**BEHAVIORAL ENGINEERING: STUTTERING AS
A FUNCTION OF STIMULUS DURATION
DURING SPEECH SYNCHRONIZATION¹**

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Past studies have shown that stuttering is eliminated when speech is synchronized with a metronomic beat, but the speech sounds artificial. The present study investigated the effect of increasing the duration of these individual stimulus beats with the stimulus-off period constant at 1 sec. When subjects were instructed to speak during the stimulus-on period, stuttering was an inverse function of stimulus duration, indicating that the known metronome effect on stuttering is one point on a continuum of effective rhythm procedures. The "naturalness" of speech increased as the stimulus duration increased up to durations of about 2 sec, and then decreased. At optimal values, stuttering was greatly reduced and naturalness and rapidity of speech were retained. These optimal values effectively controlled stuttering in a field test that used two types of specially designed portable instruments, one of which produced a tactual stimulus and the other an auditory stimulus.

When a stutterer speaks in time with an auditory metronomic beat, the stuttering is eliminated or greatly reduced (Barber, 1940). This "metronome effect" has also been found when the stimulus is visual (Barber, 1940; Brady, 1969) or tactual (Barber, 1940; Azrin, Jones, and Flye, 1968; Brady, 1969). Although the temporal parameters of the metronomic beat seem to be of major importance, as seen by the change in stuttering when the beats are irregularly spaced (Fransella and Beech, 1965; Azrin *et al.*, 1968), speeded up (Barber, 1940), or slowed down (Fransella and Beech, 1965), no systematic study of these parameters is available. If the metronome effect is to be understood, its effectiveness should be evaluated as a function of the parameters of the procedure rather than as an all-or-none procedure with arbitrarily selected temporal values. The present study selected for parametric study the duration of the individual beats. This dimension has not been investigated previously; rather, only a momentary beat has been used.

According to a previous analysis (Azrin *et al.*, 1968) the metronomic effect on stuttering results because rhythmicity of speech is

restored by the rhythmic metronomic beat. This interpretation suggests that stuttering should continue to be reduced when the stimulus beat is increased in duration, since the stimulus pattern would still be rhythmic or regular. Longer stimulus beats should also have an effect on overall rate of speech and on the naturalness of speech because a momentary beat allows only a single syllable or word to be spoken at a time and seems to impart an unnatural measured quality to the speech flow. Accordingly, the present study measured the overall rate and naturalness of speech as well as the rate of stuttering.

METHOD

Four male college students 19 to 25 yr of age were selected as subjects from several respondents to a newspaper advertisement. The criteria for selection were that they had received prior therapy for stuttering and had stuttered noticeably and continuously during the initial interview. One of the initial respondents was eliminated when it was noted that his speech was completely fluent for several hours once he was able to start speaking fluently. The subjects read aloud from a book while seated in a room where an observer was also present. Each subject wore on his wrist the apparatus described in the earlier report (Azrin *et al.*, 1968) for delivering a vibrotactile stimulus (250 Hz) to the bony projection on the wrist.

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For a 5-min period at the beginning of the 2-hr session, the baseline level of stuttering was determined by having the subject read aloud with the vibrotactile stimulus absent. The following written instructions were then read to the subject while he was presented with a tactual stimulus beat having a stimulus-on duration of 0.1 sec and an off duration of 1.0 sec:

This vibratory pulse goes on and off. The duration of the pulse will sometimes be very brief as it is now and will sometimes be longer. The time between pulses will always be 1 sec. I want you to read when the pulse is on and to pause each time the pulse goes off, then begin reading again when the next pulse comes on. You needn't stop reading abruptly when the pulse goes off; finish the word or phrase that you're saying but be sure to pause at least briefly before the next pulse begins. During very brief pulses, you may have to divide long words between two pulses.

Various stimulus durations were presented in the following ascending-descending sequence: 0.1, 0.5, 1.0, 2.0, 3.0, 5.0, 10, 20, 300, 20, 10, 5.0, 3.0, 2.0, 1.0, 0.5, and 0.1 sec. The stimulus-off duration was constant at 1.0 sec. A rest period of 1 min was given after each value; each value was presented for 6 min, the first minute of which was practice, before going on to the next value. The 300-sec value was therefore a single uninterrupted stimulus. A 5-min baseline measure without the stimulus was again taken at the end of the 2-hr session.

The response of stuttering was defined as in the previous Azrin *et al.* (1968) study as an abnormal prolongation, interruption, or repetition of a part of a word or a repetition of a whole word. Two judges scored the stuttering independently from a tape recording of the speech.

