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CLINICAL TECHNOLOGIES FOR THE REDUCTION OF STUTTERING AND ENHANCEMENT OF SPEECH FLUENCY

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ABSTRACT—Among the clinical technologies for the treatment of fluency disorders presented in this article are systems for assisting and automating feedback on stuttering severity, establishing speech changes that enhance fluency, and modifying speech-related sensory feedback for fluency enhancement. Some additional technologies, which have been implemented only in research but are expected to find their way to clinicians in the near future, are also discussed. The effectiveness of microcomputer applications for the treatment of stuttering has received little research; however, some answers about their effectiveness may be inferred from descriptions of their operational features and published specifications.

KEY WORDS: Treatment technology, speech production modifications, feedback alterations

The clinical literature on fluency disorders virtually teems with options for treating stuttering and its associated clinical signs. Although this article covers only those approaches for which technological options have been developed, they are discussed in light of the entire spectrum of available treatment options so that the comparative value of such technologies is highlighted and the extent to which these technologies can augment existing treatment programs, rather than replacing them altogether, is illustrated.

As was the case with my discussion of technologies related to assessment of stuttering in the preceding issue of *Seminars* (Bakker, 1999), I place limited emphasis on theoretical biases and preferences in reviewing the currently available technological options for stuttering therapy. A few of these technologies can also be used to "work on speech fluency outside of treatment settings, permitting their use as a part of a planned carryover program. Furthermore, a number of devices may provide clients with a backup system for augmenting

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fluency in difficult speaking situations, where voluntary control of fluency skills may be lacking.

Most current stuttering treatments, regardless of the possible use of clinical technologies, are classified as those that focus on stuttering modification and reduction or on fluency enhancement (e.g., Guitar, 1998). However, this division is somewhat broad for the purposes of this article and fails to recognize a number of distinctions in the objectives of different approaches that are important to the effective clinical management of stuttering problems, such as the following:

1. Stuttering prevention
2. Stuttering modification or "stutter easy" approaches
3. Reduction of stuttering and its related clinical behaviors
4. Fluency enhancement through changing aspects of speech production (acoustic or physiological)
5. Fluency enhancement through changes in speech-related sensory feedback
6. Reduction of fears, concerns, and negative speech-associated attitudes

The first two objectives rely on the perceptual skills of clinicians and clients for which no current technologies are available. Therefore, currently available technical tools apply only to the last four treatment objectives.

REDUCTION OF STUTTERING

One way of reducing stuttering severity is through lowering the frequency of stuttering and other associated clinical signs. This usually boils down to reducing the number, and in some cases the duration, of clients' stutters, making several of the assessment systems discussed in the previous issue (Bakker, 1999) useful in providing performance-related feedback to clients in therapy. Although these technologies were primarily designed to produce objective, quantitative data for assessing treatment outcomes, they can easily be employed for treatment purposes as well.

TECHNOLOGY TOOLS

Stuttering frequency is one available output of the *Stuttering Treatment Rating Recorder (STRR)*,[1] *Computerized Scoring of Stuttering Severity (CSSS)*, and *Stuttering Measurement Module* programs. The *STRR* was designed primarily for establishing ongoing feedback to clients in behaviorally oriented treatment programs. Its feedback screen periodically updates the current and overall status of speaking behaviors that are often targets of treatment (e.g., percentage of syllables stuttered, speech rate, and speech naturalness). These measures are derived from the clinician's cumulative and ongoing counts of stuttered (i.e., right mouse clicks) and nonstuttered syllables (i.e., left mouse clicks) and speech naturalness ratings, which are regularly prompted throughout the session.

The *STRR* displays stuttering frequency, speech rate, and judged speech naturalness ratings in a text screen format. And despite its origin as a DOS program, *STRR* functions comparably when launched in a Windows environment that is backward compatible with DOS (e.g., Windows 95 and 98, but not NT) and is started in a DOS Window. This ensures that the background housekeeping and multi-tasking related operations of the Windows operating system are kept to a minimum. *STRR* feedback is useful for clients who are able to use the program's display of numerical data to reduce stuttering while improving their speech naturalness ratings, which limits its value for young fluency clients.

