Treating Fluency and Speech Rate Disorders in Individuals with Parkinson’s Disease:
The Use of Delayed Auditory Feedback (DAF)

Paul Blanchet, Ph.D., CCC-SLP
Department of Speech Pathology & Audiology
State University of New York at Fredonia

Abstract
The purpose of this paper is to present clinical applications of delayed auditory feedback (DAF) in treating speech rate and fluency disorders in speakers with Parkinson’s disease. When used effectively with appropriate patients, DAF provides easily adjustable and often dramatic reductions in speech rate, which often leads to increased fluency. For optimal results, however, clinicians should provide instruction, modeling, and feedback. Toward that goal, the contributions of clinician instruction and other factors on the effectiveness of DAF will be discussed.

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 and voice symptoms in 200 Parkinson's disease patients, observed speech rate disorders in 20% of the patients.

Parkinson's disease accounts for 98% of all such cases of hypokinetic dysarthria seen in speech-language pathology practices (Duffy, 1995). 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 results in a reduction in range of movement (literally “less movement”), which is needed for speech production (Darley et al., 1975).

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 speech 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 movements. Perceptually, these syllables often sound "blurred" or seem to "run together" (Duffy, 1995). Additionally, fluency deficits 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, fluency, and intelligibility, 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).

Rate control intervention 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., timing of phonation with articulatory gestures). Frequent voice 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 (Keegl, Cohen, & Poizner, 1999) suggest 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 pacing boards and alphabet boards 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 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. Other non-instrumental, "behavioral" methods (e.g., clinician 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

Delayed auditory feedback (DAF) 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 often leads to increased articulatory precision, increased speech fluency, and improved intelligibility (Yorkston et al., 2000). 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 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 attenuating 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 accidently 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 people produce sound or 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 DAF may depend, in part, on how closely an individual attends to auditory feedback. This finding has important implications for the clinical use of DAF.

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 any 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 shortened, 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).

Why DAF enhances fluency remains unknown. Bloodstein (1995) noted that many stutterers prolong syllables, over-articulate, or concentrate on proprioceptive and tactile feedback while speaking with DAF, and suggested that these were compensatory speech motor behaviors designed to overcome the disruptive effects of delayed auditory feedback. Thus, it could be suggested that speakers alter their motor speech output as a method of "beating" the DAF, thereby 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).

Similarly, 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). Some researchers suggest that a more regular rhythm supports speech production, as DAF may reduce "temporal uncertainty." This may allow 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 need to make small surges of sub-glottic pressure to produce stressed syllables. This simplification of syllable production may reduce the 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).

However, more recent research interprets the fluency-enhancing effects of DAF differently. Over the last decade, the data suggests that developmental stuttering has a neurological genesis (Ambrose, Cox, & Yairi, 1997; Braun et al., 1997; De Nil, Kroll, & Houle, 2001; Fox, Ingham, Ingham, Hirsch et al., 1996; Fox, Ingham, Ingham, & Zamarripa, et al., 2000; Ingham, Fox, Ingham, & Zamarripa, 2000; Ingham, Fox, Ingham, Zamarripa, Martin, et al., 1996; Kroll & De Nil, 1998, Devous, Freeman, Watson, & Finitzo, 1991; Salmelin, Schnitzler, Schmitz, & Freund, 2000; Wu, Maguire, Riley, Fallen et al., 1995; Wu, Maguire, Riley, Lee et al., 1997), and projects a distinct neurophysiologic signature (Fox et al., 1996, 2000; Salmelin et al., 1998, 2000; Wu et al., 1995, 1997) which is hypothesized to be symptomatic to the disorder, rather than causal to the disorder (Guntupalli, Kalinowski, Saltuklaroglu, 2006).

Research has shown that exposure to choral speech functionally rectifies most of the deviant neurophysiologic activity associated with the production of stuttered speech (Fox et al., 1996, 2000; Salmelin et al., 1998; Wu et al., 1995, 1997). Subsequently, some researchers have hypothesized that the gestural information present in the "second speech signal" found within choral speech (or emulations of choral speech, such as DAF) fundamentally alters speech-related neurolinguistic processing via either an alternate premotor system, or the engagement of mirror neurons, resulting in increased fluency (Kalinowski & Saltuklaroglu, 2003; Snyder & Hough, submitted, Snyder, submitted). In short, this recent research trend hypothesizes that altered auditory feedback may enhance fluency by altering speech-related neurolinguistic activity prior to speech-motor execution, which is in stark contrast to previous perspectives that focused on speech motor output (Snyder, submitted).

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.

There is currently a paucity of treatment studies that experimentally demonstrate the effects of clinician instruction pertaining specifically to how precisely speakers match the delayed signal. The primary goal in this line of research 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 a recent study by Blanchet (in preparation) study was to evaluate the contributions of clinician instruction and delay interval on the effectiveness of delayed auditory feedback in treating speech deficits in adults with Parkinson's disease. Some preliminary findings, as well as clinical implications and suggestions for using DAF with such patients, will be discussed in detail in a future paper.

References


Snyder, G. The effects of a single silent initiating speech gesture on stuttering frequency. Manuscript in preparation.


