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REDUCTION IN RATE OF MULTIPLE TICS BY FREE OPERANT CONDITIONING METHODS

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The experimental investigation of neuromuscular tics has probably been most limited by difficulties in developing sensitive and reliable behavioral measurement techniques. The closest approximation to an experimental study of tics, by Yates (18), was based on a patient's records of her ability to reproduce her tic symptoms. Yates did not attempt to obtain objective records or measurement of the patient's tics.

The method of free operant conditioning, originally developed by Skinner (15) to study animal behavior and later modified by Lindsley (9) to study the behavior of chronic psychotics, has provided precise techniques of behavioral measurement and control. These techniques have been extended to the investigation of such pathological behaviors as vocal hallucinatory episodes (10, 11, 12), pressure of speech (13), and stuttering (7). By the application of free operant techniques, Ferster (5) succeeded in expanding the very limited behavioral repertories of two autistic children, and Brady and Lind (3) performed an experimental analysis with therapeutic results in a patient with hysterical blindness.

The basic datum of the free operant method is the frequency of a specific and reliably defined response within a controlled experimental environment. The method is most readily applied, therefore, in cases where changes in the rate of a repeated movement are of primary concern. The present report describes an application of free operant methods to the control of multiple neuromuscular tics.

METHOD

PATIENT

The patient in this experiment was a 38-year-old veteran, hospitalized in the Neurology Service of a local Veterans Administration hospital.[2] His extensive multiple tics started approximately 14 years ago, during his term of duty in the armed services. Although a medical discharge was available to him, the patient chose to continue in the service, eventually serving overseas, until regular discharge. Since then he has been employed as an accountant by a single firm.

An interview prior to the experiment revealed that the patient knew of no traumatic experience preceding the abrupt onset of tics. He told of awakening during the night with a choking sensation accompanied by a momentary inability to breathe or swallow. He recalled this as a frightening experience

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[2] The author is grateful to Norman Geschwind, M.D., Department of Neurology, Boston VA Hospital, who suggested the experimental behavioral study of this patient and who arranged for space and the loan of various apparatus components.

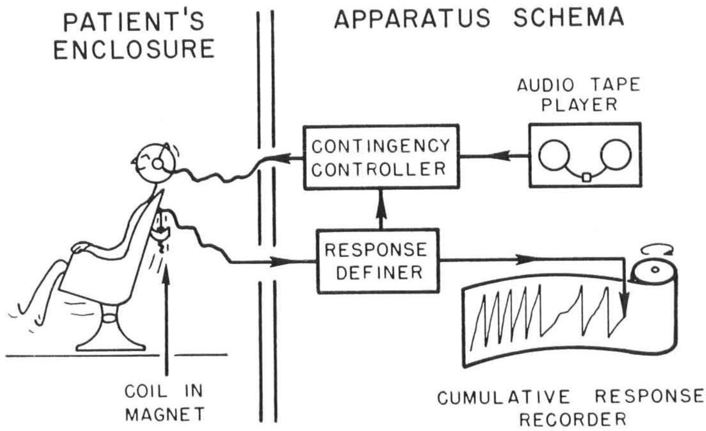

FIG. 1. Schema of apparatus used to pick up, automatically record, and program the contingent consequences of multiple tics.

and was puzzled by the subsequent development of tics. Within a few months, spasmodic movements had developed in much of his body. At the time of this experiment, his major movements included contractions of neck, shoulder, chest, and abdominal muscles, head nodding, bilateral eye blinking, opening of the mouth, and other comparatively mild facial movements.[3] The patient complained of difficulty in swallowing, hence of slow ingestion. His clear, intelligent speech was marked only occasionally by barely noticeable hesitation.

In recent years the patient was not fully aware of the presence of his tics. On occasion, when he thought himself relatively free of them, his wife reported that there was no reduction in his twitching. The patient did feel, however, that his movements were reduced in frequency while he was playing his saxophone in a local band on weekends. His greatest concern was the extent to which his tics made him conspicuous to strangers and limited his business advancement. In general, little was known of the patient's personal history.