The *Stuttering Measurement Module can* also provide updated clinical feedback on speech at intervals selected by the clinician. A revised version of the *STRR* is built into this system for users having previous experience with the *STRR* program; however, its default option (i.e., "Basic scoring") provides both online and cumulative feedback to clients in either graphical or numerical form. Even though the *Stuttering Measure-*

[1]All software and hardware resources discussed in this article appear in the Appendix.

ment Module is likely to be appropriate for a broader age-range of fluency clients, it still does not provide the type of animated feedback that would make it particularly useful for very young fluency clients. This program can also provide several stuttering related measures, (e.g., the mean length of stutter-free intervals of speech in either syllables or seconds) at the conclusion of each session, which are useful data for evaluating and monitoring the effects of treatment.

Typically, the effectiveness of response contingency interventions is related to whether or not clients receive immediate feedback about their performance; feedback is more likely to result in changes in behavior if it is provided promptly following the targeted behaviors (Rimm & Masters, 1979). Feedback provided in a delayed manner, or only after the completion of a number of trials, is likely to be less effective than those that provide immediate feedback. A major limitation of currently available programs is the manner in which feedback on speaking fluency is made available to clients. Furthermore, the research on client-oriented feedback methods and technology is extremely limited, leaving many unanswered questions about the *internal* and *external* validity of using the feedback from these systems for treating stuttering. Such information would appear to be essential for comparing the effectiveness of software-based feedback compared to that of traditional methods of providing feedback and for assessing the unique contributions of each. The lack of efficacy data, of course, is a problem not limited to technology applications for fluency disorders.

MODIFICATION OF SPEECH PRODUCTION PATTERNS

Much of the current literature on stuttering treatment indicates that most clients can achieve immediate and substantial reductions in severity of stuttering by changing their speaking production patterns. Among the changes most frequently described are: 1) speaking rhythmically, 2) reducing speech rate (e.g., prolonged speech production or slowed speech), 3) reducing abruptness of voice onsets (i.e., easy onsets), and 4) maintaining continuous phonation and airflow between pauses. Feedback for informing clients about their effectiveness in making these fluency-enhancing changes is rather straightforward.

RHYTHMIC PRODUCTION

Rhythmic speech can be established with hardware and software *metronomes* and having clients speak one syllable in time with each beat, thereby ensuring that speech production is rhythmical and at a selected rate. The most commonly available metronomes are those designed for musical practice; however, their utility for fluency intervention is surpassed by the flexibility of software-based metronomes, whose computer programs can be easily adapted to the specific needs of clients in training rhythmic speech. For example, a visually based stimulus pattern (e.g., trains of light pulses or computer-generated animations that move at the targeted pace) can be used instead of an auditory stimulus or a client can be given the option of stopping the metronome when it is not needed so that its disruptive effects on communication can be minimized (e.g., at the end of a conversational turn or when the clinician interrupts the client to give instructions).

One of the standard features of the *Kay Elemetrics Facilitator* is its ability to present auditory or visual metronome stimuli, either singly or in combination. In contrast, the *Pacemaster* provides only an auditory stimulus, but its electronics are housed in a hearing-aid size case, making it barely visible to others. At the present time, no metronome has a voice-activated operation so that the device continues to click after speakers yield their turns to a conversational partner. Perhaps future technological developments will address this limitation. It should be remembered that rhythmic speech, though effective in eliminating or substantially reducing stuttering, results in a speech pattern that sounds highly unnatural and a reputation for having poor maintenance and generalization of treatment effects. It may be more effective, however, when used primarily in early stages of treatment to aid in establishing designated speech rates.