The speech was also judged for its naturalness. Tape recordings composed of the speech of each subject during the final minute of each stimulus duration were scored independently by 12 different judges. The following instructions were given to these judges:

This is a tape recording of a person reading from a book. Sometimes this person stutters and sometimes his speech sounds unnatural because he spaces his

words in an unusual manner. Your job is to evaluate the naturalness of his speech at different points throughout the tape. At the end of each 1-min period of speech, the tape will be interrupted by my recorded voice asking you for judgment of the naturalness of that 1-min segment of speech. At each of these judgment points you are to circle "natural" or "unnatural" beside the appropriate judgment number on this score sheet. Circle "natural" if you think that the 1-min speech segment sounded natural and circle "unnatural" if you think it sounded unnatural, then go on to the next speech segment. Here is a good question to ask yourself as you make each judgment: "If I had just heard this person for the first time reading to an audience, would his speech sound unnatural to me?" Remember, base each judgment only on the previous 1-min segment of speech, not on any earlier segments of the tape.

One subject was given the apparatus to wear outside of the laboratory as an attachment to the band of his wristwatch. A thin wire worn under the shirt sleeve connected the stimulus vibrator on the watchband to the scheduling apparatus, which was in a cigarette-package-sized container (10 by 5 by 2 cm) and was worn in the shirt pocket. The stimulus duration could be adjusted over a range from 0.1 sec to 10 sec; the interstimulus duration was 1.0 sec. The subject was instructed to adjust the stimulus duration to any value he preferred to use. Unknown to the subject, a miniature time-meter, described by Azrin, Rubin, O'Brien, Ayllon, and Roll (1968), was located in the apparatus and recorded the duration that the apparatus was used. This automatic measure was paralleled by a written record kept by the subject and mailed daily to the experimenter. The time-meter was read about twice a week by the experimenter. The subject was tested about twice a week during a 30-min session in which he spoke without the apparatus for 15 min and then spoke for 15 min with the apparatus presenting the stimulus at a 2-sec on and 1-sec off cycle.

After field testing the portable tactual apparatus, the same subject was given a second portable instrument, which delivered an auditory rather than a tactual stimulus. This in-

strument was an electronic metronome designed to be worn behind the ear. For the purpose of the present study, this instrument was modified to deliver a 100-Hz tone in a 2-sec on and 1-sec off cycle. The circuit for this apparatus is a modification of the circuit described in Fig. 15.7 in the G.E. Handbook. (This special apparatus was constructed with the assistance of E. R. Libby of Associated Auditory Instruments, Inc., who state that they can supply this instrument as Pacemaster Model II. Address: 6796 Market Street, Upper Darby, Pennsylvania 19082.) The field-testing procedure was the same as with the portable tactual apparatus, except that the small size of the auditory instrument (3 by 1 by 1 cm) did not permit the attachment of a concealed time-meter. A written record of use was kept by the subject and mailed daily to the experimenter. The subject used this instrument for one month and his speech was tested weekly with and without the instrument.

RESULTS

Figures 1 and 2 present the percentage of words on which stuttering occurred, and the percentage of judges who rated the speech as natural-sounding. Figure 2 describes the four individual subjects; Fig. 1 shows the mean performance of the four subjects and also presents the number of words read per minute. Each data point is the mean of the ascending and descending sequence of stimulus durations. For the stuttering data, the mean score of the two judges is shown. The difference between the scores of the two judges did not exceed 3.5%. The figures show that stuttering increased as a function of the stimulus duration for each subject. The naturalness of the speech also increased as a function of stimulus duration up to intermediate values of 1 to 5 sec, and then decreased at the longer stimulus durations. The number of words read per minute increased as a function of the stimulus

Fig. 1. The effect of stimulus duration on the fluency, naturalness, and rate of speech synchronized with stimulus pulses spaced 1 sec apart. The data are averaged for the four subjects and the disconnected data points (see arrows) designate baseline performance when no stimulus was present. The abscissa is a logarithmic scale.

duration, reaching an asymptote at a duration of 3 sec as shown in Fig. 1. The slight decrease in the speed of reading seen at 300 sec was associated with the increased stuttering of only one subject (S-2) at that value. Performance

Fig. 2. The effect of stimulus duration on the individual fluency and naturalness of four subjects when their speech was synchronized with stimulus pulses spaced 1 sec apart. Disconnected data points designate baseline performance. The abscissa is logarithmic.

during the 300-sec stimulus duration (uninterrupted tactual stimulus) was comparable to the performance during the absence of that stimulus (see arrows) for all three measures of speech. For each subject, a stimulus duration existed from 1 to 3 sec at which the speed was relatively rapid, stuttering was virtually absent but considerable naturalness of speech was present.

