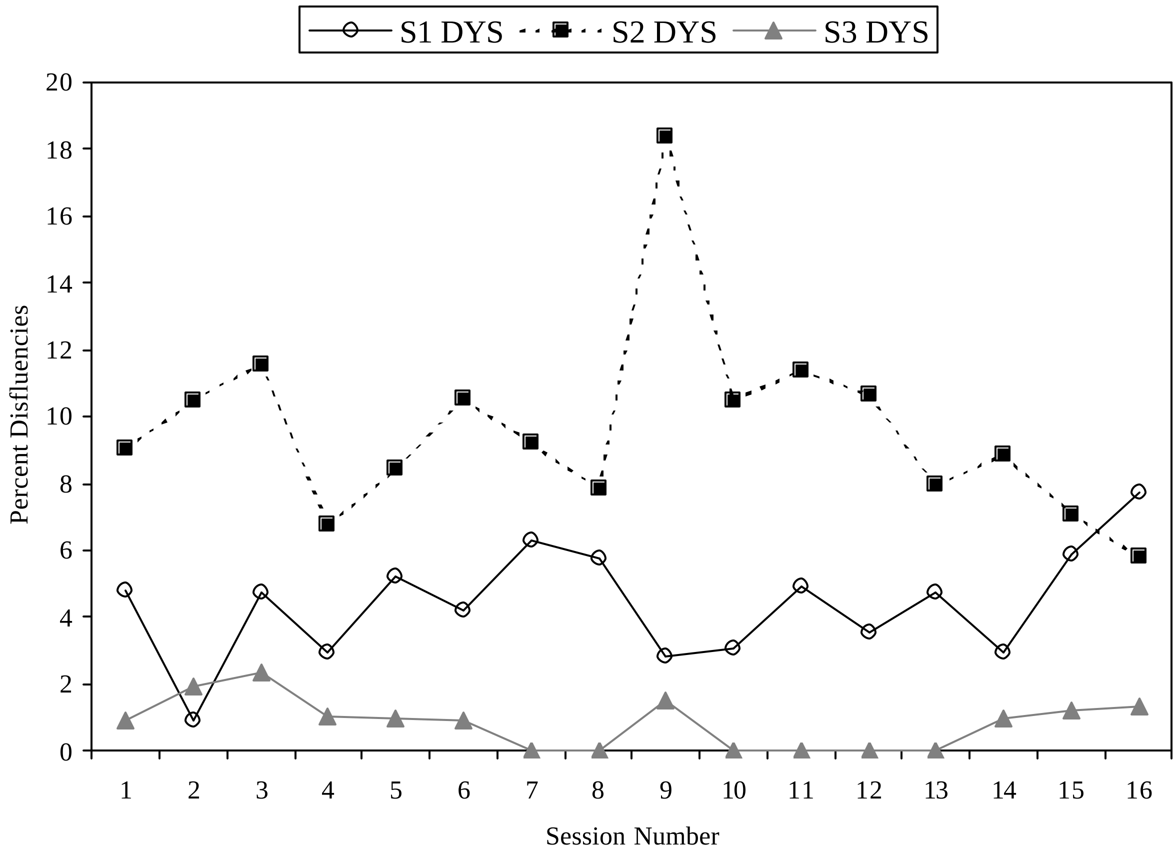

Figure 12. Percent disfluencies (number of disfluent events per hundred syllables) across sessions during paragraph reading for Speaker 1 (S1), Speaker 2 (S2), and Speaker 3 (S3).

General Summary of Results

Table 4 summarizes the results of the study for all three participants. Results revealed that the use of delayed auditory feedback during sentence reading yielded dramatic reductions in speech rate for all three speakers. Rate reductions were statistically significant and remarkably stable throughout the study. In addition, these slower rates were accompanied by improvements in either intelligibility (i.e., Speaker 3) or fluency (i.e., Speakers 1 and 2), depending on the primary speech deficit exhibited by that particular individual. As discussed above, Speakers 1 and 2 exhibited consistently high intelligibility during the sentence task, precluding further improvement through the use of DAF. Likewise, the relatively low percentages of disfluency exhibited by Speaker 3 during this task (i.e., 0 ms DAF across phases: $\underline{M}$ = 1.47, $\underline{SD}$ = 1.68) may have prevented further reductions in disfluency via DAF.

Table 4. Summary of sentence reading results for the three participants.

Results:	**Speaker 1**			**Speaker 2**			**Speaker 3**		
	RATE	**INT**	**DIS**	**RATE**	**INT**	**DIS**	**RATE**	**INT**	**DIS**
Positive effects of DAF	YES	N/A	YES	YES	N/A	YES	YES	YES	NO
Optimal DAF interval	150 ms	N/A	NO	150 ms	N/A	NO	150 ms	NO	N/A
Differential effects of instruction	YES	N/A	YES	YES	N/A	YES	YES	YES	N/A
Sentence generalization	YES	N/A	NO	NO	N/A	YES	NO	NO	N/A
Paragraph generalization	NO	N/A	NO	NO	N/A	NO	NO	NO	N/A

As indicated in the third row of Table 4, 150 ms DAF provided maximal rate reduction for all three speakers, although it was only statistically different from 100 ms in the case of Speaker 2. However, 150 ms produced no differential effects on either intelligibility or percentage of disfluency for any participant. That is, while all speakers reduced their reading rates to the greatest extent with 150 ms DAF, no specific delay interval led to optimal benefits in the other speech parameters. Simply using any of the three DAF settings was sufficient to obtain statistically significant gains in either intelligibility or fluency.

The addition of experimenter instruction during the B phases produced significantly greater improvements in speech rate and either intelligibility (i.e., Speaker 3) or fluency (Speakers 1 and 2). In other words, every speech measure positively affected by the use of DAF alone was further improved by instruction to a statistically significant extent (for all participants). However, the addition of clinician instruction also yielded significant reductions in reading rate (for Speaker 1) and percent disfluency (for Speaker 2) without the use of DAF (i.e., 0 ms), suggesting generalization of DAF effects during sentence reading.