RATE MODIFICATION

As noted earlier, *STRR* is limited to providing only numerical online feedback of speaking rate to clients, which may prevent its use with the youngest fluency clients or other clients who have difficulty in interpreting or responding appropriately to numerical data. In an effort to overcome this limitation, I have tried using a graphical feedback screen (i.e., *Speech Rate Monitor*) with clients receiving speech rate related therapies. Speaking rate is measured during selected speech intervals (e.g., 20 seconds) and displayed. With each subsequent interval the height of a bar in a histogram displays a client's speaking rate in syllables per minute (SPM) during the preceding 20-second interval, calculated from clinician-based counts of stuttered and stutter-free syllables. Because stutters [i.e., tapping the s-key] and stutter-free syllables [i.e., tapping the f-key] are counted separately, the bars of the histogram reflect the percentage of syllables spoken that were stuttered.

Speech rate training can be facilitated considerably by using an oral-reading oriented computerized metronome. These metronomes differ from those just discussed in that they print words, or units of other length, to achieve a pre-selected target rate of speech production. The client's task is to orally read the words as they emerge on the screen or to read those in a moving *highlight* that travels across a reading passage that is printed in its entirety (Bakker, 1997). The advantage of the latter format is that clients can be instructed to 'loosely follow' the highlight, using it as a guiding stimulus rather than speaking the exact rate that was programmed. Depending on the clinician's instructions, clients can stay somewhat behind or ahead of the highlight, when natural rate changes urge them to do so. This methodology, while ensuring an overall approximation of the targeted speech rate, permits the rate-related deviations that normally occur in speech to be accommodated.

One of the easier methods for controlling speech rate is with Delayed Auditory Feedback (DAF). Increasing the length of the temporal delay in presenting a client's speech through headphones, ordinarily decreases speaking rate, and clinicians typically vary such feedback from a long (i.e., 250 ms) to a brief (i.e., 50 ms) delay. However, the delay setting of DAF does not ensure that a targeted speaking rate will be established, and some clients are able to ignore the effects of DAF altogether. Thus, DAF should be accompanied by instructions to clients when used to modify or control speaking rate. Moreover, if a specific speaking rate needs to be closely approximated (e.g., to conform to a published treatment programs's procedures or to compare with norms) the clinician must measure them.

EASY ONSETS

Training clients who stutter to use *gentle voice onsets* routinely when speaking is another common way to enhance speech fluency. Objective feedback from instrumental measures of voice onset abruptness is not a standardized technology (e.g., Bakker, Ingham, & Netsell, 1997), which may also be confounded by phonetic variations. One appealing solution to this problem would appear to be the use of laryngeal, contact microphones that respond to voice-related vibrations in the soft tissues of the neck rather than sound. Although it may seem reasonable to assume that the vibrations in this tissue directly reflect voice-onset abruptness in the larynx, this approach is subject to a different type of bias. Voice-related vibrations are greater for closed than for open vowels, because more acoustic energy is trapped within the vocal tract in the production of closed than for open vowels. Additional research is needed to find methods that measure voice onset abruptness accurately and reliably and are unaffected by vocal tract adjustments during speech. Research is also needed to determine if the fluency enhancing effects of gentle voice onsets are related to the physical aspects of voice onset abruptness, its perceptual correlates following the filtering effects of the vocal tract, or both.

Despite the positive results obtained with gentle voice onset related treatment procedures for several decades, only one treatment facility (the Precision Fluency Shaping program at Hollins College; Webster, 1974) used instrumentation to evaluate voice onset abruptness for a long time (i.e., *Voice Onset Monitor*). Recently, however, an integrated software/hardware system, *Dr. Fluency,* was introduced, which is able to provide multimedia feedback of both acoustic (i.e., voice-onset abruptness and segmental duration) and physiological (i.e., speech breathing) measures. This system is primarily useful for therapies that follow the *Precision Fluency System* treatment model closely. In order to facilitate home use of *Dr. Fluency,* a separate edition was made available for purchase by people who stutter. With the home version, it would be possible for someone who stutters to increase the number of practice hours markedly and to have increased opportunities for generalization and maintenance.