The patient had undergone psychological counseling for a number of months and had received pharmacological treatment which included a variety of tranquilizing and muscle-relaxing drugs. Neither treatment had afforded symptomatic relief. The patient displayed no outstanding symptoms of psychopathology. His tics were considered symptomatic of an extrapyramidal system disturbance and untreatable by conventional methods.

Since he had experienced no success with other methods, the patient was highly motivated to participate in this experiment. Although he was soon discharged to return to work in a neighboring state, he voluntarily rehospitalized himself two months later for continuation of the experiment.

ARRANGEMENT OF APPARATUS

Patient's enclosure: A quiet, well ventilated room with observation facilities was equipped with a comfortable swivel-tilt armchair, an ashtray, a set of comfortable earphones which the patient wore throughout all experimental sessions, and a Grass EEG console (see Figure 1).

Operandum: A large U-shaped magnet, securely attached to the outside of the chair back, served as a convenient device for summating multiple tics. Although the swivel arc of the chair was restricted and the chair's casters removed, its tilt was freely

[3] Some of the patient's movements were so strong that, when he was seated in a chair on casters, they caused slight rolling.

operative. An induction coil rested in a "nest" of electrical tape strung between the poles of the magnet.[4] Slack in the tape was adjusted so that when the patient was seated in the chair his most noticeable spasmodic movements, regardless of locus or amplitude, created a slight movement of the coil in the magnetic field.

Response definition and recording: The current induced in the moving coil was amplified by one channel of an EEG recorder to operate a sensitive relay. The operations of this relay were directly recorded as tics. The duration and amplitude of the recorded tics were determined by setting the amplifier gain so that each strong and obvious tic would operate the response relay and cumulative response recorder. After initial selection, this amplifier gain was held constant throughout the experiment.

RESPONSE-CONTINGENT EVENTS

In free operant conditioning, the frequency of a response is altered by programing particular consequences contingent upon the emission of that response. Generally this method has been used to generate steady rates of responding or to increase the frequency of a given response. When *reduction* in the frequency of a symptom is desired, the event contingent upon symptom occurrence may be 1) the removal of a positive stimulus or 2) the presentation of an aversive stimulus. In this experiment, both types of tic-contingent events were used.

By the use of a tape recorder, a positive stimulus (music) could be removed or an aversive stimulus (noise) presented when a tic occurred. Pulses from the response relay were transmitted through a timer to a circuit which controlled the tape recorder output to the patient's earphones (see schema in Figure 1). All recording and controlling equipment was located in a nearby room.[5]

Music: In order to maximize the patient's interest, the music used in the experiment was selected by the patient himself from the hospital's music library. Boredom and satiation were minimized by using several selections with no repetitions.

The contingency arrangement was programed so that each tic produced a 1.5 second interruption of music. If the patient did not tic for at least 1.5 seconds, he could hear the music until it was automatically interrupted by the next tic. In effect, this schedule differentially reinforced time intervals between tics of 1.5 seconds or more.[6]

Noise: Azrin (1) found that responses could be eliminated by making the presentation of white noise contingent upon their occurrence; and Flanagan, Goldiamond and Azrin (7) successfully reduced chronic stuttering by presentation of a stutter-produced loud tone. In the present experiment a tape loop of white noise (60 db) was used as a tic-produced aversive stimulus.

The contingency was arranged so that each tic produced 1.5 seconds of noise over the patient's earphones. When the patient was tic-free for at least 1.5 seconds, the noise was automatically interrupted and did not recur until the next tic.

CONTINGENCY TESTING

As a control measure to test the effect of the contingencies described above, periods of continuous music and continuous noise were used. This amounted to removal of the contingency requirement which, in the case of music, more nearly approximated the conditions of music therapy.

SELF-CONTROL

The effects of music and noise were compared with the patient's own efforts to control his tics. A signal light (60 watt bulb)

[4] Michael J. Malone, M.D., offered the general idea of the "tic chair" and magnetic pickup.

[5] The cooperation, assistance, and patience of David Adkins and the staff of the EEG laboratory at the Boston VA Hospital made possible the occupancy of sufficient space to approximate good environmental control.