As expected, however, extended use of DAF during sentence reading did not lead to generalization of effects to paragraph reading without the use of DAF. Evidently, none of the speakers transferred their DAF-induced speech patterns to a non-DAF speaking situation involving a novel and more linguistically complex task. During paragraph reading without DAF, reading rates were generally lower than those produced during sentence reading without DAF for Speakers 2 and 3, most likely due to the inclusion of pause time between the sentences of the paragraphs. Speaker 1, however, read the paragraphs at rates comparable to his sentence rates, suggesting faster articulation rates (i.e., the rate at which speech segments are produced) during paragraph reading.

As revealed in Figures 10 and 11, Speakers 1 and 2 exhibited stable intelligibility during the paragraph task, although mean percentages were slightly lower than during sentence reading. Speaker 3, however, read the paragraphs without the use of DAF much less intelligibly (*M* = 51.70%, *SD* = 18.79) than he did the sentences without the use of DAF (*M* = 82.66%, *SD* =

10.02). This may have resulted from the increased cognitive, linguistic, and motor demands imposed by reading of the passages. In addition, as Speaker 3 frequently reported becoming fatigued toward the end of the experimental sessions, it is possible that this contributed to his poor intelligibility while reading paragraphs without the aid of DAF or experimenter instruction (after 30-40 minutes of sentence reading). The deterioration of Speaker 3's intelligibility during this task demonstrates the detrimental effects of increasing task difficulty with a Parkinson's disease patient already exhibiting an intelligibility deficit, as well as general muscular weakness.

While Speaker 3 exhibited relatively low percentages of disfluency during the paragraph task (M = .82, SD = .76), Speaker 1 became somewhat more disfluent during this task (M = 4.41, SD = 1.66) than during sentence reading without the use of DAF (M = 2.74%, SD = 1.15). Speaker 2, however, exhibited a marked deterioration in fluency during paragraph reading (M = 9.65, SD = 2.88) relative to sentence reading without the use of DAF (M = 4.86, SD = 2.88). Interestingly, the identical standard deviations of these two sets of values indicate higher, but more stable, levels of disfluency during paragraph reading than during sentence reading. Additionally, Speaker 2's relatively high level of disfluency during the paragraph task, along with the inclusion of pause time, may have contributed to his decreased reading rate during the paragraph task (see Figure 4). That is, the increased proportion of total speaking time taken up by the disfluent events most likely decreased his overall reading rate, or productive speech output (i.e., number of syllables produced per second).

DISCUSSION

The present experiment was conducted in order to obtain valid and reliable data pertaining to the efficacy and efficiency of delayed auditory feedback as a rate control intervention for dysarthric speakers with Parkinson's disease. That is, the primary research questions addressed not only the issue of whether DAF was effective in reducing speech rate in these patients, but also sought to determine which parameters of the task were most important in maximizing its effectiveness. Information of this nature is potentially useful for speech-language pathologists attempting to use DAF more efficiently with dysarthric speakers, as well as future investigators in this area. Specific variables of the DAF protocol systematically manipulated were the duration of the delay interval (in milliseconds) and the presence or absence of clinician instruction. In the following sections, the five research questions of this study will be addressed individually.

Question 1: Does DAF Reduce Reading Rate in Speakers with Parkinson's Disease?

Results revealed that for all three speakers with Parkinson's disease, delayed auditory feedback was effective in producing reductions in speech rate which were dramatic, statistically significant, and remarkably stable throughout the study. Regardless of age, disease severity, and specific speech deficits, all participants exhibited maximum rate reductions of over 50% in comparison to their habitual sentence reading rates (i.e., the no DAF condition). Even Speaker 3, who exhibited habitual sentence rates below the normative mean of 4.7 syllables per second (Hammen & Yorkston, 1996), demonstrated the ability to produce significantly slower speech rates while using DAF. Thus, he "responded" well to the DAF, despite not initially appearing to be what has previously been considered an "ideal candidate" for delayed auditory feedback (Yorkston et al., 1988). The fact that Speaker 3's intelligibility improved significantly following an even further reduction in speech rate (i.e., well below normative values) supports the rationale for attempting a rate control intervention with similar patients. This trade-off between speech rate and intelligibility will be discussed further later in this chapter.

Previous studies also reported rate reductions using DAF, but did so primarily through the use of group difference designs (e.g., Singh & Schlanger, 1969), case studies (Downie et al., 1981), and one-group before-after designs (e.g., Hanson & Metter, 1980). The present study, however, clearly demonstrated the controlling effects of the DAF using an experimental single-subject design. Pre-specified manipulations of the independent variables (i.e., delay interval and clinician instruction) were systematically made using time-series measurements of objective dependent variables (i.e., speech rate, percentage of intelligible syllables, and percent disfluencies).

In addition, the no DAF condition (i.e., 0 ms DAF) provided a "running baseline" throughout the entire experiment, allowing a session-by-session evaluation of the effects of DAF (in comparison to no DAF). This design was used to maximize the internal validity of the study, or the extent to which the treatment variables (i.e., the various intervals of DAF used, both with and without clinician instruction) were responsible for observed changes in the dependent variables (i.e., speech measures). Although the study by Dagenais et al. (1998) also used an experimental single-subject design to assess the speech effects of DAF, the present study provided the first experimental evaluation of specific parameters of a DAF-based intervention, without the potentially confounding effects of other forms of speech-language therapy.

Question 2: Does DAF Improve Intelligibility and Fluency?

In addition to documenting session-by-session changes in speech rate as a function of DAF, the present study also documented changes in intelligibility and speech fluency. As discussed in the previous chapter, the use of DAF led to statistically significant improvements in intelligibility for Speaker 3, and fluency for Speakers 1 and 2. The specific behaviors positively affected by DAF corresponded with the primary speech deficit exhibited by each individual participant. However, the consistently high intelligibility exhibited by Speakers 1 and 2 throughout the study precluded further increases via the use of DAF (i.e., a ceiling effect). These ceiling effects may have resulted, in part, from the objective measure of intelligibility used in the present study (i.e., percent of intelligible syllables). That is, the discrete measurement of whether or not a particular syllable was intelligible may have overlooked more subtle differences in intelligibility among sentences. Future studies should consider incorporating some type of rating scale (i.e., a Likert scale) in order to assess ease of understanding of an entire sentence (e.g., 1 = not at all understandable, 7 = easily understandable).

