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A SYNCHRONIZATION EFFECT AND ITS APPLICATION TO STUTTERING BY A PORTABLE APPARATUS[1]

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The present study attempted to determine how a rhythmic beat affects ongoing behavior. A regular stimulus beat was presented to normal subjects who had been instructed to push a bar from side to side. Other subjects had been instructed to emit a vocal response. The individual vocal and motor responses became synchronized with the individual beats of the rhythm. The time between stimulus beats determined the modal interresponse time. These results indicate a synchronization effect: ongoing behavior tends to become synchronized with an ongoing stimulus rhythm. An attempt was made to apply these findings to the problem of stuttering, which can be considered as a disturbance of the natural rhythm of speech. Stutterers were instructed to synchronize their speech with a simple regular beat presented to them tactually by a portable apparatus. The result was a reduction of 90% or more of the stuttering for each subject during the period of synchronization. This effect endured for extended periods of spontaneous speech as well as for reading aloud and was found to be attributable to the rhythmic nature of the stimulus and not to other factors.

EXPERIMENT I: CONTROL OF SIMPLE MOTOR AND VOCAL RESPONSES BY RHYTHM

Rhythmic stimuli are believed to exert substantial behavioral influence, as evidenced by the extensive natural use of music. Yet, the basis of this control by music remains unexplained. One known property of music is that when music is contingent upon a response it can be a reinforcer, as shown by Barrett's (1962) punishment of tics by timeout from music and by Ayllon and Azrin's (1965, 1968*a*, 1968*b*) reinforcement of adaptive behaviors of chronic mental patients in their token reinforcement system. Loud music has been found to act as a punisher (Smith and Curnow, 1966) and is similar in that respect to the effect of simple noise on human behavior (Azrin, 1958). Even when it is not contingent on behavior, music seems to have distinctive properties; the GSR and respiration have been found to increase during some types of music and to decrease during others (Zimny and Weidenfeller, 1962, 1963; Ellis and Brighouse, 1952). Also, the use of music therapy for mental patients seems to be based on the assumption that music affects the general emotional state. Non-contingent music has often been reported as increasing the level of ongoing behaviors, but these reports are often conflicting (see review by Uhrbrock, 1961). Even when a complex musical sound pattern affects ongoing behavior, the question remains as to which aspect of the complex was responsible. The present study attempted a more analytic study of the effect of rhythm by investigating whether a simple regular beat influenced ongoing behavior. The procedure differed from previous studies of rhythm in that the response was a simple and discrete movement of a bar or a simple vocal response, rather than a complex behavioral sequence; similarly, the rhythmic stimulus was a fixed beat rather than a complex musical pattern. The simple nature of the response and the stimulus permitted the evaluation of any point-to-point correspondence in time between them and the eval-

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uation of any change in the overall rate of response.

METHOD

Subjects

Twenty six high school or college students 14 to 22 yr who responded to an advertisement were used. Each subject served for one-half or one full day and was paid $1.50 per hour.

Apparatus

The subject was seated in a sound-proofed room at a table on which was located a console containing the motor-response apparatus and the stimuli. A red light served as a signal to work; the subject was to rest when it was not illuminated. The motor-response apparatus was a movable bar. This response bar, 7-in. long, could be moved from side to side over a 180° arc, at both limits of which a brief buzzing sound, about 70 msec in duration, provided response feedback. About one pound of force was required to move the bar. To insure that the subject used only one hand in moving the response bar, a lever was located on the left side of the console; response feedback for moving the response bar resulted only if the subject also had been holding this lever down. The verbal response apparatus was a Lavalier microphone, worn on the chest, the output of which activated a voice-operated relay. Because of the closeness of the microphone to the subject's mouth, the relay was especially sensitive to vocal sounds and insensitive to nonvocal sounds. A small pilot light on the console flashed for 70 msec at the onset of each vocal response, thereby providing feedback to the subject that the response was sufficiently loud. A sound-light combination was used for the stimulus beat. The sound was a 1000-Hz tone of 80-db intensity; the light stimulus was provided by two 3-in. diameter translucent windows on the console that were backlighted by 7-w lamps. The overhead illumination was fairly dim and was provided by a 25-w bulb shining through a smoked glass shield so as to give prominence to the visual portion of the rhythmic stimulus. A fan provided air movement and resulted in an ambient noise level of 60 db. The scheduling and recording equipment was located in a different room; the subject was alone except during the instruction period.

Instructions

The following instructions were read to the 16 subjects assigned to the motor-response apparatus:

> "Your job is to test this equipment. It works in the following way: hold the lever down with your left hand and move the stick back and forth to sound the buzzer. Hold, do not throw, the stick. The equipment turns off when the work light goes off. The work light is the small, red light mounted on the console. It will probably go off quite soon since it's on now. This will happen every 10 or 15 minutes. You may rest during this time. When it comes back on, resume working. Usually the light and tone flash on and off (both are continuous and uninterrupted during the instructions). Please remain in the room until I return".

The instructions for the 10 subjects given the verbal-response apparatus were the same except for the response description which was:

> "Say the word 'Do' loudly and distinctly. This voice light (pointing) goes on when the word is loud enough".

Only one subject asked how fast she was to work; she was told to work at whatever rate she wished.

Procedure

The experimental design consisted of three separate procedures, each of which used different subjects. The first procedure used six female subjects and compared performance of the motor response in the presence of the rhythm with performance in its absence. The stimulus rhythm was presented during alternate 1-hr periods of a 6-hr session. During the rhythm periods the stimulus was presented every 1.1 sec; the duration of each stimulus beat was 0.1 sec. During the intervening 1-hr periods in which the rhythm was absent, the stimulus light and tone were uninterrupted; the tone sounded continuously and the light was illuminated continuously. The session began with the rhythm absent.