[6] In technical terms, this schedule is a time contingent crf drl of 1.5 seconds with an unlimited hold (6).

was introduced and the patient was instructed to control his tics by his most frequently used methods for as long as the light was on.

EXPERIMENTAL SESSIONS

The patient was informed that we would be studying the effects of various conditions on his tic rate. He had selected a lasting supply of music tapes with the understanding that he would hear them at least some of the time during the experiment. He was instructed to make himself comfortable and to remain seated in the chair, with earphones on, throughout the sessions. Aside from previously mentioned instructions concerning the signal light, no further explanation was given. The experimental room was closed, and recording was begun. Experimental conditions were changed without interruption by adjusting the controlling equipment. The duration of sessions varied from two to three hours depending on meal schedules and other hospital routines. No attempt was made to set up predetermined time intervals for each experimental condition. With a few exceptions due to time limits, each condition was run long enough to show its maximal effect when compared with the normal tic rate or operant level.

RESULTS

Cumulative records of the first four sessions showing the effects of music and noise on tic rate are shown in Figure 2.[7] These sessions were conducted during a 48-hour period prior to the patient's discharge. The remaining sessions were held two months later when the patient voluntarily rehospitalized himself for continuation of the experiment.

[7] The cumulative response recorder feeds paper at a constant speed while each tic impulse moves the recording pen one step in a vertical direction. After 450 tics have been recorded, the pen automatically resets to the base and is ready to step up with the next tic (see Figure 1). Horizontal lines in the curves are periods when no tic impulses occurred.

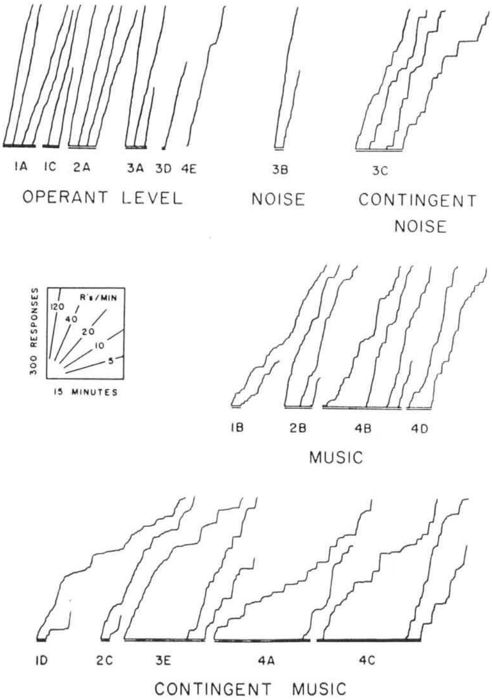

FIG. 2. Cumulative response records of the first four experimental sessions showing changes in tic rate under conditions of tic-contingent noise and tic-contingent interruption of music and control runs of both noise and music without the contingency requirement. The experimental sessions are numbered and the sequence of conditions within each session identified by letters. Double bars connect all immediately successive curves under designated conditions. Breaks in double bars indicate a change of conditions.[8]

To facilitate comparison of tic rates under the various experimental conditions, the continuous records in all figures have been telescoped and grouped. The steeper the

[8] For example, the first four pen excursions labeled 1A were continuously recorded tics during a 26-minute period at the start of the first session to get an operant level. Without interruption, the 1B curves follow, showing 27 minutes of tics under continuous music. The two curves labeled 1C record a return to the operant level for 10 minutes, followed immediately by the 1D period of 34 minutes with each tic producing interruption of the music. The 2A curves show operant level rates at the start of session 2, followed by 25 minutes of continuous music (2B), then 21 minutes of tic-contingent interruption of music (2C), and so on. The same identification system is used in Figure 4 for sessions 7 and 8.

slope of the curves, the higher the tic rate. Rate estimates may be made by reference to the grid showing rates for representative slopes.