Computer Aided Fluency Establishment Training (Cafet) provides feedback on respiration, voice onset, and continuity skills believed to be related to fluency. It differs from that of most prolonged speech related treatment methodologies by focusing on these targeted speech production skills directly during normal speech production. This implies that clients who successfully complete this program produce speech that is both fluent and sounds natural; however, there are virtually no published data available on the effectiveness of *Cafet* in reaching these clinical objectives.

A number of technical aspects of *Cafet* could limit its clinical usefulness. Only one breathing belt is used for tracking a client's breathing patterns during speech production, and a one channel measure of speech breathing can not detect or display discoordinations of the thoracic and abdominal/diaphragmatic components of speech breathing that might occur. Moreover, the breathing curve produced on the *Cafet* monitor does not reflect accurate changes in volume, because such changes must be obtained with a system that combines the results of thoracic and abdominal measures into a composite volume curve. Voice onset abruptness is measured only in a relatively crude manner, as well. Thus, *Cafet,* should not be considered a comprehensive system for monitoring a client's respiratory–phonatory coordinations for speech and voice, despite its potential usefulness in achieving its own distinct therapeutic objectives.

FEEDBACK OF CONTINUED PHONATION AND AIR FLOW

There are few systems that target the continuity of phonation and airflow during speech, even though the clinical literature makes it clear that gains in these target areas may significantly improve speech fluency. A system that provides visual feedback of the relative duration of *phonation intervals* in speech is currently in the experimental stage of development (Ingham, 1999). Indirect feedback on the continuity of both phonation and airflow may be obtained with the *Cafet* system; however, its feedback screen does not provide any quantitative information. As a result, implementation of continuity targets in treatment still depends primarily on the perceptual abilities of clinicians and clients.

FLUENCY ENHANCEMENT THROUGH ALTERED FEEDBACK

DELAYED AUDITORY FEEDBACK

The use of delayed auditory feedback as a methodology for establishing designated speaking rates and other speech changes (e.g., prolonged speaking skills, gentle voice onsets, and continuity of phonation) was discussed in the previous section. A related, but different use of DAF capitalizes on its side effect of producing immediate and substantial reductions in speech dysfluency for many individuals who stutter in spite of the fact that DAF negatively affects speech fluency of normally fluent speakers. Because of the fluency enhancing effects of DAF, it has become an attractive choice for people who stutter seeking to control stuttering on their own (Kehoe, 1998). Although many questions about the effects of DAF remain unanswered, clinicians might consider having a DAF system available. At the very least, it would allow their clients who stutter to find out for themselves how much benefit they would have using a DAF system as a backup in situations where fluency is strongly desired and might otherwise be unobtainable.

Because we presently do not know which aspects of DAF are responsible for its fluency enhancing effects for people who stutter, it is difficult to make meaningful comparisons among available products or to suggest minimal standards for their specifications. Given this uncertainty, it may be best for clinicians to consider systems that permit all aspects of the auditory speech signal to be available as feedback for a client. Fortunately, most available devices produce a high quality, some times even high fidelity, auditory feedback, reducing the decision among available devices to their peripheral features in determining their usefulness for individual needs and circumstances. The *Desktop Fluency System* and the *Pocket Fluency System* of Casa Futura Technologies are relatively inexpensive, small devices that contain a voice actuated mode and are compatible for use on most telephone systems in this country.

Frequency Altered Feedback

A relatively recent addition to electronic technologies for enhancing fluency is frequency altered (or shifted) feedback (FAF). By selectively shifting the fundamental frequency of one's speaking voice, up or down, the perceptual quality of speech is altered substantially, making personal identification almost impossible. This technology has been used at times during radio or television broadcasts when the identity of an interviewee needs to be kept confidential. Despite the obvious and dramatic quality change, the FAF modified speech signal retains its intelligibility and some recent literature on its use to enhance fluency appear promising (Kehoe, 1998). It can establish immediate and substantial reductions in stuttering frequency for many, but not all, persons who stutter and results in speech that is normal sounding. The latter feature sets it apart from the use of DAF, which achieves fluency at the cost of perceptual speech changes that sound unnatural. Like DAF, the technologies used to produce FAF are likely best evaluated in terms of their inclusion of desired peripherals.