The second procedure used 10 female subjects and determined whether two different rhythms produced different behavioral effects on the motor response. The subjects were given the stimulus every 0.9 sec during half of the 6-hr session and every 1.3 sec during the other half. Half of the subjects received the 1.3-sec rhythm in the morning; the other half received that value in the afternoon.

The third procedure used 10 subjects, five females and five males, and determined whether two different rhythms produced different behavioral effects on the vocal response. The subjects were given the stimulus every 0.6 sec during half of the 2-hr session and every 0.9 sec during the other half. Half of the subjects received the 0.9-sec rhythm first. All subjects were given one session. The 6-hr sessions were interrupted by a 30-min lunch period after the third hour; the 2-hr sessions were interrupted by a 1-hr rest period after the first hour. During all sessions, the work light was disconnected every 15 min for 1 min, during which the experimenter recorded the counter readings in the adjacent room while the subject was not responding.

RESULTS

The rhythmic stimulus produced a slight change in overall rate of the motor response as compared with the absence of a rhythm. The mean response rate was 56 per min during the 1.1-sec beat and 62 per min without the beat. All six subjects had a lower rate of response during the rhythm, but for none of them was the response rate changed more than 16% by the rhythm. This difference was statistically significant ($P < 0.05$) by the Wilcoxin non-parametric matched-pairs test (Siegel, 1956). Similarly, a slight increase in rate resulted from the faster rhythm for the other nine subjects (a failure of the recording apparatus occurred during the 0.9-sec beat for the tenth subject). The mean response rate was 71 per min during the faster rhythm (0.9-sec beat) and 58 per min during the slower (1.3-sec beat). The difference in response rate exceeded 20% for five of the subjects and was reversed in direction for three subjects. This difference was not statistically significant. For the vocal response, the mean response rate was 58 per min during the faster rhythm (0.6-sec beat) and 52 per min during the slower (0.9-sec beat). This difference was not statistically significant.

Figure 1 shows how the motor responses were spaced in time for the six subjects who received the comparison between the rhythm and no-rhythm conditions. Synchronization of the behavior with the rhythm would be shown when the interval between responses (inter-response time) was equal to the interval be-

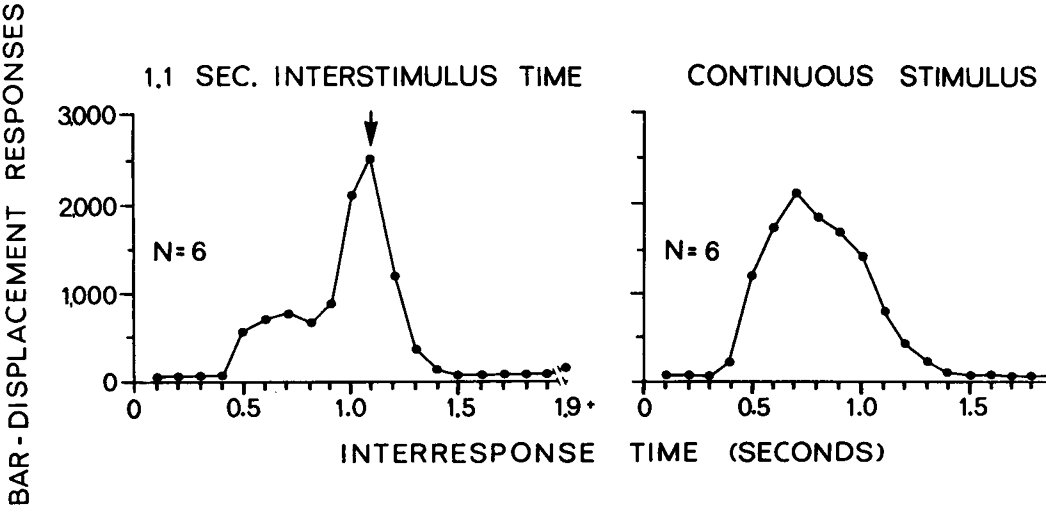

Fig. 1. The distribution of time intervals between responses for six subjects. In the left graph, a stimulus was presented every 1.1 sec. The arrow designates the interresponse time that coincides with the interstimulus time. In the right graph for the same six subjects, the stimulus was continuous and steady with no beat. The times between responses were recorded in 100-msec class intervals up to 1.9 sec. The data point on the extreme right of each graph includes all interresponse times greater than 1.9 sec. Each data point is the number of responses during a 3-hr period averaged for the six subjects.

tween stimulus beats. In the absence of the beat, the interresponse times were distributed fairly broadly from 0.5 sec to 1.1 sec with a single mode at 0.7 sec. During the 1.1-sec beat, the distribution became bimodal, with the principal mode precisely at the value of the interstimulus interval (1.1 sec). The curves for individual subjects (not shown here) resembled the averaged data of Fig. 1 in that the modal interresponse time was identical to the interstimulus time of 1.1 sec for five of the six subjects during the stimulus rhythmic, but differed from 1.1 sec for all subjects in the absence of the rhythm. The slight secondary mode at 0.7 sec seen in the averaged curve was caused by the sixth subject, who exhibited no synchronization with the stimulus.