Similarly, the relatively low percentages of disfluencies exhibited by Speaker 3 during sentence reading without the use of DAF may have prevented further rate reductions during intervention. Again, although previous studies reported some improvements in speech behaviors using DAF (e.g., Downie et al., 1981; Hanson & Metter, 1980; 1983; Yorkston et al., 1988), the present study provides the first experimental demonstration of session-by session changes in both intelligibility and fluency using objective measurements.

Improvements in Intelligibility

The increased intelligibility exhibited by the participant presenting the poorest habitual intelligibility (i.e., Speaker 3) confirms previous findings that speech rate is an important behaviorally modifiable variable for improving intelligibility (Duffy, 1995). For example, Darley et al. (1975) reported a 0.78 correlation between variable speech rate and intelligibility. The fact that Speaker 3 exhibited the slowest reading rates of all three participants, as well as the lowest intelligibility percentages, confirms previous findings of significant correlations between speech rate and intelligibility (e.g., Dworkin & Aronson, 1986). That is, speakers with slower rates sometimes exhibit poorer intelligibility than those who produce "more appropriate" rates. Such was the case with Speaker 3, particularly when reading paragraphs without the benefit of DAF and/or instruction from the experimenter.

In general, speech rate is thought to be "excessive" for a particular individual when it is beyond the capabilities of the person's neuromuscular control system (Yorkston et al., 1988). As was the case for Speaker 3, a Parkinson's disease patient may actually be speaking more slowly than unimpaired speakers, but may still be speaking at an excessive rate given his or her neuromotor impairment. Appropriate intervention, such as the use of DAF, may result in an even further rate reduction, as was exhibited by Speaker 3. In such cases, the primary goal is not a "normal" speech rate, but "compensated intelligibility." That is, the primary concern is not how the speaker's rate compares to normative values, but whether his or her speech can be made more intelligible by a reduction in rate (Yorkston et al., 1988).

It has been widely purported that for many dysarthric speakers, intelligibility must take priority over speech rate. For example, Yorkston et al. (1988) recommended that when intelligibility reaches 90%, increases in speech rate should be attempted. The target rate should continue to increase as long as intelligibility is maintained. Thus, the primary treatment goal should be to use the least intrusive rate control technique that provides adequate rate reduction, while optimizing intelligibility. In the present study, Speaker 3 exhibited over 90% intelligibility during the second B phase (i.e., the use of DAF + experimenter instruction) with all three DAF settings (i.e., 50 ms, 100 ms, and 150 ms). Therefore, a clinician working with a similar patient might consider continuing treatment with 50 ms DAF, which, being the shortest delay interval, yielded the highest reading rates of the three DAF settings (see Figure 7). Likewise, future investigators conducting research in this area should consider including participants with lower than normal speech rates (if available) in order to obtain further information regarding how this sub-population of Parkinson's disease speakers is benefited by the use of DAF. That is, the results of the present study suggest that the concept of an "ideal candidate" for DAF (i.e., patients exhibiting excessive speech rates) should be reconsidered.

Improvements in Fluency

As discussed in the previous chapter, Speakers 1 and 2 exhibited statistically significant reductions in the frequency of disfluent events while reading with delayed auditory feedback (with any of the three interval settings). The effects of DAF on this objective measure of speech fluency in dysarthric speakers have not been reported previously. However, the present results are consistent with findings of studies examining the effects of DAF on the speech of developmental stutterers (e.g., Bloodstein, 1995; Goldiamond, 1965; Ingham, 1984). That is, stutterers exhibit a tendency to prolong syllables to overcome the "disruptive" effects of DAF, such as sound and syllable repetitions. Thus, speakers who do things to "beat" the DAF are incidentally doing things that are likely to improve speech fluency as well (Bloodstein, 1995). This was evidently the case for Speakers 1 and 2, as evidenced by greatly reduced reading rates during the DAF conditions (see Figures 1 and 4). Responding more like highly-trained stutterers than neurologically-impaired patients, these individuals demonstrated the ability to "beat" the DAF in order to significantly reduce their reading rates and improve their speech fluency.

Besides slowing their speech rates, stutterers typically attempt to cancel out, or “match,” the delayed signal before continuing with the rest of the utterance. This tactic adds an element of predictability to the speaking task, as any signal that informs a stutterer when to begin a speech segment typically increases fluency (Starkweather, 1987). Perhaps a more regular rhythm supports speech production, as DAF may reduce “temporal uncertainty.” This allows the speaker more time to plan temporal patterns, thus simplifying the complex task of speech production (Kent, 1983). Also, allotting equal time for each syllable results in a reduction of stress contrasts, which reduces the need to make small surges of sub-glottic pressure that produce stressed syllables. This simplification of syllable production lessens requirements for maintaining optimal glottal tension, as the vocal folds do not have to be readjusted for tension with each brief surge in sub-glottic pressure (Bloodstein, 1995). This may be important for dysarthric individuals exhibiting difficulty initiating or maintaining phonation (Yorkston et al., 1995), and may have contributed to greatly increased speech fluency exhibited by Speakers 1 and 2 while reading with DAF.

As stated above, the relatively low percentages of disfluencies exhibited by Speaker 3 during sentence reading without the use of DAF (i.e., $\underline{M}$ = 1.47%, $\underline{SD}$ = 1.68) may have prevented further rate reductions during intervention. In addition, the fact that his disfluencies were not completely eliminated despite reading rates as low as approximately one syllable per second (see Figure 7) suggests that certain types of disfluent events may not be easily remediated by rate control interventions. For example, phrase repetitions and interjections (frequently exhibited by Speaker 3) may reflect the presence of a cognitive, rather than strictly motor, deficit. Such disfluencies are often considered “normal” or “more typical disfluencies” (Bloodstein, 1995), and are frequently observed in the speech of unimpaired speakers. In contrast, disfluencies such as sound and syllables (especially when produced rapidly and with several iterations), are often considered “less typical disfluencies”, and are used to help verify the presence of a fluency disorder (Bloodstein, 1995).

