MODIFICATION OF ACTIVITY LEVEL THROUGH BIOFEEDBACK AND OPERANT CONDITIONING¹

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The biomotometer, an electronic device that simultaneously measures activity and provides auditory feedback to the subject, was used in combination with material reinforcers in two experiments attempting to modify activity level in children. In the first study the activity level of an 11-year-old highly active boy was decreased below mean baseline during conditioning in a classroom setting. His level of activity returned to baseline when feedback was withdrawn. In the second study, activity level of a 10-year-old hypoactive boy was increased over mean baseline level during conditioning in a free-play setting, and returned to slightly below baseline during five extinction trials. Results of these studies indicate that the biomotometer is a useful instrument for modification of activity level.

DESCRIPTORS: activity level, modification, biofeedback, operant conditioning, children

Considerable attention has been devoted to the development of behavior-modification techniques to reduce disruptive or inappropriate behavior in the classroom (Becker, Madsen, Arnold, and Thomas, 1967; O'Leary and Drabman, 1971; Quay, Werry, McQueen, and Sprague, 1966); frequently focusing on out-of-seat behavior (Pihl, 1967; Twardosz and Sajwaj, 1972), or attention span (Cobb, Ray, and Patterson, 1971; Johnson, 1969; Walken, 1969). It has been suggested (Werry and Sprague, 1970) that these techniques represent a primary, often essential approach to the successful treatment of hyperactivity.

Recently, there have been attempts to compare the efficacy of conditioning techniques with that of stimulant medication in the treatment of hyperactivity, and there is some evidence (Ayllon, Layman, and Kandel, 1975; Christensen, 1975) to suggest that behavioral techniques may

be superior to drug treatment, most likely in the area of improved learning and performance.

In the present study, a new device, the biomotometer was used to count activity and also to provide auditory feedback. A combination of auditory feedback and operant conditioning was used in an effort to decrease activity level in a highly active boy and to increase activity level in a hypoactive boy. Both studies used basic operant designs involving baseline, conditioning, and return-to-baseline conditions, with each subject serving as own control.

Apparatus

The biomotometer, the instrument used for measuring and modifying activity level in the present study, has been described in detail in a previous study, in which it was found to provide a reliable and valid measure of activity level (Schulman, Stevens, and Kupst, *in press*). Briefly, the instrument consists of a small plastic box (8.2 by 5.3 by 2.8 cm; weight three ounces) worn at the waist; the box contains an electronic package that measures activity by angular displacement of mercury switches. Activity counts stored within the unit are tabulated through a

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separate readout box unit and digital display counter. During modification, the subject is able to monitor his/her own activity level by means of a crystal earphone connected to an adjustable audio feedback circuit inside the apparatus. Thus, each time the subject exceeds a designated number of activity counts during a preset time interval, a feedback tone signal (a "beep") is delivered through the earphone. An adjustable volume control allows the setting of the feedback signal within a range audible to the subject, but not loud enough to be startling or painful.

Immediately after an excessive activity count is registered and a beep produced, a new time interval begins; thus, an active subject receives frequent feedback at relatively short intervals.

Behavioral correlates of activity counts depend somewhat on the setting of the measurement. Observational estimates of classroom behavior indicate that certain gross motor behaviors register counts within a well-defined range. For example, a reading of 500 counts per hour is well within the range of a well-behaved child during normal classroom activity. This reading would almost preclude any quick or prolonged out-of-seat movement. A reading of 700 per hour would allow for some movement, but if the child were out of the seat for more than 15 min in that hour, the count would probably rise above 700. This can be compared to a reading of 1000 to 1400 counts if the child were to follow the teacher about the classroom for most of an hour's time.

More specific motor behaviors have been examined in terms of activity counts. These counts depend on the duration (some behaviors typically last longer) and quality (gross *versus* fine motor movements). For example, sitting quietly in a classroom will give a very low count, around 20 per 5 min, fidgeting (gross movements) 40 counts per 5 min, and squirming in the seat 60 to 70 counts per 5 min. For 5 min of crawling about the floor, the count would be approximately 100. Activity counts for running also depend on duration: a child running for 30 sec will accumulate approximately 40 counts. Per-

sistent running, therefore, raises the overall count considerably.