Amplification of Fundamental Frequency

A different but related auditory feedback manipulation can enhance fluency through selectively amplifying the fundamental frequency of the speaker's voice (the *Fluency Master*) through recording vocal fold oscillations with a contact microphone. The *Fluency Master* is housed in a hearing aid sized case so that it is barely detectable by others. Its effects, however, do not appear to be as powerful as those possible with FAF or DAF (Kehoe, 1998); however, more research is needed.

Speech Masking

Perhaps the earliest technology used for achieving fluency enhancement through auditory feedback manipulation was the *Edinburgh Masker.* Its initial version provided bilateral masking noise, which was triggered by a voice-actuated switch to prevent unnecessary interference with communication. Although the *Edinburgh Master* usually produces immediate and substantial reductions in stuttering, its effects may not be as strong for most stuttering individuals as those obtained with DAF or FAF. Moreover, the literature on its potential for generalization is not very promising (Ingham, 1993).

Voice-actuated masking is also a standard feature of the *Facilitator,* and the *Desktop Fluency System* provides a manual switch for masking (Kehoe, 1998). The types of masking noise produced vary across the devices, and the critical parameters for maximizing establishment of speech fluency in specific individuals who stutter are unknown. Perhaps, masking should be considered as an alternative for clients for whom neither DAF nor FAF proved to have its intended effect.

CASE STUDY

Assessment

An adult stuttering client, after administration of the SSI-3 (Riley, 1994) and using the *CSSS* program, evidence the following: 13% syllables stuttered, an average of 1.8 seconds for the three longest stutters, and a fluent speaking rate of 189 syllables per minute. Because of the severity of this client's frequency and duration of stuttering events, it was decided that intensive fluency shaping should be employed.

Goal I: Achieve fluent speech at a substantially reduced speaking rate (30 words per minute of stutter-free speech for 10 consecutive minutes on at least 3 consecutive trials) during oral reading.

Intervention 1: Use of a computerized metronome with a rate cue using a highlighting effect set at 30 words per minute as a model for the target rate. The words per minute metric was chosen because the computerized metronome proceeds one word at a time.

Results: The targeted speech rate was not met within a reasonable amount of time and a more compelling rate modification strategy (DAF) was considered.

Intervention 2: Use of DAF set at 250 ms delay.

Results: After practicing for two consecutive sessions, the client succeeded in completing three consecutive 10-minute trials with stutter-free speech, during oral reading.

Goal II: While maintaining fluent speech at the established reduced speaking rate with DAF set at 250 ms, the client will achieve consistent usage of gentle voice onsets and continuity of phonation more than 90% of the time during oral reading as judged by the clinician.

Intervention 3: The client is instructed, using explanation and modeling, in the use of gentle voice onsets and continuous phonation while receiving DAF, set at a 250 ms delay. These new skills are assessed subjectively by the clinician.

Results: Satisfactory performance by the client was achieved by the fifth session.

Goal III: Maintenance of stutter-free speech, while maintaining a predominance of gentle voice onsets and continuity of phonation, at gradually increasing rates of speech production during oral reading.

Intervention 4: Reduction of DAF-delay in steps of 50 ms.

Results: The client achieved a rate of 113 words per minute of stutter-free speech while showing evidence of a consistent usage of gentle voice onsets and continuous phonation at the twelfth session. This rate was produced while DAF was set at 50 ms delay. However, the client was unable to move beyond this point and maintain speech fluency. It was decided that the resulting speech, though somewhat slow, was acceptable for use in daily situations, and future procedures would target generalization and maintenance of the achieved fluency in monologues and conversations, first in therapy, and later in designated situations away from the clinic without the use of DAF.