Additionally, as listed in Table 1, Speaker 3 exhibited vowel distortions, extraneous vocalizations (typically in utterance-initial position), and difficulty initiating phonation. Such phonatory disturbances have been observed previously in Parkinson’s disease patients (e.g., Illes, Metter, Hanson, & Iritani, 1988; Kreul, 1972; Metter & Hanson, 1986), and reflect the need among some patients for improved vocal fold coordination. As discussed previously in the present chapter, the smooth transitions between syllables facilitated by DAF reduce the need to reinitiate vocal fold activity (Starkweather, 1987). However, DAF may not be effective in the case of utterance-initial vocalizations or voicing initiation difficulties, as the first syllable of an utterance is not “fed back” to the speaker until it has already been initiated. That is, the speaker must be able to initiate a speech segment in order for it to be processed by the DAF unit and “fed back” via headphones. Further studies are needed to evaluate the differential effects of DAF on the frequency of various types of disfluencies. In addition, clinicians using DAF to treat the speech deficits of Parkinson’s disease patients must be aware of such potential limitations, and might consider other interventions for specific disfluencies not completely eliminated by using DAF.

Question 3: Are There Differential Effects of Various DAF Intervals?

As discussed previously in the present paper, one of the primary purposes of this study was to experimentally evaluate the effects of three different delay intervals (i.e., 50 ms, 100 ms, and 150 ms) on speech behaviors. The goal of this manipulation was to determine whether each participant found one or more delay interval “optimal” in improving speech performance. The use of multiple delay intervals during each session over an extended period of time was not previously reported. Results of the present study revealed that all three participants experienced the greatest degree of rate reduction during use of 150 ms DAF (although it was only statistically different from 100 ms in the case of Speaker 2). This was expected, as the longer the duration of the delay interval, the longer the "time lag" between production of a syllable and its perception. In other words, the speakers were required to prolong each syllable longer while reading with 150 ms DAF than with either 50 ms DAF or 100 ms DAF, resulting in a slower speech rate. Unlike the participants in the Dagenais et al. (1998) study, those in the present study demonstrated the ability to respond to (i.e., "process") the delayed signal by their differential responses to the various delay intervals.

However, although 150 ms produced the slowest reading rates for all three speakers, this did not lead to any differential effects on either intelligibility (for Speaker 3) or fluency (Speakers 1 and 2). That is, none of the speakers found any delay interval significantly more effective in reducing their particular speech deficits. Simply using any of three DAF settings was sufficient to obtain statistically significant improvements in either intelligibility or fluency. Close examination of the data (see Figures 3 and 6) reveals that, for both Speakers 1 and 2, reading with 150 ms DAF reduced percent disfluencies to the greatest extent during several of the experimental sessions (and virtually eliminated all disfluencies in the case of Speaker 1). However, the differences among the three DAF settings were not statistically significant. Thus, for both speakers, all three delay intervals used during intervention were effective in reducing the frequency of disfluent events to low levels (relative to the no DAF condition). Similarly, Speaker 3 exhibited intelligibility in excess of 90% throughout the final phase of the study (i.e., phase B2) with all three DAF settings (see Figure 8).

Again, previous studies reported speech benefits using delay intervals between 50 ms (e.g., Downie et al., 1981) and 150 ms (e.g., Hanson & Metter, 1983), but have not documented the differential effects of multiple delay intervals across time. In fact, intervals in excess of 150 ms have not typically been used with dysarthric speakers; such long intervals have reportedly produced "disastrous" effects on the speech of some individuals (Dagenais et al., 1998; Rosenbek et al., 1978). Adverse reactions to relatively long delay times are commonly observed during clinical use of DAF, and most likely result from inadequate matching of the delayed signal. As discussed above, a 150 ms delay (for example) produces a relatively long time lag between production of a syllable and its perception. Unless the speaker continues to prolong the syllable until the delayed auditory signal is perceived, this signal will not be completely "canceled out." This results in a salient and potentially aversive "echo" which limits the rate reduction benefits of DAF, and may actually *elicit* speech disfluencies. Such behaviors have been observed with stutterers (e.g., Goldiamond, 1965), dysarthric speakers (e.g., Dagenais et al., 1998; Rosenbek, 1978), as well as unimpaired speakers (e.g., Black, 1951; Lee, 1951; Soderberg, 1968).

Previous authors have suggested that, in order to minimize such disruptive effects of DAF, users should "speak along with the cadence of the delay time" (e.g., Goldiamond, 1965). Unfortunately, previous studies have not assessed the ability of speakers to match various delay intervals during extended use of DAF. For example, Yorkston et al. (1988) found that increasing the delay interval from 150 ms to 200 ms resulted in no further decrease in speech rate, suggesting that their participant must not have been precisely matching the delayed signal. Likewise, Dagenais et al. (1998) found that altering the duration of the delay interval, even dramatically, produced no systematic changes in speech rate. For one speaker in particular, adjusting the delay interval from 196 ms to 231 ms and then to 0 ms inexplicably resulted in virtually no change in speech rate. In the present study, however, the significantly different reading rates exhibited by all three speakers in response to changes in delay time (see Figures 1, 4, and 7) demonstrated their ability to respond to these alterations by matching the delayed signal.

Benefits of Using Multiple Delay Intervals

The present study sought to demonstrate the effects of multiple delay intervals on speech characteristics based on the rationale that doing so in clinical practice offers the speaker more specific treatment options, which may prove beneficial at some point during the course of intervention. Results revealed that all three participants found 150 ms DAF to be an optimal delay interval for rate reduction, but not significantly more effective than 50 ms DAF or 100 ms DAF in improving intelligibility (Speaker 3) or fluency (Speaker 1 and 2). However, documentation of the superior rate control capabilities of 150 ms provides useful information for future investigators and clinicians.

First, some Parkinson's disease patients may respond more favorably to, or may simply prefer, one particular DAF setting. The three participants in the present study demonstrated the ability to modify their reading rates differentially in response to every alteration in delay time made by the experimenter, and did not verbally express any particular preferences regarding delay intervals. However, when working with similar patients achieving substantial speech benefits with three different levels of DAF, clinicians are afforded the option of utilizing the setting that the individual speaker prefers or responds most favorably to.