In sum, rapid, accelerating or decelerating movements will trigger a count, and, depending on the duration of the behavior, the count will continue to rise or to stabilize. Exaggerated slow movements tend to keep the count low. In a 5-min period, active behavior will register as very high (50 to 200 counts) and inactive behavior will count low (0 to 50 counts). If a child is consistently "hyperactive" for an hour (excluding verbal or very fine movement) the count will be high. A "hypoactive" child, on the other hand, can remain relatively inactive, but in a 5-min period, receive a count as high as 150 to 200.

Besides its reliability of measurement, the biomotometer appears to be mechanically reliable. In general, children do not tend to remove the box. It is easy to attach, and is in a natural, unexposed position; adaptation occurs quite rapidly to the box, but adaptation to the earpiece takes somewhat longer.

In the modifying phase of the present study, the feedback/time ratio was adjusted to provide the maximum number of feedback "beeps" within the capacity of the two biomotometer units used. For Subject 1, the biomotometer was set to deliver one beep if three activity counts were registered in a 15.8-sec interval. For Subject 2, the biomotometer delivered one beep if three counts were registered in a 20.7-sec interval.

EXPERIMENT I: DECREASING ACTIVITY LEVEL

Subject 1

Subject 1 was an 11-yr-old boy who was admitted to the Day Hospital program of Children's Memorial Hospital three months before the study. He was referred by the public school he attended, and was described as highly active with a short attention span. Major presenting problems included acting silly, seeking attention inappropriately, and frequent aggressive outbursts. Diagnostic evaluations by Day Hospital staff noted an unsocialized and aggressive behav-

ior disorder, with a specific learning disability in perceptual motor functioning.

Reports from Day Hospital staff and informal observations before the study indicated that he tended to be quite active in the Day Hospital classroom, with frequent fidgeting, out of seat behavior, and talking to other children. Thus, it was agreed that he would be an appropriate subject for an experiment attempting to decrease activity level. He did not receive any medication during the study.

Procedure

All trials with Subject 1 were conducted under actual classroom conditions at the Day Hospital program. There were generally several other children present in the room, and the class was staffed by a combination of teachers, child-care workers, and volunteers. Measurement intervals were from the start to completion of the subject's daily classroom assignments, and hence varied from 30 to 60 min. After discarding an initial trial for adaptation to the apparatus, five trials were conducted in each of the following three conditions:

Baseline. Before the first baseline trial, Subject 1 received the following instructions: "This is a study of energy and movement. This box (the biomotometer without the earphone) measures how much energy you use when you move around. (The term "activity" was avoided in the explanation so as to remove the experiment from any association with connotations of "hyperactivity".) After you wear this box for several sessions, you will get a chance to earn rewards. You will need to wear the box each day until your classwork is done."

Conditioning. A criterion for reward was established by subtracting 20% from the subject's mean baseline activity. He was rewarded on all trials in which activity fell below criterion. The instructions from the conditioning phase of Experiment I were modified to reflect the purpose of the conditioning, to decrease activity. Thus, the subject was told: "When you hear a beep, that means you are moving around too much.

The fewer beeps you hear, the better chance you will have to earn a reward. If you hear too many beeps, you will not get a reward." Ten 30-min sessions were used to modify activity level. If the subject's count went below criterion, immediately afterward he was permitted to choose from a variety of toys, games, and candy rewards. In order to maintain a high rate of activity, the subject was not informed of the criterion number, nor of the number of beeps he would need to hear in order to get a reward.

Return to baseline. To assure the subject's continued cooperation in the experiment after conditioning, a reward contingency was maintained after feedback was withdrawn. Before the return to baseline trials began, the subject was given the following instructions: "For the next few sessions, you will wear the box without the earphone. You will still have a chance to earn rewards. All you have to do to earn a reward is to wear the box for the whole session. You will earn a reward for wearing the box and not for getting any number of beeps." Thus, no instructions were given to the subject concerning increasing his activity level during these trials.