Figure 2 shows the interresponse-time distribution for the motor response averaged for the 10 subjects given the 0.9-sec and 1.3-sec stimulus beat. Consider first the 0.9-sec beat in the left portion of the figure. At the 0.9-sec beat, a bimodal distribution resulted with the principal mode coinciding precisely with the interstimulus interval and the secondary mode coinciding with a duration equal to one-half of that (0.4 or 0.5 sec). The curves for the individual subjects showed that of seven who had a single mode, it coincided precisely with the interstimulus interval of 0.9 sec for five subjects and with the half-value for one subject. Three subjects showed two distinct modes, one of which was at precisely the value of the interstimulus interval for each of the three subjects. The second mode was equal to one-half that value for one subject and at twice that value (1.8 sec) for another. Consider now the 1.3-sec beat. The right portion of Fig. 2 shows that a bimodal distribution of interresponse times also occurred in the averaged data during this 1.3-sec beat for these same subjects. Again, one mode was at the precise duration (1.3 sec) of the interstimulus interval and the second mode at one-half of that duration (0.6 or 0.7 sec). The individual curves showed that of seven subjects who had a single mode, it was at precisely the duration of the interstimulus interval (1.3 sec) for four subjects, and at one-half that duration for three subjects. For the single subject who had a bimodal distribution, one mode was at the interstimulus interval and the other at the half-value. The single subject who did not synchronize at the 0.9-sec beat also was the only one who did not synchronize at the 1.3-sec beat.

Figure 3 shows the interresponse-time distribution for the vocal responses averaged for

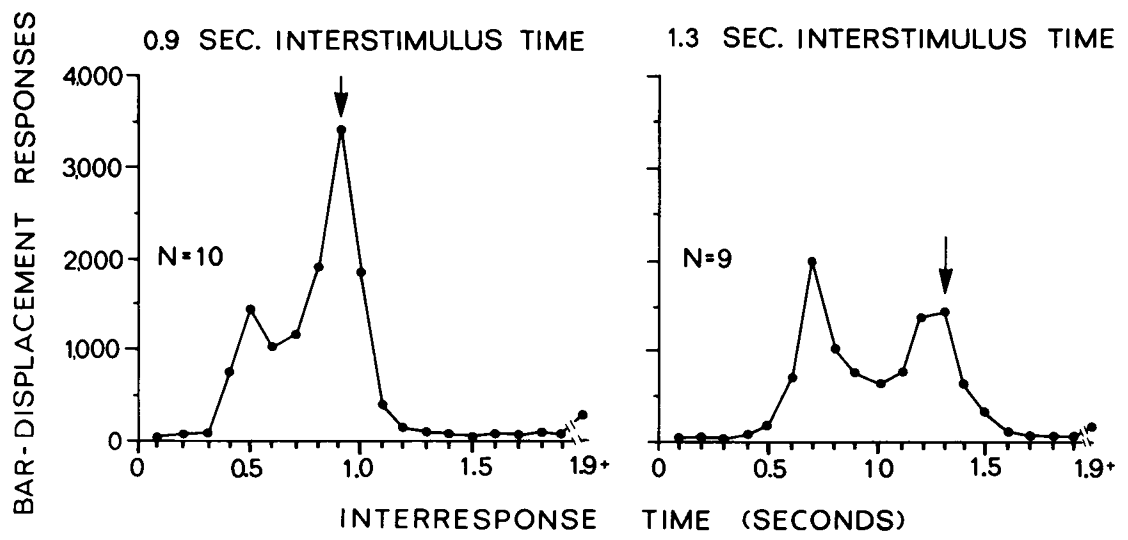

Fig. 2. The distribution of time intervals between responses for 10 subjects. The response was moving a lever. The stimulus was presented every 0.9 sec in the left graph and every 1.3 sec in the right graph for the same subjects except for one subject for whom the recording apparatus was defective during the 1.3-sec stimulus beat. The arrow designates the interresponse time that coincides with the interstimulus time. The time between responses was recorded in 100-msec class intervals. The data point on the extreme right of each graph includes all interresponse times greater than 1.9 sec. Each data point is the number of responses during a 3-hr period and is the average for the 9 or 10 subjects.