Secondly, early treatment is widely encouraged in Parkinson's disease to retard the inevitable degeneration of function (Rosenbek & LaPointe, 1978). Many Parkinson's disease patients experience a gradually deterioration of communicative abilities as the disease progresses (Adams, 1997). At such time, a longer DAF interval, which would yield a slower speech rate, may be needed to maintain the level of intelligibility and/or fluency previously achieved with a shorter interval (e.g., 50 or 100 ms). Extended use of multiple delay intervals during each treatment would afford the patient the opportunity to gain practice with longer intervals, which may need to be used during a later stage of their disease. This may be especially important for relatively young Parkinson's disease patients (such as Speaker 2, who was 36 years of age at the time of data collection), who may eventually experience substantial increases in disease severity.

Lastly, the use of delay intervals yielding speech rates slower than needed to achieve significant speech gains is advantageous when increasing the demands of tasks used during treatment. For example, the present study used sentence reading as the sole speech during intervention (i.e., the use of DAF, both with and without experimenter instruction). This relatively simple speech-language activity was utilized in order to maximize the internal validity of the study, and to provide a replicable DAF protocol that could be used easily and effectively by clinicians working with Parkinson's disease speakers. Previous authors observed that some Parkinson's disease patients perform better on more structured tasks, such as reading, than on spontaneous speech tasks (Yorkston, Miller, & Strand, 1995). The inclusion of more complex tasks, such as picture description and spontaneous speech, may have accounted for the limited effectiveness of DAF previously reported (e.g., Dagenais et al., 1998; Yorkston et al., 1988).

These findings are certainly not surprising, as spontaneous speech often places increased motor, linguistic, cognitive, and social demands on the speaker (Norris et al., 1998). Reading also facilitates a more rhythmic speech pattern with relatively equal duration between stressed syllables, or "isochrony" (Starkweather, 1987). Clinical evidence suggests that this enhances the use of the DAF signal to predict when the next syllable should be produced (Bloodstein, 1995; Kehoe, 1998). Based on these observations, as well as the positive findings of the present study, clinicians should consider using reading as the sole speech task, at least until stable responding to the DAF has been obtained. Further studies are needed to evaluate the speech effects of DAF using other tasks (e.g., picture description, monologue, etc.) by conducting systematic replications of the present experiment (Barlow & Hersen, 1984). This is a well-established guideline for the use of single-subject designs that, unfortunately, has not been followed by researchers investigating potential rate control interventions for dysarthric speakers.

Question 4: Are There Differential Effects of Clinician Instruction?

As hypothesized, the addition of experimenter instruction during the B phases of the present study resulted in significantly slower sentence reading rates for all three participants (see Table 4). In addition, instruction significantly improved intelligibility (for Speaker 3) and speech fluency (for Speakers 1 and 2). In other words, every speech measure positively affected by the use of DAF alone (during the A phases) was further enhanced by clinician instruction (during the B phases) to a statistically significant extent. However, it must be noted that the addition of clinician instruction also yielded significant reductions in reading rate (for Speaker 1) and percent disfluency (for Speaker 2) without the use of DAF (i.e., 0 ms), suggesting generalization of DAF effects during sentence reading. These possible carry-over effects will be discussed further in a following section.

As discussed throughout the present paper, the contribution of clinician instruction, modeling, and feedback pertaining to how well a speaker matches the delayed signal has not been reported previously. For example, Yorkston et al. (1988) suggested that DAF users be trained to not speak rapidly enough to "overdrive" the unit. However, although the authors acknowledged that some patients require overt instruction to reduce their speech rates with DAF, these investigators did not assess the effects of such instruction experimentally.

As discussed above, a delay interval of 150 ms is relatively difficult to match, but yields significantly slower speech rates than either 50 ms or 100 ms, as was confirmed by the present findings. For example, Speaker 1 actually produced the greatest number of speech disfluencies during phase A1 (i.e., DAF alone) while reading with 150 ms DAF, although this delay interval produced the slowest reading rates (see Figures 1 and 3). His response to the longest delay interval used was similar to that other many normal speakers (Black, 1951; Lee, 1951). That is, the delayed signal often indicates that the last sequence of speech gestures should not have been terminated, inducing the speaker to repeat production of the speech segments. As indicated in Figure 3, however, the introduction of experimenter instruction in phase B1 virtually eliminated Speaker 1's disfluencies during the 150 ms DAF condition.

This differential effect of instruction was expected, and suggests that the initial stage of a DAF-based rate control intervention may not be the best time to determine an individual speaker's "optimal delay," as is often observed in the published literature (e.g., Adams, 1994; Hanson & Metter, 1980; 1983). For example, examination of the disfluency data for Speaker 1 (see Figure 3) suggests that, had experimenter instruction not been introduced in session 5, the high percent disfluency exhibited with 150 ms DAF during phase A1 (i.e., DAF alone) would have continued during phase B1. The addition of instruction, therefore, resulted in maximal speech improvement for Speaker 1 using the longest delay interval offered to him during intervention.

The disruptive effects of DAF on the speech of normal speakers have been shown to be modified or prevented according to the level of attention paid to the delayed signal (Ingham, 1984). For example, Goldiamond et al. (1962) instructed normal speakers to listen to their voices while speaking with DAF, resulting in greatly reduced speech rates. Instructing the speakers to ignore the signal, however, did not lead to significantly reduced speech rates. This suggested that the variability of responses to DAF might depend, in part, on how closely an individual attends to auditory feedback. In other words, some speakers produce sound or syllable repetitions, while others prolong syllables (Goldiamond et al., 1962).

The ability of all three participants in the present study to modify their reading rates using three different delay intervals, to a significantly greater degree when given feedback and modeling from the experimenter, confirms the effectiveness of attending to (and matching) the delayed signal. The published literature confirms the long-standing clinical observation that Parkinson's disease patients exhibit wide variability in speech rate (both intra- and inter-speaker), and have difficulty modifying their speech rates when instructed to do so (e.g., Darley et al., 1975; Ludlow et al., 1987). However, results of the present study (during the B phases) suggest that when given clear, consistent, and specific instructions, Parkinson's disease speakers are able to modify their speech rates during a relatively simple speech-language activity.