In order to obtain a graphic representation of the temporal flow of speech, one subject (S-1) was given the same paragraph to read under different stimulus conditions while his speech was tape-recorded. Figure 3 shows an oscillograph of sample tape recordings of the speech of the subject while reading this passage (1) with the stimulus absent, (2) during a momentary stimulus beat, and (3) during an intermediate stimulus duration. During the 0.1-sec stimulus, the synchronized speech was highly regular with each word or syllable corresponding precisely with a single stimulus beat. In accordance with the instructions, the speech during the 2.0-sec stimulus condition was interrupted at least briefly during each stimulus-off period. During the 2.0-sec stimulus condition as well as during the no-stimulus condition, the longer pauses tended to be associated with grammatically appropriate pause points, such as at the end of a phrase or sentence. In contrast, the speech during the momentary beat was interrupted by pauses of fairly constant duration after each word, giving the speech pattern a chopped appearance. As indicated by the transcription on the figure, no stuttering occurred when speech was synchronized with the 0.1- or the 2.0-sec stimulus. The general appearance of the speech pattern under the no-stimulus condition was graphically similar to the appearance under the 2.0-sec stimulus condition.

The subject who participated in the field testing of the two portable instruments used the tactual apparatus first. He reported that he experimented with various stimulus durations during the first two days of the field test, and then selected a stimulus value of 2 sec. Regular examination of the instrument showed that he used that duration for the remainder of the field test.

This subject used the tactual apparatus frequently. The concealed time-meter showed an average of about 2.5 hr of stimulus presentation each day. This apparatus measure of us-

Fig. 3. Sample oscillograph of the speech of one subject during the no-stimulus condition and during synchronization with two different durations of the tactual stimulus. The upward movement of the speech pen reflects increases in speech intensity.

age was in general agreement with the reports made on the cards mailed in daily by the subject, which stated that the stimulus was turned on for an average of about 2 hr per day and that the apparatus was worn about 7 hr per day. The laboratory tests given over the four-week period showed that an average of 27% of the words were stuttered without the apparatus and 2% with the apparatus. These percentages did not deviate by more than 3% between test sessions during the four weeks. During each test session, the subject was asked what problems were encountered. He reported some difficulty in attending to the stimulus while conversing during the first two days of use, but this problem was reported to have diminished greatly after the first week. The other problems reported were (1) the need to have a shirt pocket for the scheduling apparatus, (2) the need for a long-sleeved shirt for concealing the connecting wire, (3) the weight of the apparatus, (4) the pressure of the vibrator apparatus on the wrist, and (5) the time needed to put the apparatus on each morning.

None of these problems were reported by the subject while using the portable auditory

apparatus. He stated that the auditory instrument was inconspicuous, easily attached and removed, and that the auditory signal was more easy to attend to than the vibrotactile stimulus. The only reported problem was that the auditory instrument was somewhat difficult to turn on and off while in place. The subject stated that on some occasions he failed to turn the instrument off immediately after completing a speech episode. The reports mailed daily by the subject indicated that he wore the auditory instrument for an average of 5 hr per day and that he used it for an average of about 2 hr daily. Weekly tests in the laboratory showed that an average of 28% of the words spoken were stuttered without the auditory apparatus and that an average of 5% were stuttered while using it. Variations in these percentages between the four sessions did not exceed 4%.

After this subject had used the portable apparatus, and again after he had used the portable auditory instrument, a standard series of questions concerning the field tests was asked of the subject and of his closest friends. The subject and his friends stated independently that while he was using each instru-

ment his stuttering was almost absent and that his speech sounded natural. The questions were asked individually of the friends by telephone immediately after permission was obtained from the subject to do so.

DISCUSSION

The duration of the stimulus beat was a major influence on the degree of stuttering. Stuttering was least frequent when the stimulus was a momentary beat; this is the same value used in the standard metronome procedure. Stuttering increased as a function of the stimulus duration but still remained at a near-zero level when the stimulus was as long as 1 sec for all subjects and 5 sec for one subject. These results show that the stimulus need not be a momentary beat to reduce stuttering effectively and that the standard metronome procedure uses an end point on a continuum of effective stimulus durations.