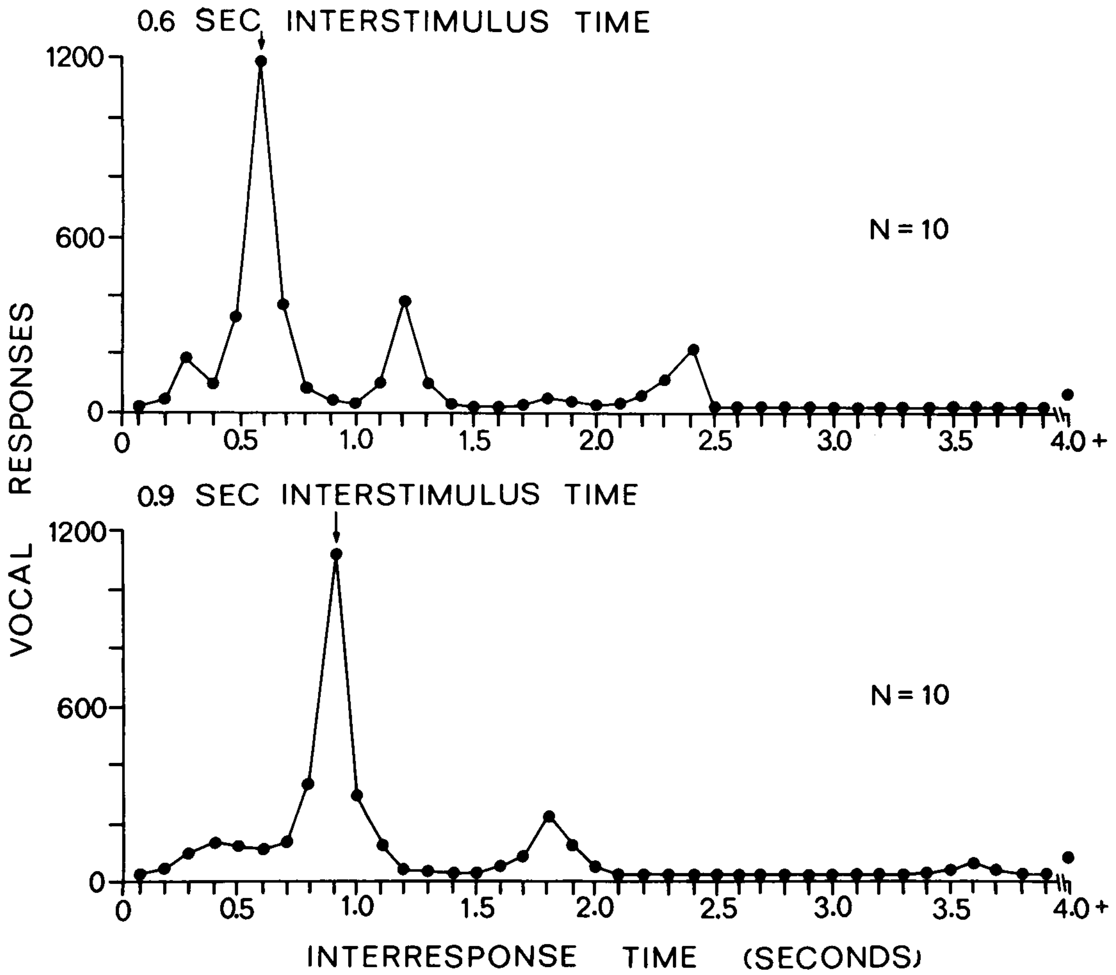

Fig. 3. The distribution of time intervals between responses for 10 subjects. The response was saying the word "Do". The stimulus was presented every 0.6 sec in the upper graph and every 0.9 sec in the lower graph for the same 10 subjects. The arrow designates the interresponse time that coincides with the interstimulus time. The time between responses was recorded in 100-msec class intervals. The data point on the extreme right of each graph includes all interresponse times greater than 3.9 sec. Each data point is the number of responses during a 1-hr period and is the average for the 10 subjects.

the 10 subjects. The upper portion of the figure for the 0.6-sec beat shows five modes which correspond precisely with the interstimulus interval or with precisely one-half (0.3 sec), twice (1.2 sec), thrice (1.8 sec), or four times (2.4 sec) that value. The curves for the individual subjects showed that two subjects had a single mode, three had a bimodal distribution, three had three modes, and two had four modes. All but two of these modes were an exact multiple of ½, 1, 2, 3, or 4 times the interstimulus value. The lower portion of Fig. 3 is for the 0.9-sec beat and shows four modes which correspond with an exact multiple of ½, 1, 2, or 4 times the interstimulus value of 0.9 sec. The curves for the individual subjects showed that three subjects had one mode, five had two modes, none had three modes, and one had four modes; one subject had no distinct mode. All but three of these modes were at an exact multiple of ½, 1, 2, or 4 times the interstimulus duration. Examination of the curves for individual subjects revealed that all 10 subjects showed one or more types of synchronization of their vocal response during the 0.6-sec beat; nine of the 10 showed some synchronization during the 0.9-sec beat.

Event recordings were taken during the vocal response procedure. Figure 4 shows sample recordings obtained from S-8, who is shown here because she synchronized her behavior with the beat in several different ways at different times. Straight timing, half-timing, third-timing, and quarter-timing are illustrated.

Examination of the individual interresponse time distributions for each 15-min period showed that synchronization seemed to endure for the entire 3-hr period. For the 10 motor-response subjects in Fig. 2, for example, nine synchronized during the first 15 min of the 0.9-sec beat and all but one of the nine also synchronized during the last 15 min. Similarly, seven of these subjects synchronized during the last, as well as the first, 15 min-period of the 1.3-sec beat. Synchronization is defined here as a modal interresponse time that is an exact integral fraction, or multiple, of the interstimulus interval.

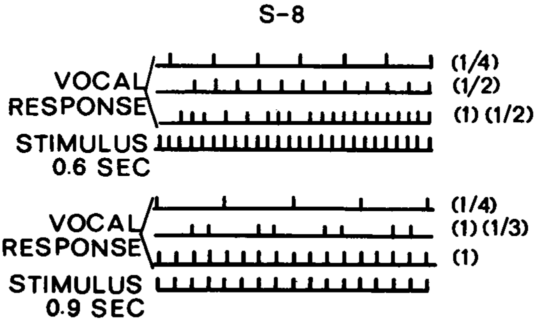

Fig. 4. Sample event recordings of the vocal responses of one subject at different times during a single session. The tone-light stimulus occurred every 0.6 sec in the upper portion of the figure and every 0.9 sec in the lower portion. The vocal responding was recorded as the output of a voice-operated relay; only the onset of each vocal response actuated the recording pen. The numbers to the right designate the type of synchronization occurring between the responses and the stimulus beat for each time period.

DISCUSSION

The results showed that for the motor responses, the rhythm slightly decreased the overall rate of responding relative to the rate of responding in the absence of the rhythm. This slight change of overall performance is in general agreement with most previous studies of non-contingent music which also found no substantial change in ongoing performance (Smith and Curnow, 1966; Freeburne and Fleischer, 1952; Newman, Hunt, and Rhodes, 1966; and review by Uhrbrock, 1961). The present results also indicated a slightly higher rate of motor responding during the faster rhythm for some subjects. Some previous comparisons of different types of music have also reported very slight differences in performance levels during one of the musical pieces (*i.e.*, Freeburne and Fleischer, 1952) but conclusions about the speed of the rhythm are not possible in such studies because the musical pieces were different on several other qualitative dimensions. The present difference in response rates can be attributed only to the quantitative difference in the rate of stimulus presentation because the rhythms were otherwise identical.