Thus, the present findings support the assertion that in order to facilitate optimal use of delayed auditory feedback, clinicians must provide instruction, modeling, and feedback. Clinician instruction is frequently used in speech-language therapy with persons exhibiting neuromotor impairments, but was not previously reported during use of DAF. The present study delineated clinician instructions for purposes of replication by speech-language pathologists, as well as future investigators. By wearing a headphone/microphone assembly, the experimenter was able to determine how precisely each of the three participants matched the delayed signal throughout the study. Verbal feedback and demonstrations of accurate matching were given as needed by the experimenter (himself a stutterer and experienced DAF user). The utilization of an A-B-A-B single-subject design in this study allowed a comparison of the speech performance of each participant both with and without instruction, making an evaluation of the relative contribution of this instruction feasible.

As discussed in the review of the literature, delayed auditory feedback has been used primarily as a prosthetic device with Parkinson's disease patients, with carry-over of speech benefits rarely expected (or attempted). However, it may be difficult for an individual with a degenerative neurological disease to generalize a behavior unless he or she is given instruction on what the desired behavior actually is. That is, simply instructing the patient to wear a DAF unit "as needed" or to "begin talking" does not provide any guidelines for properly matching the delayed signal in order to obtain maximal speech benefits (like those achieved by the present participants).

As highlighted by Duffy (1995), overt instruction improves performance, as most patients do not improve simply by talking. Likewise, Rosenbek and LaPointe (1978) asserted that few patients can modify rate without careful, systematic instruction. Changes in speech rate, when appropriate for a particular speaker, must be taught. The ability to alter speech with instruction is taken as a positive prognostic indicator, although this assumption was not previously tested experimentally. Feedback is essential to motor learning, especially during the initial stages, and should be immediate and precise relative to the treatment goals (Schmidt & Lee, 1999; Yorkston et al., 1988). Such feedback should be specific, and can instrumental (e.g., a DAF unit) or administered by the clinician (e.g., instructions and demonstration on how to effectively *use* the unit). As Rosenbek and LaPointe (1978) asserted, the clinician should be as active in DAF training as in any other form of treatment, as generalization can only be achieved if the clinician provides feedback regarding the speaker's performance. The issue of generalization of DAF-induced speech changes will be explored in greater depth in the following section.

Question 5: Does Extended Use of DAF Generalize to Habitual Speech?

As discussed in previous sections, the overall goal of this study was to obtain data related to the specific speech effects of delayed auditory feedback, and how manipulating specific parameters of the task (i.e., delay interval and clinician instruction) might maximize the effectiveness of DAF as a rate control technique. Thus, priority was given obtaining valid and reliable data related to the *acquisition* of the DAF-induced speech pattern, rather then to its *transfer* to habitual speech (i.e., speaking without wearing a DAF unit). This approach was contrary to that taken in previous studies examining the effects of DAF on the speech of dysarthric individuals. That is, most of these investigations focused primarily on "home use" of DAF or infrequent measurement sessions (e.g., Downie et al., 1981; Hanson & Metter, 1980; 1983), rather than a systematic evaluation of session-by-session effects of DAF on objective speech measures. The general consensus that the primary use of DAF should be prosthetic (i.e., that effects do not generalize) may be due to the lack of stable acquisition of a DAF-induced speech pattern in previous studies.

For example, portable DAF units (e.g., Kehoe, 1998) offer home practice, as well as independent "self-therapy," but only after a speaker becomes proficient at the task (i.e., carefully matching the delayed signal while speaking with DAF). At such time, the auditory feedback may be faded by either gradually reducing the delay interval or gradually attenuating the volume of the feedback signal. This provides a systematic method for reducing the speaker's reliance on the device. The study by Dagenais et al. (1998) was the first published attempt to gradually fade the duration of the delay interval using a changing-criterion design (Barlow & Hersen, 1984). Unfortunately, the inability of any of the participants to exhibit stable speech rates while using DAF prevented the gradual fading of the delay interval, which was one of the primary purposes of their study.

Further research is needed to demonstrate the usefulness of DAF as a behavioral rate control intervention, rather than simply a prosthetic device. To the extent that Parkinson's disease patients are capable of transferring treatment gains achieved with any rate control method, it is certainly reasonable to attempt generalization procedures using a DAF unit. However, before successful generalization of a behavior can occur, stable acquisition of that behavior must be demonstrated, as was the case with the three speakers in the present study (Schmidt & Lee, 1999).

The present study incorporated a paragraph reading task as a generalization probe. The purpose of this task was to identify any potential "carry-over" of speech gains achieved with DAF to a more linguistically demanding and ecologically valid speech-language task (Norris et al., 1998). In addition, the 0 ms (i.e., no DAF) condition used during the sentence tasks provided a "running baseline" throughout the study, allowing a session-by-session comparison of speech performance with and without the use of DAF. Statistical analyses revealed that the addition of clinician instruction yielded significant reductions in reading rate (for Speaker 1) or percent disfluency (for Speaker 2) without the use of DAF (i.e., 0 ms), suggesting generalization of DAF effects during sentence reading. That is, reading sentences while using three different levels of DAF (i.e., 50 ms, 100 ms, and 150 ms) supplemented by clinician instruction evidently led to improvements in either rate or fluency for each of these two speakers during an identical task (i.e., sentence reading) without using DAF.

As expected, however, extended use of DAF during sentence reading did not lead to generalization of effects to paragraph reading without the use of DAF. Evidently, none of the participants transferred their DAF-induced speech patterns to habitual oral reading of an entire passage. As indicated in Figure 10, no speaker exhibited significant speech rate reductions during the paragraph tasks across the 16 sessions; this lack of relationship was confirmed by statistical analysis. In addition, Speakers 1 and 2 exhibited slightly poorer intelligibility during the paragraph task, while Speaker 3 experienced a marked deterioration in intelligibility without the use of DAF (see Figure 11). Likewise, while Speaker 3 maintained relatively low percentages of disfluencies, Speakers 1 and 2 became more disfluent during this task than during sentence reading without the use of DAF. This deterioration of speech fluency was marked in the case of Speaker 2, and contributed to a decrease in his productive speech output (i.e., number of syllables produced per second), as illustrated in Figure 10.