It was decided in advance that return to baseline would proceed for a minimum of five trials, after which the experiment would be terminated if a return to mean activity level before conditioning was observed. As shown in Figure 1, the five trials indicated that activity level had returned to or above baseline level.

RESULTS

Due to the variable measurement intervals used in Experiment I, activity counts were standardized by conversion to a counts-per-hour rate measure. Figure 1 depicts activity counts per hour for Subject 1 across 15 trials.

As seen in the figure, the subject successfully lowered his activity level below criterion during the conditioning phase and was rewarded after all five trials. Mean baseline rate was 715 counts per hour (standard deviation = 157). Criterion for reward during conditioning was set at 572 counts per hour, 20% below the subject's mean

Fig. 1. Activity rate for Subject 1 in free-play in baseline, conditioning, and extinction conditions.

baseline activity rate. He remained well below criterion on all five conditioning trials (mean = 383; standard deviation = 75). He received a mean of 96 feedback beeps per trial during conditioning. Activity level rose sharply during the return-to-baseline condition (mean = 710; standard deviation = 212), with performance comparable to the original baseline condition. With the exception of the third conditioning trial (509 counts per hour) activity level under feedback and reward remained consistently below all of the pre- and postconditioning trials.

Informal observations of this subject during conditioning noted a decrease in out-of-seat behavior. Several favorable comments from teachers concerning his improved behavior were also reported. He seemed keenly aware of the auditory feedback and reinforcement contingency. At the end of the classroom hour, he frequently

commented to the examiner about his performance, *e.g.*, "I heard only a few beeps today." It is also notable that he showed a consistently high level of activity in the absence of feedback and reward, a finding consistent with results of a previous study on the stability of activity level [Schulman, Suran, Kupst, and Stevens (*in press*)].

EXPERIMENT II: INCREASING ACTIVITY LEVEL

Subject 2

Subject 2 was a 10-yr-old boy admitted to the inpatient psychiatric unit of Children's Memorial Hospital five months before the study. Chief presenting complaints were repeated runaway episodes and failure to do school work. Psychological evaluation following admission indicated a

borderline psychotic condition of probable insidious onset. Severely impaired reality testing and heavy reliance on autistic fantasy as a primary defense were noted.

In addition, behavioral observations by inpatient staff indicated that the subject was frequently passive and lethargic, often withdrawing completely from unpleasant situations. Motor coordination was considered underdeveloped, and speech and articulation were extremely slow and deliberate. Since many of the staff felt that the subject's hypoactivity and slow speech were both manipulative and maladaptive, it was decided that an experimental procedure designed to increase his activity level would be an appropriate intervention.

During the baseline and the first eight trials of the conditioning phase of the experiment, the subject received a dosage of 50 milligrams of chlorpromazine three times daily. For the remainder of the experiment, the subject received 75 milligrams of chlorpromazine three times daily. Medication was increased independently of the progress of the experiment; the subject's physician was unaware of the results, and indicated that the increase was necessary due to the subject's anxiety surrounding an upcoming week-end pass.

Procedure

Since it was not feasible to select a particular situation occurring consistently within the subject's daily routine, during which a conditioning procedure to increase activity level could be implemented, an experimental setting was devised. Subject 1 wore the biotometer in a series of daily 30-min sessions in a classroom converted to a playroom setting. There were several desks and chairs in the room, a blackboard on one wall, and books and other academic materials accessible on shelves. Before each session, the subject was permitted to choose a variety of toys available in nearby storerooms to play with during the sessions. In addition, a large box, containing toy cars, guns, and a target set with rubber-tipped darts, was placed in the room before

each session. To control as much as possible for the effects of previous activities during the day, the sessions were held at the same time each afternoon, following the subject's scheduled rest period. The examiner sat in one corner of the room throughout the experiment. He did not play with the subject, and did not initiate verbal interaction. When approached verbally, he responded briefly in a reflective, nondirective manner.

Baseline. After familiarizing the subject with the apparatus, he was given initial instructions similar to those given to Subject 1 in the first experiment, with the exception of the last sentence, which was changed to read: "During the next half hour, you may do whatever you like."