A possible basis for the change of the overall rate of response was seen in the detailed analysis of the temporal distribution of the responses. For all but three of the 26 subjects, the responses tended to synchronize with the rhythmic beat; this synchronization did not decrease during the period of presentation. The simplest form of synchronization was also the most common; one response was made for each stimulus beat. Synchronization also took the form of double-timing, half-timing, third-timing, and quarter-timing, wherein a response was made on every nth beat as evidenced by modal interresponse times that were an integral multiple of the interstimulus interval. Thus, the overall rate of response could either decrease or increase depending on which form of synchronization was present or dominant.

The major finding of this study was the synchronization effect which may be generally described as a tendency for ongoing motor and verbal responses to become synchonized with, or to occur in phase with, an ongoing stimulus rhythm. The phenomenon was not restricted to a particular rhythm since synchronization occurred at the four different rhythm values of 0.6, 0.9, 1.1, and 1.3 beats per sec. This spontaneous synchronization effect has not been investigated and reported previously. A critical feature of the present study is that the synchronization effect occurred without any instructions to the subjects to attend to the rhythm. Nor did the subjects indicate verbally any implicit belief that they should synchronize their behavior with the rhythm. Subjectively, the reaction of the experimenters while testing the apparatus was that it was difficult to avoid synchronization; the beat seemed to "pull" the behavior into phase with the beat. Dancing, marching, and singing appear to be examples of natural behaviors in which this synchronization effect operates. It is possible that the high natural frequency of these behaviors and their use as therapeutic aids in recreational therapy are based in part upon this tendency for behavior to be "carried along" by a rhythm. A recent example of this rationale is a therapeutic program in which rhythmic activities were described as a necessary and effective starting point for motivating chronic regressed schizophrenics (Goertzel, May, Salkin, and Schoop, 1965).

EXPERIMENT II: THE EFFECT OF A VIBROTACTILE RHYTHM ON STUTTERING

Experiment I showed that ongoing motor and vocal responses tended to synchronize with an ongoing rhythmic stimulus. This finding might have practical utility in eliminating behavioral disorders characterized by a disturbance of rhythm. One such disorder seems to be stuttering, in which the natural speech rhythm is disturbed. The synchronization effect of Exp. I suggested an application to stuttering by synchronizing individual verbal units, such as words or syllables, with an ongoing rhythm. Indeed, such a procedure has long been known (see discussions by Bloodstein, 1949; Beech, 1967; Fransella and Beech, 1965) in which a stutterer is instructed to speak in time with an auditory metronomic beat; the result has been a reduction of stuttering. Yet, almost no quantitative study has been conducted of this metronomic effect since an early study by Barber (1940) dismissed the effect as an instance of "distraction" of attention. An exception is the recent work by Fransella and Beech (1965). The procedure has gone unmentioned in several recent treatments of stuttering and of speech disorders generally (Hejna, 1960; Travis, 1957; Rieber and Brubaker, 1966; Murphy and Fitzsimons, 1960; Freund, 1966). As noted by Meyer and Mair (1963), the probable reasons for the lack of attention to this metronome effect may be simple lack of knowledge about the phenomenon as well as of its theoretical basis.

The present study attempted to reexamine this metronome effect with three main objectives. First, the study examined the phenomenon in more detail than has been available in previous studies. Specific attention was given to the rapidity of onset of the effect, individual differences between subjects, durability of the effect in time, possible carry-over effects upon termination of the rhythm, applicability to spontaneous speech as well as reading aloud, and changes in the overall speech rate. Second, the study examined this metronome effect as an instance of the more general synchronization effect with the objective of providing the needed theoretical basis for its existence other than as an artifact of distraction. If the reduction of stuttering is attributable to the rhythm itself, then a tactual rhythm should also be effective, as suggested by the results of Barber (1940), but pulses that are not rhythmic should have no effect on stuttering, as suggested by the results of Fransella and Beech (1965). The present study, therefore, used a tactual rhythm and an arhythmic comparison procedure. The third objective was to provide a practical method of reducing stuttering in the stutterer's natural environment. Consequently, a portable apparatus was developed that could be worn inconspicuously by the stutterer and which served as the source of the rhythmic stimuli. Meyer and Mair (1963) described a portable apparatus for achieving this same objective, and reported that it was useful for the clinical treatment of stuttering but, unfortunately, provided no quantitative data as to its effectiveness. The rationale for developing the apparatus here stemmed from the behavioral engineering approach described elsewhere (Azrin, Rubin, O'Brien, Ayllon, and Roll, 1968; Azrin and Powell, 1968). *The target behavior* was defined as rhythmic speech and the specific response was defined as the spoken word. The *controlling behavioral event* was a rhythmic stimulus provided by a *portable apparatus* so that it could operate continuously in the stutterer's natural environment. This application of behavioral engineering differs from the previous ones (Azrin *et al.*, 1968; Azrin and Powell, 1968) in that the controlling stimulus is a discriminative stimulus and not an operant consequence. Operant conditioning procedures have been found effective in modifying stuttering (Flanagan, Goldiamond, and Azrin, 1958, 1959; Siegel and Martin, 1965*a*; 1965*b*; Goldiamond, 1965; Martin and Siegel, 1966*a*, 1966*b*; Quist and Martin, 1967). The complete behavioral engineering approach, however, would require an apparatus that could differentiate stuttering from normal speech in order to schedule an operant consequence automatically for a stuttering response. Unfortunately, this problem of an apparatus definition of stuttering has not yet been solved.

METHOD

Four male college undergraduates were selected from 12 respondents to an advertisement for participants in a stuttering study. The criteria for selection were that the respondent stuttered very noticeably during the initial interview, that he had reported receiving prior therapy for stuttering, and that he was available at the desired hours.