This lack of transfer of gains made during intervention demonstrates the potentially detrimental effects of increasing task demands with Parkinson's disease speakers without continuing to administer the speech intervention (e.g., the use of DAF, supplemented with clinician instruction and modeling). These findings suggest that once results similar to those of the present study have been achieved, clinicians should continue to use DAF at the most effective setting(s) for that particular speaker, while gradually increasing the complexity of activities used in treatment. Although not evaluated experimentally in previous reports, others have suggested that DAF can be included in “traditional behavioral therapy” (e.g., Duffy, 1995; Rosenbek & LaPointe, 1978). These authors have proposed that goal should be to “wean from the machine,” while maintaining speech improvements. Specific suggestions have included focusing of the “feel” of speaking with DAF, alternating DAF use with short periods of speaking without DAF, and progressing from reading to “prepositional speaking” while preserving improvements (Rosenbek & LaPointe, 1978). However, generalization studies are needed to develop efficient methods of transferring speech improvements achieved during a DAF-based intervention.

Conclusions

In general, results of the present investigation demonstrated the effectiveness of delayed auditory feedback in establishing significantly slower speech patterns in three Parkinson’s disease speakers of various ages, speech characteristics, and degrees of motor involvement. These reductions in reading rate were consistent across 16 treatment sessions, and were accompanied by a significant improvement in intelligibility for one speaker, and significant improvements in speech fluency for the two remaining speakers. All three participants responded differentially to various delay intervals, although any DAF setting used was sufficient for achieving significant gains in either intelligibility or fluency. Additionally, providing the speakers with systematic instruction and modeling pertaining to optimal matching of the delayed signal resulted in further speech rate reductions (in comparison to the use of DAF alone). This clinician instruction also led to significant improvements in intelligibility (for Speaker 3) and fluency (Speakers 1 and 2). These positive findings provide a “model” protocol to be referred to by future researchers and clinicians endeavoring to further explore and refine the use of delayed auditory feedback as an intervention for speakers with Parkinson's disease. For example, generalization studies examining the efficacy of the proposed DAF protocol using more complex speech-language activities (e.g., passage reading, monologue, conversation) are especially needed.

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APPENDIX A

CONSENT FORM

1) STUDY TITLE: Factors influencing the efficacy of delayed auditory feedback in treating dysarthria associated with Parkinson's disease.

2) INVITATION TO PARTICIPATE: You are invited to participate in a research project to help us learn how to improve upon a speech therapy technique which is sometimes used with Parkinson's disease (PD) patients. You have been invited because your speech pattern makes you a good candidate for this technique, and improvements in your speech are expected as a result of your participation.

3) PERFORMANCE SITE: LSU Speech and Hearing Clinic or participants' residences.

4) CONTACTS: The investigators listed below are available to answer any questions about the research, M-F, 8:00 a.m. - 4:00 p.m.:

Paul R. Hoffman, Ph.D.
Department of Communication Sciences and Disorders
Louisiana State University: (225) 388-3937

Paul G. Blanchet, M.S.
Department of Communication Sciences and Disorders
Louisiana State University: (225) 388-8872

Robert C. Mathews, Ph.D.
Chairman, LSU Institutional Review Board
Louisiana State University: (225) 578-8692

5) PURPOSE OF THE STUDY: Many people with PD have difficulty speaking. Some patients speak very quickly or too softly, repeat sounds or words, or "blur" their words together. This can make communication with others difficult. A technique known as delayed auditory feedback (DAF) has been used effectively with some PD speakers. In general, DAF often helps people to slow down their speech and pronounce their sounds more clearly. Unfortunately, few studies using DAF with PD speakers have been published. Because of this, we have very limited information about how speech-language pathologists can best use DAF with their patients. This study will evaluate different aspects of the technique to see how they affect improvements made during treatment.

6) PARTICIPANT INCLUSION/EXCLUSION CRITERIA: Individuals with a neurologist's diagnosis of Parkinson's disease and at least a Stage I severity rating. Selected participants will also meet the following criteria: a passing score on a dementia screening, native speakers of English, normal or corrected vision, adequate hearing, and no history of reading difficulties. Lastly, participants must have a presenting complaint of at least two of the following speech symptoms: rapid speech rate, imprecise articulation, disfluencies, and poor intelligibility.

7) NUMBER OF PARTICIPANTS: 3-5

8) STUDY PROCEDURES: We are seeking permission for you to participate in a study. Your task will be to simply read sentences and short passages both with and without DAF. During the sessions, you will wear a comfortable earphone/microphone headset. While reading into the microphone, your voice will be made slightly louder before you hear it through the headphones. The volume on the DAF unit is easily adjustable and will be kept at a comfortable level at all times. In addition, the unit will give your voice a slight time delay (or echo), so you will hear what you say slightly after you say it. Each session will last between 25-45 minutes. The study will consist of 18 sessions, and there will be 2-4 sessions per week (depending on your availability) scheduled at your convenience. The sessions will be audiotaped, and these recordings will be used to provide measurements of your speech.

9) RISKS/BENEFITS: This study does not involve any known risk, as all aspects of the procedure are completely safe. By participating, you will gain practice and experience with a potential speech treatment technique for several weeks by a doctoral student in communication disorders. This intervention will be provided in your residence, if you choose, and will be free of charge. It is expected that the intervention will result in slower and more easily understandable oral reading.

10) RIGHT TO REFUSE: Participation in this study is voluntary. If you decide to participate, you are free to withdraw your consent and discontinue the study at any time.

11) PRIVACY: The information collected during this study will be treated confidentially. Your name will not appear anywhere in the published research report(s). Written and audiotaped data will be stored in locked cabinets, available only to the research personnel directly involved in this study. Data will be kept confidential unless release is legally compelled.

12) FINANCIAL INFORMATION: There is no cost to the participants, nor is there any financial compensation for participating in the study.

13) WITHDRAWAL: As mentioned above, you are free to discontinue your participation at any point during the study, and there will absolutely no consequences of your withdrawal.

14) REMOVAL: Under no circumstances will the investigator remove any of the participants from the study without his or her consent.

15) SIGNATURES:

"The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I can contact Robert C. Mathews, Chairman, LSU Institutional Review Board, (225) 578-8692. I agree to participate in the study described above and acknowledge the researchers' obligation to provide me with a copy of this consent form if signed by me."