Conditioning. After examining the baseline data (Figure 2), an arbitrary criterion of 600 activity counts per trial was established as the number necessary for the subject to be rewarded at the end of each conditioning trial. This number was considered to represent a considerable increase over mean baseline activity level, and an increment above the highest activity attained during any single baseline trial (527 counts).

Before the conditioning trials, the biotometer with the earphone was again demonstrated to the subject. He was given the following instructions: "For the next ten sessions, the purpose of our energy study is to help you use more energy by moving around more. You will be wearing the box with the earphone. When you hear a beep, that means you are doing a good job of moving around and using energy. The more beeps you hear, the more energy you are using. If you use enough energy by moving around, you will get to choose a special reward at the end of the session. If you do not use enough energy, you will not receive a reward. Remember that in order to have a chance to earn a reward, you must wear the box and the earphone for the whole session." As in the first experiment, candy and toy reinforcers were given immediately after the session, and the subject was not informed of the exact criterion of his reward.

Fig. 2. Activity rate for Subject 2 in classroom in baseline, conditioning, and extinction conditions.

RESULTS

Figure 2 depicts the total activity counts obtained during each of the 25 trials conducted in Experiment II. During 10 baseline trials wearing the biometer without auditory feedback, Subject 2 scored a mean of 382 activity counts (standard deviation = 98). For the 10 conditioning trials with feedback and reinforcement, mean activity rose to 641 (standard deviation = 153). The subject received a mean of 196 feedback signals per trial during the conditioning phase. As shown in Figure 2, Subject 2 exceeded the reward criterion in six of 10 trials. In addition, all of the four trials in which he failed to meet criterion exceeded the mean baseline activity.

It appears that the increase in the subject's medication after Trial 8 of the conditioning

phase had no consistent effect. Activity level on Trial 9 fell below criterion, but on the following trial, the subject totalled 801 activity counts, second highest of the 10 trials. In the return-to-baseline condition, activity level decreased sharply for the first four trials, but rose above the mean baseline on the final trial. Mean activity for return to baseline was 273 (standard deviation = 161), lower than the original baseline rate.

In short, the results show that the combination of feedback and reward was effective in raising activity level above mean baseline level, but that the effects of the experimental manipulation did not generalize during the extinction phase. This conclusion is supported by informal observations of subject's behavior during the sessions. On the final trial of the conditioning phase, the

subject walked back and forth across the room, counting aloud to keep track of the feedback beeps he received. He stopped after counting 200 beeps, indicating to the examiner that he thought this would be enough to earn a reward. In contrast, in Trial 3 of the return-to-baseline condition, the subject announced at the beginning of the session that he did not feel like doing anything that day, and promptly stretched out on a table and slept for the entire session. These observations would seem to indicate that on certain occasions, the subject was very attentive to the experimental contingencies, and responded accordingly.

It should be noted that the number of activity counts desirable during a 1-hr classroom session is lower than the number expected during a 0.5-hr free-play session. Also, the difference in rate and total measures should be kept in mind when comparing results obtained with an active subject in a classroom setting with a hypoactive subject in free play.

DISCUSSION

The present results are consistent with the growing body of literature that indicates that activity level can be modified successfully through the use of various environmental contingencies. From these experiments, it appears that the combination of feedback and reinforcement provides a simple and effective means for both increasing and decreasing activity level. It must be pointed out, however, that the most effective contingency is not yet known. A further step must be taken to differentiate the effects of auditory feedback alone, material reward alone, auditory feedback plus material reward, and baseline with instructions. Currently, our activity research has expanded to a public-school setting, where, as part of this research, experiments have been planned to test for these effects, as well as for long-term effects of reinforcement.

The biotometer appears to have several advantages for use in a clinical or applied set-

ting. Since it monitors free-ranging as well as sedentary movements, it can be used in a number of varied settings. As such, it may help to avoid some of the difficulties inherent in generalizing from a laboratory study of activity level. Also, the feedback that allows the child to monitor his/her own behavior seems a desirable step toward self-control. In addition, the adjustable feedback count/time-interval ratio of the biotometer permits the study of a range of reinforcement paradigms and contingencies that may be tailored easily to suit the needs of the individual subject.

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