Two speech tasks were used, both of them in the presence of an observer seated in the same room near the subject. The first task was similar to those used in previous studies of stuttering; it consisted of reading aloud from a book. The second task differed from those used previously; it was designed to approximate spontaneous speech. The subject described aloud the contents of a series of pictures assembled from popular magazines. The subject determined how much time was spent on each picture. None of the pictures or reading material was presented more than once to the same subject.

Each of three judges scored the speech independently from a tape recording for four of the six sessions in which each subject participated. One judge scored the speech for the other two sessions. Each word was scored as either stuttered or nonstuttered, although several speech blockages often occurred on a single word. The response of stuttering was defined as an abnormal prolongation, interruption, or repetition of a part of a word or a repetition of a whole word. The following written instructions and examples were given to the judges:

> You will be listening to a tape recording of a person reading (speaking). The entire monologue is from the book. (For the spontaneous speech task, the judge had before him a typed transcript of the session.) Follow the monologue in the book (transcript) and mark through each word that can be described by any of the following:
>
> 1. The speaker begins to say the word but hesitates before completing it (example—sub——marine).
> 2. The speaker pronounces any syllable of the word in a prolonged manner (example—suuuubmarine).
> 3. The speaker repeats some part of the word before completing it (example—su su su su submarine or subma ma marine).
> 4. The speaker says the word correctly but repeats the whole word before going on (example—inside *the the* submarine) except when a whole phrase is repeated.
>
> The tape can be stopped and restarted by operating the foot pedal. The tape can also be reversed and replayed if you wish to hear some parts of it more than once.

The first four columns of Table 1 show the sequence of experimental procedures. During the entire first session, the subjects read aloud without the rhythmic stimulus; during the entire second session, they engaged in the spontaneous speech task, also without the rhythmic stimulus. These two sessions provided a baseline measure of stuttering. The third and fourth session provided about 50 min of reading and spontaneous speech, respectively, with the rhythmic stimulus present; a 17-min period without the rhythmic stimulus was given at the start and end of the session, thereby providing for within-session evaluation of the effect of the rhythmic stimulus. Session 5 provided a longer period (100 min) of reading with the rhythmic pulse present to determine whether the effect of the rhythm would change in time. This period was preceded and followed by 17 min of reading without the rhythm. The last session compared the effects of (1) the rhythmic stimulus with (2) the arhythmic stimulus with (3) the stimulus absent in a counterbalanced time sequence. The within-session changes in conditions were made by the experimenter without interrupting the ongoing speech.

Apparatus

An apparatus was designed that could be worn conveniently and inconspicuously and that delivered a rhythmic tactual stimulus. The tactual stimulus was delivered to the bony projection on the wrist (the distal end of the ulna) which was found to be particularly

Table 1

Percentage of words stuttered with and without an accompanying tactual rhythm for each of four subjects while reading aloud or speaking spontaneously during each of six sessions.

Session No.	*Duration (Minutes)*	*Speech Task*	*Stimulus Condition*	*Percentage of Words Stuttered* *S-1*	*S-2*	*S-3*	*S-4*	*Mean* S_1–S_4
1	83	Reading	No Stimulus	70	20	16	20	32
2	83	Spont. Speech	No Stimulus	69	27	18	9	31
3	17	Reading	No Stimulus	75	17	4	17	28
	50	Reading	Rhythmic Stimulus	8	1	0	2	3
	17	Reading	No Stimulus	65	20	10	18	28
4	17	Spont. Speech	No Stimulus	64	29	19	11	31
	50	Spont. Speech	Rhythmic Stimulus	11	2	1	1	4
	17	Spont. Speech	No Stimulus	53	26	14	10	26
5	17	Reading	No Stimulus	73	10	5	25	28
	100	Reading	Rhythmic Stimulus	8	1	0	0	2
	17	Reading	No Stimulus	62	16	7	21	26
6	17	Reading	No Stimulus	71	8	11	20	28
	17	Reading	Arhythmic Stimulus	64	10	23	27	31
	34	Reading	Rhythmic Stimulus	10	1	1	2	3
	17	Reading	Arhythmic Stimulus	72	17	10	21	30
	17	Reading	No Stimulus	67	17	13	19	29

sensitive to vibrotactile stimulation. The vibrator was a bone conductor (Sonotone Model BR1500) with its usual case replaced by a formed plastic covering. The vibrator diaphragm was connected to a thin, slightly conical metal plate positioned on the projecting bone; a leather watchband held the cone-vibrator assembly in place with the cone under the band and the vibrator above it as seen in Fig. 3. Thin wire connected the assembly to a transistorized circuit (Fig. 11.6 in the G. E. Transistor Manual, 7th edition) contained in a plastic case 9 by 6 by 3 cm that could be worn in the shirt pocket or in a shoulder holster beneath the shirt such that the entire apparatus was concealed. The circuit provided a 250-Hz vibration, which is known to have a low threshold of tactual sensitivity (Knudsen, 1928). The apparatus was activated by flipping a switch on the case which could be accomplished easily even when the case was worn in the holster. The apparatus provided a 100-msec stimulus pulse at a rate of 90 pulses per min. The intensity and stimulus rate were held constant during the experiment. The intensity was adjusted by the subject to a value that was tactually perceptible but not audible at distances greater than 4 in. from the ear. During the arhythmic stimulus condition, the wristband assembly was connected to a separate scheduling circuit that delivered the stimulus pulses at irregular intervals, from 0.3 to 1.3 sec apart but still averaging 90 pulses per min; each pulse remained at 100-msec duration.