_________________________ _________________

Signature of Participant Date

APPENDIX B

LOUISIANA STATE UNIVERSITY DYSARTHRIA CHECKLIST

Client: ______________________ Date: ______________ Clinician: ___________________

1. Articulation errors are fairly consistent from one production to another. _______

2. The majority of articulation errors are omissions or cluster reductions. _______

3. There is little or no improvement between spontaneous versus elicited versus automatic versus imitative speech. _______

4. Motivation in terms of instructional emphasis results in better production. _______

5. There is an intelligibility problem. _______

   Rate from 1 to 5 (1 the poorest & 5 normal)

   Spontaneous language _____
   Tikofsky _____
   Grandfather passage _____
   Cookie Theft picture _____
   Automatic speech _____
   Imitative speech _____

6. Deviant Speech Dimensions

   A. Respiration

   -- Shortness of breath ___________________
   -- Exerts great effort for speech ___________________
   -- Asymmetrical movement in respiratory structure ___________________
   -- "Belly in" breathing ___________________
   -- Compensatory movements during breathing ___________________
   -- Trouble panting or sniffing ___________________
   -- Forced inspiration/expiration ___________________
   -- Audible inspiration or stridor ___________________
   -- Grunt at end of expiration ___________________
   -- Abrupt changes in loudness ___________________
   -- Low intensity during speech ___________________

B. Phonation

-- Abrupt change in pitch w/o change in loudness ____________________
-- Monopitch ____________________
-- Voice tremor during speech or simple phonation ____________________
-- Hoarse or harsh phonation during speech or simple phonation ____________________
-- Breathiness during speech or simple phonation ____________________
-- Strained-struggle voice ____________________
-- Phonation breaks ____________________

C. Resonance

-- Hypernasality during speech ____________________
-- Hypernasality with single words ____________________
-- Nasal emission or nasal snorting ____________________
-- Drooping velum noted during oral peripheral ____________________

D. Articulation

-- Imprecise consonants in single words ____________________
-- Imprecise consonants in speech ____________________
-- Prolonged phonemes ____________________
-- Distorted vowels ____________________
-- Actual errors ____________________

E. Prosody

-- Rate is too slow or too fast ____________________
-- Short rushes of speech at times ____________________
-- Tonal features (intonation) inappropriate in context ____________________
-- Stress inappropriate for context or dialect ____________________
-- Pausing inappropriate in context ____________________
-- Duration of vowels inappropriate ____________________
-- Location of pauses are inappropriate for context or dialect ____________________

7. Type of Dysarthria and confirmatory signs (these don't need to be present)

A. Flaccid

-- confirmed medical diagnosis ____________________
-- confirmed by acoustic pattern index ____________________
-- all movement (reflex, automatic, voluntary) affected ____________________
-- specific cranial nerves involved ____________________
-- weakness of muscular contraction noted ____________________
-- individual muscles weakened and noted ____________________
-- hypotonus (flaccidity) notes ____________________
-- atrophy of individua l muscles ____________________
-- muscle strength reflex absent ____________________
-- fasciculations evident ____________________

B. Spastic

-- confirmed medical diagnosis ____________________
-- confirmed by acoustic pattern index ____________________
-- weakness or paralysis of movement patterns ____________________
-- hypertonus (spasticity) particularly near movement inititation ____________________
-- movement is slow ____________________
-- limited range of movement ____________________
-- little or no muscle atrophy ____________________
-- muscle stretch reflex increased ____________________
-- overactive sucking reflex ____________________
-- overactive jaw jerk ____________________
-- Hoffmann sign positive ____________________
-- Babinsky sign positive ____________________

C. Ataxic

-- confirmed medical diagnosis ____________________
-- confirmed by acoustic pattern index ____________________
-- inaccuracy of movement in gait, limb coordination, speech, and/or equilibrium ____________________
-- terminal crescendo tremor (intention tremor) ____________________
-- movements tend to be slow in starting and slow reaching objective ____________________
-- dysrhythmia is present ____________________
-- affected muscles are hypotonic ____________________
-- over-reaching occurs ____________________
-- pendulous reflex is present ____________________
-- jerky, irregular eye movements; nystagmus ____________________

D. Hypokinetic

-- confirmed medical diagnosis ____________________
-- confirmed by acoustic pattern index ____________________
-- limited range of movement ____________________
-- general increase in muscle tone (rigidity) ____________________
-- individual movements are slow ____________________
-- difficulty in initiating movements or arrests of movement ____________________
-- resting tremors ____________________
-- abrupt but very fast and limited movement occurs at times (festination) ____________________
-- loss of automatic assisting of one hand by the other in skilled acts ____________________
-- reduction in normal blinking and smiling ____________________
-- loss of normal arm swing during walking ____________________

E. Hyperkinetic

-- confirmed medical diagnosis ____________________
-- confirmed by acoustic pattern index ____________________
-- rapid, abnormal, involuntary movements occur. These are unsustained (tics) or sustained (chorea) ____________________
-- slowness of movement is evident ____________________
-- athetosis (repetitive twisting or writhing that slowly blends together) is present

F. Mixed Dysarthrias

-- confirmed medical diagnosis ____________________
-- combination of acoustic characteristics from the pattern index ____________________

G. Specific paralysis

-- confirmed medical diagnosis ____________________
-- specific portion of the cranial nerve exam noted ____________________

VITA

Paul Gerard Blanchet was born in Queens, New York, May 7, 1966, the son of Charles and Frances Blanchet. After graduating from Kings Park High School in 1984, he enrolled in the State University of New York, College at Fredonia. Upon receiving a Bachelor of Arts degree in psychology in 1988, Paul enrolled in the Master of Science program in experimental psychology at Northeast Louisiana University in Monroe. After graduating in 1990, he worked with persons with developmental disabilities for five years before beginning doctoral studies at Louisiana State University in Baton Rouge. Paul is currently pursuing a Doctor of Philosophy degree in Communication Disorders, which will be conferred in December of 2002.

During his doctoral studies, Paul served as research assistant, lab instructor, and course instructor in the department of Communciation Sciences and Disorders. He was also employed at the Veterans Administration Medical Center in Biloxi, Mississippi as a graduate clinician. Paul is currently Assistant Professor of Clinical Speech-Language Pathology at Louisiana State University Health Sciences Center in New Orleans. His primary research and clinical interests include neuromotor speech disorders, disorders of speech rate and fluency, speech physiology, and treatment efficacy research. Thus far, he has taught graduate courses in research methods, speech science, and phonetics.