Operant level determinations: The patient's normal tic rate (operant level) ranged between 64 and 116 tics per minute (tpm), with some decrease in the short run at 4E during the last session in Figure 2. No diurnal variations in tic rate were noted. Although sessions were run during various hours of the day and evening to capitalize on limited time, neither fatigue nor hunger affected tic rate or response to experimental conditions.[9]

Effects of noise: There was a very slight increase in the tic rate during a brief seven-minute period when continuous white noise (60 db) was played ("noise" in Figure 2). However, when made tic-contingent, noise reduced the tic rate to about 40 tpm ("contingent noise" in Figure 2). The long tic-free intervals toward the end of the contingent noise period may have been due to dozing which the patient later reported. Because of its apparent soporific effect, noise was not used further.

Effects of music: Continuous music ("music" in Figure 2) reduced the tic rate about as much as did contingent noise (40 tpm). However, when each tic interrupted the music ("contingent music"), the rate was lowered to 15 to 30 tpm. During every period of contingent music, the effect of the contingency was an additional reduction of 40 to 50 per cent in tic rate. After the first session there was no overlap between the range of rates under continuous music and under tic-contingent interruption of music. The differential magnitude of these effects on this patient thus requires no statistical test.

The fact that contingent music produced a greater reduction in rate of ticing than did continuous music appears to be the result of longer, more frequent tic-free periods when the contingency was in effect. The improbability of fatigue effects is indicated by a comparison of the 4A rate under contingent music obtained at the start of a morning session with the 1D, 2C, and 3E rates under this condition recorded at the end of the three previous sessions.

Effects of self-control: The tic-reducing effect of contingent music is compared with the patient's sustained efforts of self-control in Figure 3 (fifth session). In response to instructions and a signal light, the patient reduced his tic rate to 50 to 60 per minute. This rate is only slightly higher than that previously obtained with contingent noise and non-contingent music. Under the condition of tic-contingent interruption of music, however, rates were considerably lower, ranging from 20 to 35 per minute.[10] Again there was no overlap between the range of rates under the three conditions (operant level, self-control, and contingent music). Note the initial rapid tic rate at the beginning of the C period of contingent music. This increase in rate following a period of self-control (B) parallels what clinicians have observed in tiqueurs (17). It appears that this effect was strong enough to counteract temporarily the effect of the contingent music (C).

In addition to the differential effects on tic rate of self-control and the music contingency condition, there was also a difference in the patient's general behavior topography. In the B period of self-control, the patient was observed to engage in head-holding and general prolonged contraction. In contrast, during the E period of self-control, he engaged in relaxed tapping with finger or foot and occasional singing. This new form of behavior was first observed as the patient accompanied contingent music in the C period.

These differences in behavior topography

[9] Sessions 2, 4, and 8 were run in the morning and terminated for the patient's lunch; sessions 1 and 3 occurred in the afternoon; sessions 5 and 7 were conducted in the evening.

[10] This differential effect was reproduced repeatedly in session 6, which is not shown here.

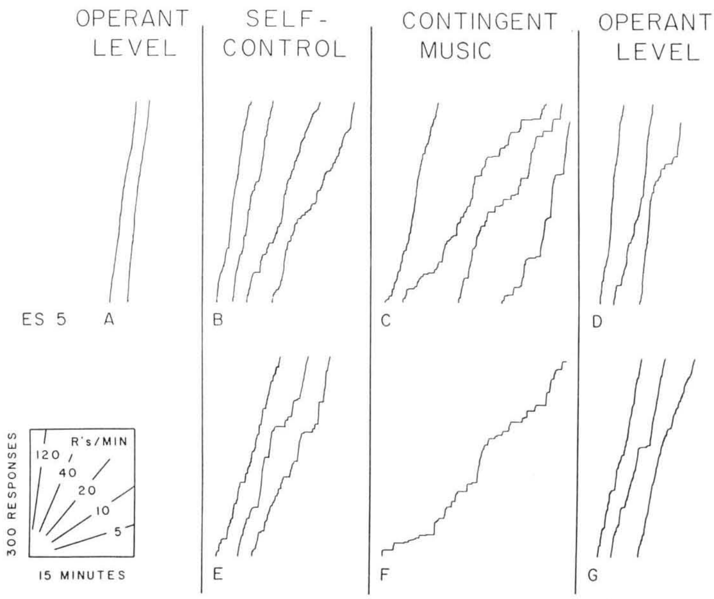

FIG. 3. A continuous cumulative record of the fifth experimental session showing rate changes under sustained self-control compared with the greater reduction under tic-produced interruption of music. The sequence of conditions is indicated by letters.