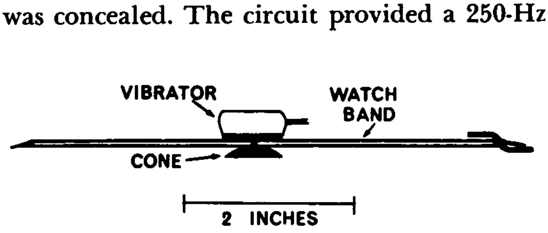

Fig. 5. The apparatus for transmitting tactual stimuli to the wrist of the subject. A regular watchband is worn slightly forward of the usual position such that the metal cone presses against the bony projection on the wrist. The vibrations to the cone are generated by a pocket-worn device (not shown here) that transmits its signal through the thin wires that are seen to be connected to the vibrator mechanism.

Instructions

Before the start of the third session, the subjects practiced reading aloud in time with the rhythm for 5 min. Similarly, a 5-min practice period of speaking in time with the rhythm was given before the start of the fourth session. The instructions were to speak one word per pulse unless the word was too long, in which case the word was to be syllabically divided between pulses.

RESULTS

All subjects followed the instructions with no apparent or stated difficulty. As instructed, they awaited a pulse to initiate a word and then paused for the next pulse before initiating the next word. When a word was long, only one or two syllables were usually spoken during a beat, and the remainder during the next beat. Figure 6 is an event recording taken from the tape of one subject and shows the synchronization of speech with the stimulus beat when the stimulus beat was introduced.

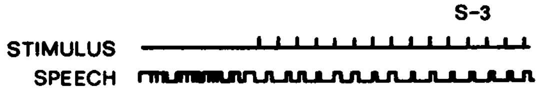

Fig. 6. Sample event recording of a subject reading aloud at the time that the stimulus beat was introduced. The speech pen was activated by the output of a voice-operated relay. The stimulus is vibrotactile and occurs every 0.9 sec.

Table 1 shows the percentage of words stuttered during each condition and within each session by each subject as well as the mean of all four subjects. The data for Sessions 1 to 4 are the means of the scores of the three judges; the scores for the individual judges were within 5% of the mean scores; for this reason only one judge was used for Sessions 5 and 6. When the rhythmic stimulus was absent during all of Sessions 1 and 2, stuttering occurred on a mean percentage of 30% of the words for both reading and spontaneous speech. When the rhythm was present during Sessions 3, 4, 5, and 6, stuttering was reduced to about 3% of the words. This reduction of about 90% occurred for each of the four subjects and for the spontaneous speech (Session 4), as well as for reading (Sessions 3, 5, and 6). The reduced level of stuttering during the rhythmic pulse was maintained from session-to-session and was as low (2.5%) during the 100-min period of Session 5 as it was during the 34-min period of Session 6 (3.3%) or the 50-min period of Session 3 (2.8%). The arhythmic stimulus (Session 6) did not reduce stuttering discernibly for any subject during either of the two 17-min periods. The four subjects stuttered to different degrees. In the absence of the rhythmic pulse, about 70% of the words were stuttered by S-1 but less than 30% for the other three subjects. During the rhythmic stimulus, stuttering was virtually absent for S-2, S-3, and S-4, being 2% or less of the words.

Figure 7 shows the intrasession changes in stuttering during Sessions 3 and 4. The introduction of the rhythmic pulse immediately reduced the stuttering, which remained at a low level for the entire 50-min period for both the reading (upper portion of the figure) and for the spontaneous speech (lower portion of the figure). When the rhythmic pulse was discontinued, stuttering immediately increased

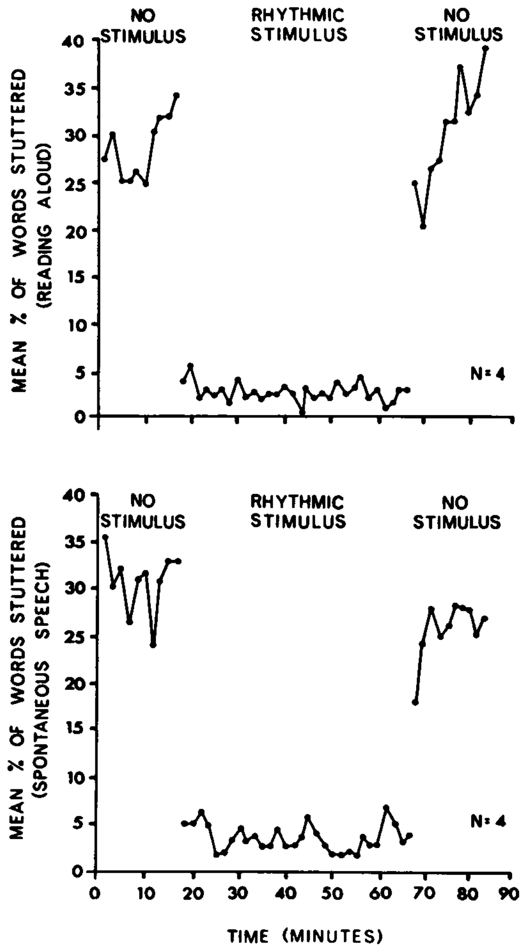

Fig. 7. The percentage of words stuttered during two sessions. Each session began and ended with a 17-min period during which the tactual stimulus rhythm was absent. The tactual stimulus was presented 90 times per min during the 50-min period in the middle of the session. The upper graph is for the task of reading aloud; the lower graph for the same subjects is for a spontaneous speech task. Each data point is for a 100-sec period averaged for the four subjects.

and returned to its previous level within 5 min. Examination of the intrasession records of individual subjects (not shown here) revealed this same abrupt decrease of stuttering when the rhythmic stimulus was introduced and the abrupt increase when it was terminated for each subject within each of the four sessions (Sessions 3 to 6) in which the rhythmic stimulus was introduced and withdrawn.