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APPENDIX

Tools for the Treatment of Fluency Disorders

Author/Producer	*Item*	*Address*	*WWW/E-mail*
	Pace Master	6796 Market Street, Upper Darby, PA 19082	Unknown
	CSSS: Computerized Scoring of Stuttering Severity	8700 Shoal Creek Blvd., Austin, TX 78757-6897	www.proedinc.com
Bakker, K., Ingham. R., Ingham-Costello, J., Frank, P., & Fingland, T.	The Stuttering Measurement Module	Dept. of Communication Sciences & Disorders; Southwest Missouri State Univ.; 901 S. National Ave. Springfield, MO 65804	KlaasBakker@mail.smsu.edu
CAFET, Inc.	Computer-Aided Fluency Establishment Training	4208 Evergreen Lane, Suite 213, Annandale, VA 22003	Unknown

APPENDIX

TOOLS FOR THE TREATMENT OF FLUENCY DISORDERS (CONTINUED)

Author/Producer	*Item*	*Address*	*WWW/E-mail*
	Desktop Fluency System Pocket Fluency System	PO Box 7551, Boulder, CO 80306-7551	
	Pacer/Tally for Pacing or Tallying Responses	555 Academic Court, San Antonio, TX 78204	www.hbtpc.com
	STRR: Stuttering Treatment Rating Recorder	Dept of Speech & Hearing Sciences, University of California–Santa Barbara, CA Santa Barbara, CA 93106	Roger J. Ingham sphlingh@ucsbuxa.ucsb.edu
Kay Elemetrics Corp	The Facilitator	2 Bridgewater Lane, Lincoln Park, NJ 07035-1488	www.kayelemetrics.com
National Medical Equipment	Fluency Master	Manhasset Hills, NY	Unknown
Speech Therapy Systems, Ltd.	Dr. Fluency	Otniel, 111, 90407, Israel	www.dfluency.com
Sunset Software	Slow Speech Rate Drill for Dysarthric Speakers	11750 Sunset Blvd., Suite 414, Los Angeles, CA 90049	Unknown
Windows	Speech Rate Monitor	Dept. of Communication Sciences & Disorders, Southwest Missouri State Univ., 901 S. National Ave., Springfield, MO 65804	KlaasBakker@mail.smsu.edu

ARTICLE FIVE

SELF-ASSESSMENT QUESTIONS

1. Which of the following techniques is effective for demonstrating immediate speech fluency to clients early on in therapy?
   (a) DAF
   (b) masking
   (c) FAF
   (d) all
2. Frequency altered feedback has as an advantage that:
   (a) speech rate reductions are almost immediate
   (b) it produces voice onsets, and continued phonation
   (c) dysfluency is typically reduced while speech naturalness is preserved
   (d) feedback is perceived as natural by the client
3. The role of fluency enhancing devices is best described as:
   (a) replacement of traditional therapy by speech language pathologists
   (b) assessment and diagnostic oriented only
   (c) tools for facilitating, and augmenting existing therapies
   (d) controversial; virtually no evidence exists supporting the use of fluency enhancing devices for treating stuttering
4. Which of the following statements about feedback displays is most true?
   (a) most software systems for feedback of stuttering severity and fluency provide alternate displays for adapting to the needs of individual clients
   (b) displays should emphasize numerical feedback as it is the most objective, exacting and effective method for expressing results

(c) the treatment efficacy of alternate feedback displays is poorly researched
(d) the development of alternate feedback screens is generally too expensive for feedback systems intended for fluency clients

5. What is the most likely reason that metronomes do not produce speech fluency that generalizes to real life situations?
(a) rhythmic speech is too unnatural to be acceptable for most daily communicative situations
(b) the auditory stimulus used in most metronomes becomes annoying to users
(c) speech tends to take on a slurred quality and may become inarticulate
(d) the effect of using metronomes wears off