shown during the B and E periods of self-control may account for the longer tic-free intervals in E than in B. They may also explain the differential response to contingent music in C and F. In other words, it appeared that the patient used two different methods of reducing his tics and that these two methods had different effects on subsequent tic reduction under contingent music. During B, self-control was effected by a generalized rigid contraction which was followed in C by an initial increase in rate despite the availability of contingent music. In contrast, during E self-control was achieved through release methods with the subsequent rapid and marked rate reduction under contingent music (F).

Reliability of the effect of contingent music: The previously described data from six experimental sessions showed that tic-contingent interruption of music reduced the patient's tic rate far more than did non-contingent music, tic-produced white noise, or the patient's efforts at self-control. During those sessions, the patient had approximately six hours' exposure to contingent music. Following a two-month interruption of the experiment, the reliability of the tic-reducing effect of contingent music was subjected to empirical test by a series of replications on the same patient.[11] The result of alternating operant level control periods (7A, 7C, 7E, and 7G; and 8A, 8C, 8E, and 8G) with periods of tic-produced interruption of music (7B, 7D, and 7F; and 8B, 8D, and 8F) are shown in Figure 4. The effect of contingent music on tic-free intervals was dramatically and reliably demonstrated by reductions of from 55 to 85 per cent below the operant rate on each of these six replications.

The tic-reducing effect of contingent music was more immediate and prolonged than in earlier sessions. Tic-free intervals

[11] Both Claude Bernard, in 1865 (2), and Murray Sidman, in 1961 (14), have pointed out that the most convincing test of reliability of an "effect" is the demonstration of its reproducibility in a series of replications.

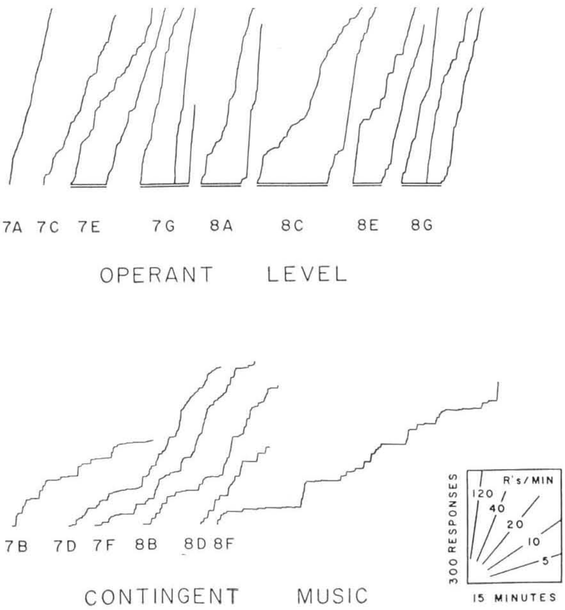

FIG. 4. Records of sessions 7 and 8 demonstrating reproducibility of the marked tic-reducing effect of tic-contingent interruption of music in six replications. Letters designate the sequence of conditions within numbered sessions.

were, for the most part, considerably longer and more frequent than previously, and only brief bursts of tics occurred with high local rate. The patient expressed irritation at the end of session 8 because he had wanted to hear the remainder of a jazz concert being played during 8F (the period with lowest tic rate: nine per minute). He commented that he was concentrating on the musical ideas and became annoyed when his brief bursts of tics interrupted it. During most of the 44-minute 8F period of contingent music he was observed to be almost motionless as he listened to the music.

The pattern of tic-free intervals followed by brief intervals of heightened local rate which developed in response to contingent music appeared to generalize to the operant ticing rate as early as session 4. If this was a true generalization, it may have therapeutic implications. On the other hand, it may simply represent a minor shift of unknown nature in the tic rate. Because of possible operandum unreliability (discussed below), the most valid comparisons should be limited to the differential effects of self-control, non-contingent music, and contingent music relative to the operant tic rate.