The overall rate of speaking was also affected by the rhythmic stimulus. Table 2 shows the mean number of words spoken per minute in the presence and absence of the rhythmic stimulus for both the reading and spontaneous speech for each subject. The data for a given procedure are based on all sessions, or parts of sessions, in which that procedure was used. Table 2 shows that for the most severe stutterer, S-1, the overall rate of speech was increased by the rhythm; for the three less severe stutterers, the speech rate decreased. During the rhythmic stimulus, the number of words spoken per minute was somewhat less than the number of beats per minute (90). The principal reasons for this discrepancy seemed to be the assignment of syllables rather than words to some beats and the natural pauses in speech before beginning some sentences.

Table 2

The effect of the stimulus rhythm on the overall speed of speaking. The mean number of words spoken per minute for each subject.

	Reading		*Spontaneous Speech*	
Subject No.	*Stimulus Off*	*Stimulus On*	*Stimulus Off*	*Stimulus On*
S-1	21	53	19	47
S-2	78	61	62	43
S-3	120	74	90	75
S-4	70	67	120	59

DISCUSSION

The rhythmic stimulus reduced the stuttering of each subject by about 90%, which is roughly comparable to the percentage reduction reported by Barber (1940) who also used rhythmic pulses. The reduction of stuttering endured for as long as the rhythm was presented: from session-to-session and throughout a 100-min session of continuous reading or a 50-min session of continuous speaking. Previous studies had evaluated this metronome effect for less than 5 min under a given rhythm condition (Barber, 1940; Beech, 1967; Fransella and Beech, 1965). The rhythmic stimulus had an immediate effect on the stuttering; stuttering was reduced during the first minute that the rhythm was presented. Little carry-over was seen; stuttering returned to its former level within 5 min after the rhythm was discontinued. The arhythmic stimulus did not reduce stuttering to any degree for any subject, thereby confirming the finding of Fransella and Beech (1965) that arhythmic stimuli did not reduce stuttering. Stuttering was reduced during the spontaneous speech task as well as during the reading task. Previous studies had reported data only for reading. The above findings were obtained for each of the four subjects. For the one subject who stuttered on 70% of his words, the rhythm reduced stuttering sufficiently to increase the overall speech rate. For the other three subjects who stuttered on less than 30% of their words, the overall speech rate was reduced somewhat, since synchronization with the rhythm did not permit more than 90 words to be spoken per minute.

The present apparatus and method appear to hold promise as a practical therapy for stutterers. The magnitude of the reduction of stuttering was substantial, and did not deteriorate in time, either within a fixed period or from day-to-day. The tactual mode of stimulation prevented the interference with ongoing sounds that an auditory mode would entail. Similarly, this non-auditory mode allowed the stimulator to be concealed completely under clothing, in contrast with the visible attachment required by the auditory mode. Since the rhythmic stimulus was provided by a self-powered apparatus, the subject did not need to provide his own rhythm by gesture or intonation, a procedure that occasionally has been used in clinical practice (see discussion by Bloodstein, 1949).

An apparent disadvantage of the procedure is that stuttering recurred when the rhythm was terminated; this problem should be easily solved by activation of the apparatus during all speech episodes. A second disadvantage is the measured quality of the speech; this problem seems unavoidable with this type of stimulation. A third disadvantage is the slowing of the speech which occurred for three subjects; this problem might be reduced partly by using a faster beat such as used by Barber (1940) and by Fransella and Beech (1965) in parts of their studies.

The present use of a rhythmic pulse to control stuttering was suggested by the results of Exp. I which had revealed control of motor and verbal responses by a rhythmic stimulus. Other possible explanations of this effect on stuttering are distraction, slowing down of the speech, or auditory masking. The distraction explanation states that the stutterer is distracted by the rhythmic pulse and stops stuttering because of the consequent inattentiveness to his speech. This interpretation was originally suggested by Barber and seems to be the most widely held view. Yet Barber's own data show that the rhythmic "distraction" (Barber, 1940) reduced stuttering far more than the nonrhythmic ones (Barber, 1939, conditions VI-XIV) indicating that distraction was not the principal basis for the effect. Similarly, Fransella (1967) found no reduction of stuttering when the subjects were given a distracting counting task, but found a large reduction during the rhythmic beat. Also, the arhythmic pulses did not reduce stuttering, a finding of Fransella and Beech (1965) which was confirmed in the present study; both the rhythmic and arhythmic pulses are presumably equally distracting.

Fransella and Beech (1965) tested whether stuttering might have been reduced because of the slowing of the speech but rejected this interpretation on the basis of their finding, which confirmed Barber's (1940) finding, that even a fast rhythmic pulse reduced stuttering, even though this faster rhythm produced more rapid speech. The auditory masking interpretation might seem plausible since nonrhythmic masking sounds are known to reduce stuttering (Trotter and Lesch, 1966); this interpretation is untenable, however, because the tactual rhythm of the present study and the tactual and visual rhythm of Barber's (1940) study reduced stuttering when no auditory pulses were present. In light of the above findings, the metronome effect on stuttering cannot be explained as either distraction, auditory masking, or a slowing of speech. Rather, the pulse rhythm *per se* seems to play a distinctive role in reducing stuttering. As stated previously, the neglect of the metronome procedures seems to have resulted in part from a lack of a theoretical explanation of its effectiveness, other than as an artifactual and indirect consequence of such factors as general distraction or a slowing of speech. The present study provides a possible theoretical explanation of the reduction of stuttering by a metronome beat: behavior, verbal or nonverbal, tends to become synchronized with ongoing rhythmic stimulation; stuttering can be considered as a deviation from the natural temporal patterning of spoken speech. By deliberately synchronizing speech with a rhythmic pulse, a regular temporal patterning is reinstated.

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