The results were in agreement with the interpretation (Azrin *et al.*, 1968) of the metronome effect as a rhythmic phenomenon in that the stimulus beat was still regular at the longer stimulus durations. This interpretation does not, however, account for the increase in stuttering at durations longer than 5 sec unless perhaps one invokes an *ad hoc* qualification such as that the imposed temporal rhythm must be compatible with the natural temporal rhythm of speech; or that the subjective sense of rhythm decreases at longer stimulus durations.

Stimulus duration seemed to affect the overall rate of speech primarily by limiting the opportunity to speak. Since only one syllable or word could be spoken at the shorter durations but several could be at the longer ones, the observed increased rate of speech at the longer durations is almost a necessary consequence. The rate of speaking was reduced to about one-half by the momentary stimulus, but was about "normal" at durations of 2 sec and longer. The only exception to this relation was a slight reduction in speech rate when stuttering became frequent at the longest stimulus duration.

The effect of the stimulus duration on the naturalness of speech can be understood by considering naturalness as determined jointly by the degree to which the speech was overly regular and by the amount of stuttering. Two

requirements for natural-sounding speech are the absence of pronounced speech regularity and the absence of stuttering. At the short stimulus durations, the pauses after each word gave the speech an obviously regular, measured quality. Speech during the longer stimulus values was not noticeably regular but was characterized by the occurrence of stuttering. At the intermediate stimulus durations, stuttering was absent and the pauses usually corresponded with grammatically appropriate pause points. The overall effect when speaking in synchronization with the intermediate stimulus durations was that the speech did not have an overly regular quality and contained little stuttering, thereby leading to the judgment by the listeners that the speech was natural sounding.

The results suggest that a more effective use of the metronome procedure as a clinical technique would be to have a stimulus duration of about 1 to 3 sec and a stimulus-off duration of 1 sec. At these intermediate durations, stuttering was reduced to about the same level as at the momentary beat in the traditional metronome procedure. In addition, the overall rate of speech was about doubled and the speech was more natural-sounding. The optimal stimulus duration differed slightly between subjects indicating that the selection of a duration should be individualized. Goldiamond (1966) has reported a "juncturing" procedure for reducing stuttering that is somewhat similar to the present optimal procedure but uses no external stimulus rhythm. His stutterers were taught to interrupt their speech at natural pause points.

The field tests of the two portable instruments by one subject indicated that the present findings may be of clinical value. The desirability of lengthened stimulus durations was evidenced by the subject's choice of an extended (2-sec) duration rather than a momentary one with the tactual apparatus. The everyday usefulness of both instruments was shown by the amount of time each was worn (tactual, 7 hr; auditory, 5 hr) and used (both, 2 hr) each day as well as by the reports of improved speech by the subject and by his friends. The periodic laboratory tests revealed that each apparatus was effective for as long as it was used. No permanent improvement was noted, since stuttering returned when neither stimulus was available. Conversely, no

adaptation of the effect was noted because stuttering continued to be reduced to a low level when either stimulus was available. The disadvantages of the portable tactual apparatus were described by the subject as being primarily esthetic in nature, but may well be sufficiently great to suggest the use of the auditory mode of stimulus presentation which substantially reduced the power requirements and, therefore, the size of that apparatus.

REFERENCES

- Azrin, N., Jones, R. J., and Flye, Barbara. A synchronization effect and its application to stuttering by a portable apparatus. *Journal of Applied Behavior Analysis*, 1968, 4, 283-295.
- Azrin, N., Rubin, H., O'Brien, F., Ayllon, T., and Roll, D. Behavioral engineering: postural control by a portable apparatus. *Journal of Applied Behavior Analysis*, 1968, 1, 99-108.
- Barber, Virginia. Studies in the psychology of stuttering, XVI. Rhythm as a distraction in stuttering. *Journal of Speech and Hearing Disorders*, 1940, 5, 29-42.
- Brady, J. P. Studies on the metronomic effect on stuttering. *Behavior Research and Therapy*, 1969, 7, 197-204.
- Fransella, F. and Beech, H. R. An experimental analysis of the effect of rhythm on the speech of stutterers. *Behavior Research and Therapy*, 1965, 3, 195-201.
- Goldiamond, I. *Operant analysis of control of fluent and non-fluent verbal behavior*. Unpublished manuscript, 1966.
- Meyer, V. and Mair, J. M. M. A new technique to control stammering: a preliminary report. *Behavior Research and Therapy*, 1963, 1, 251-254.

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