Intrasession decrease in operant level rate did appear with regularity during the last two sessions (Figure 4). Operant tic rates 7C, 7E, 8C, and 8E, which were recorded between periods of contingent music, showed somewhat longer tic-free intervals than those recorded at the beginning of these sessions (7A and 8A) or those recorded at the end of these sessions (7G and 8G). The reasons for this decrease are far from clear, but the decrease may have something to do with attention. The patient reported that during these sessions he was anticipating more music and knew he would not hear it if he had many tics.

DISCUSSION

The results of this experiment clearly demonstrate that non-contingent music and tic-contingent white noise reduced the tic rate to a level comparable with that produced by self-control. A far more powerful reduction was produced by tic-contingent interruption of music.

In evaluating the differential control of tic rate shown in these data and the possible extensions of the basic method to other symptoms for either therapeutic or research purposes, the most pertinent consideration is the design of the operandum, the device which permits the symptom to operate a switch (16). Two major requirements of a good operandum are the reliability of its operation and the specificity of the response class which actuates it.[12] The fragile tape arrangement of our crude operandum does not insure reliable operation for continued general application. It is not stable enough to maintain accurate calibration during repeated use. A more stable operandum might have permanently fixed pickups, preferably embedded in upholstery in different areas of a chair.

Although a chair operandum provided a relatively comfortable situation for the patient, it did restrict his motility more than might be desired. Moreover, it was not specific to tic movements alone. A more tic-specific operandum would be operated solely by tic movements. Improved specificity of tic measurement without restrictions on motility might be obtained by pickups placed at the loci of various tics which would be telemetered by transmitters worn on the patient's belt or in a pocket (8). The patient could then engage in routine daily activities while effects of interest are continuously recorded.

Once the operandum requirements have been refined, therapeutic effects can be more reliably evaluated. The use of tic-contingent interruption of music could be extended in time or otherwise modified. For example, the duration of the tic-free interval necessary to produce music could be progressively lengthened. With remote recording, the long term effects of an appropriate contingency arrangement could be evaluated by furnishing the patient with a portable contingency controller to plug into his home radio or television set for relief of his symptom. The contingencies for music and noise, already demonstrated to be effective, could be combined in a multiple contingency whereby each tic would bring 1.5 seconds of noise and pauses greater than 1.5 seconds would bring music, until the next tic impulse simultaneously interrupted the music and restored the white noise.

The observed behavior changes offered as possible explanations for differential tic rates recorded under self-control could be objectively measured to evaluate the interaction between symptomatic and non-symptomatic responses. For example, if operanda had been provided for simultaneously recording the patient's finger-tapping and singing, it might have been possible to show an inverse relationship between the rate of vocalizing and finger-drumming and the tic rate. In addition, experiments could be run to determine whether tic movements may be diminished or even eliminated by differentially reinforcing another more circumscribed and more socially acceptable motor response which serves the same discharge function as tics.

A free operant conditioning analogy to the negative practice technique used by Yates (18) could be readily investigated by positively reinforcing the patient for each tic. If this variation of the method is therapeutic, positive reinforcement of the symptom should be followed by reduction in the operant tic rate.

The general aspects of the pickup and continuous recording system described here provide a method for direct and objective

[12] Ferster (4) has discussed in some detail the general requirements of an accurate operandum (manipulandum). This device, which is manipulated by the subject's behavior, also defines the response being conditioned or attenuated. It is the point of contact between the subject and the automatic recording equipment. For these reasons its operating characteristics are of utmost importance.

behavioral measurement of motor symptom frequency which would be useful in studying the effects of drugs, the influence of attention, and variations in tic rate during diagnostic or therapeutic interviews.

SUMMARY

A method for continuous automatic recording of the rate of multiple tics has been used in a demonstration of differential control of tic rate by free operant conditioning procedures.

The results showed that the multiple tics of a neurological patient, previously refractory to pharmacological and psychological therapies, could be reduced in rate by self-control, by tic-produced white noise, and by continuous music. The most dramatic, rapid, and reliable reduction resulted from tic-produced interruption of music. The power of tic-contingent environmental consequences in controlling this patient's symptom was shown, and suggestions were offered for extending and refining the basic method for more definitive investigations of this and other motor disturbances.

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