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Chapter 8

Operant Conditioning Methods in Diagnosis*

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The major scientific problem facing psychiatry today is diagnosis and evaluation. Psychiatry is the only branch of medicine which does not have diagnostic laboratories reporting their results in the dimensions of natural science. There is no lack of motivation regarding therapy. There is no lack of therapeutic theory and study material. There is, however, an almost total lack of sound, reliable, and valid laboratory techniques for evaluating therapeutic methods. In most cases, our diagnoses are little more than legal justification for hospitalization. Diagnosis makes scant medical sense unless it is reliable and can be used to select and predict the effects of different methods of treatment.

The goal of the research described in this chapter is to provide psychiatry with culture-free, automatic, laboratory measures of the behavioral excesses and deficiencies which characterize the psychoses. The strategy is to accomplish this goal by clinically relevant adaptations of the method of free-operant conditioning. The direct measurement and continuous, automatic recording of the behavior of single individuals in carefully controlled experimental environments have made the method of free-operant conditioning one of the most powerful for the experimental analysis of behavior.[16] The details of this method and its advantages for the measurement of behavioral pathology have been previously described.[10, 12] Therefore, this chapter only summarizes the psychiatric diagnostic devices developed to date.

These devices fall into three general classes. First are *nonspecific measures* which indicate the severity of the behavioral pathology but not its specific nature. These nonspecific measures are roughly analogous to measures such as elevated oral temperature in physiological illness. Second are *specific deficiencies* which involve much narrower ranges of behavior than do the nonspecific measures and suggest sub-types of psychosis which might differentially respond to different forms of therapy. An analogy in physiological medicine is the absence of a certain type of body cellular function (*e.g.*, insulin or thyroid deficiency). Third is *specifically emergent behavior pathology* which indicates the presence of a sub-type of psychosis. An example in physiological medicine would

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be the presence in the diseased individual of invading organisms not found in the healthy person. The emergent indicators of disease are much easier to deal with scientifically. The history of medicine shows us that a decade or two after the isolation of an emergent disease indicator, a specific therapy usually appears.

The other outstanding strategic gain shown in the history of physiological medicine is the successful experimental production of a disease within the laboratory. Usually, twenty or thirty years after the successful laboratory production of a specific disease, an efficient therapy is discovered. For this reason, laboratory production of the psychoses in lower animals or, if that is not possible, reversible production of psychosis in humans, is of paramount importance. However, the laboratory production of psychosis must wait until it is clearly defined and measured in its native state so that one may be sure of producing the same disease and not a mere topographical pun.

NONSPECIFIC FREE-OPERANT MEASURES

Figure 1 shows the inside of an experimental room containing our simplest apparatus for recording free-operant responses. The patient sits before a sloping panel on which is mounted a plunger which requires 300 grams of force to pull and which can respond to rates as high as 20,000 responses per hour. The small tray to the right of this plunger receives small objects which are used as rewards, or reinforcement, for the pulling of the plunger. The tray is illuminated and the room darkened briefly when a reinforcement is presented. The reinforcing circuit is primed on the average once every minute, so that opportunities to be reinforced are unpredictably presented from 0.25 to 2.25 minutes apart. Since reinforcement opportunities are not predictable, normal organisms respond at even rates on this schedule of reinforcement[6].

When severely psychotic patients are reinforced with small pieces of candy in this fashion, they do not pull the plunger at even rates, but pause frequently. During these pauses patients with easily observable symptoms display them. Brief psychotic incidents and longer psychotic episodes lasting for 30 minutes to an hour are easily recorded and measured as interruptions in the rate of plunger pulling[12].

Five to 10 per cent of chronic psychotics show marked rhythms in their rate of response, *i.e.*, their ability to manipulate the environment. During periods of weeks or months in which they pull the plunger at low rates, these patients are in more severely psychotic phases and are apt to be more untidy, destructive, assaultive, or hallucinatory. The patients showing these cycloid psychoses are classified among the nonsystematic schizophrenias according to Leonhard's classification[7, 9]. In figure 2 the median number of plunger pulls (responses) for the first 10 hours on a 1-minute variable-interval schedule of reinforcement is summarized for five classes of subjects. Note that the reinforcer used with each class of subject must be appropriate to the species and its current deprivation level. Note also that the dogs, normal persons currently not hospitalized for psychosis, and psychotic children all responded at rates above 100 responses per hour and that the chronic psychotic adults were much less responsive than the senile psychotics.

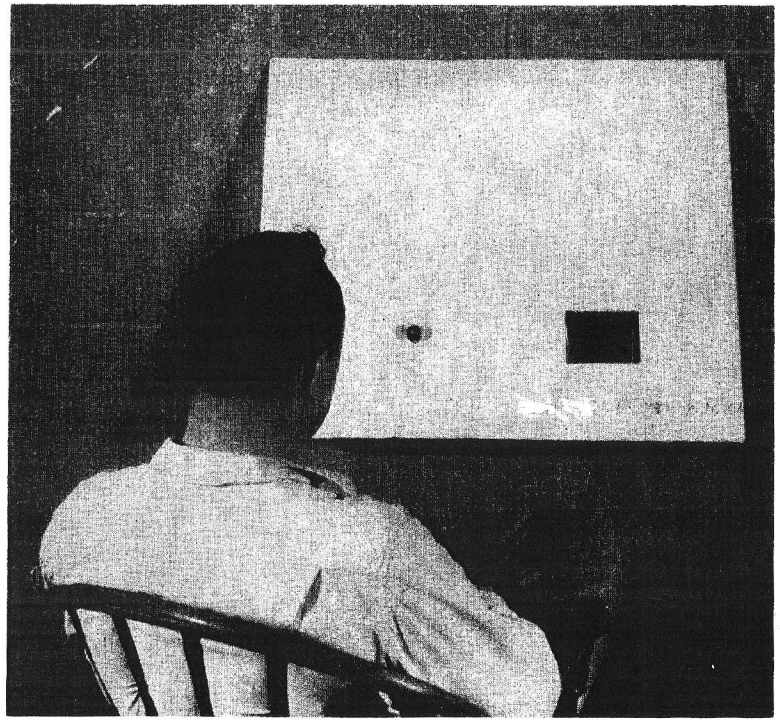

Fig. 1. Experimental room with plunger for free-operant responding and reinforcer dispenser.

There are two problems in measuring the severity of a psychosis by determining the extent to which it interferes with a simple adjustive free-operant response. (1) One must be sure that an *appropriate reinforcer* is used. For example, the low rate of operant response by acute psychotics reported by King, Merrell, Lovinger, and Denny[8] was undoubtedly due to the use of candy as a reinforcer. Although candy is an appropriate reinforcer for chronic psychotics, money (nickels) is a more appropriate reinforcer than candy for acute psychotics. Therefore, if we wish to evaluate the behavior of a patient moving from severe to less severe psychosis and, finally, to discharge, we must change the nature of the reinforcing stimulus as the patient becomes less severely psychotic. (This was done with the patient whose data are shown in figure 3). (2) Since rate of response may be greatly reduced by *physiological illness,* one must be careful to rule out physiological illness when using these nonspecific measures of psychosis. For this reason, in our laboratory we measure oral temperature, pulse, diastolic and systolic blood pressure, and body weight and have our nurse do a brief physical examination of each patient before each daily experimental session. We also conduct regular blood and urine examinations to screen for the presence of systemic disease. It is obvious that a patient with ulcerated gums and dental caries will not respond at a high rate for candy reinforcement!

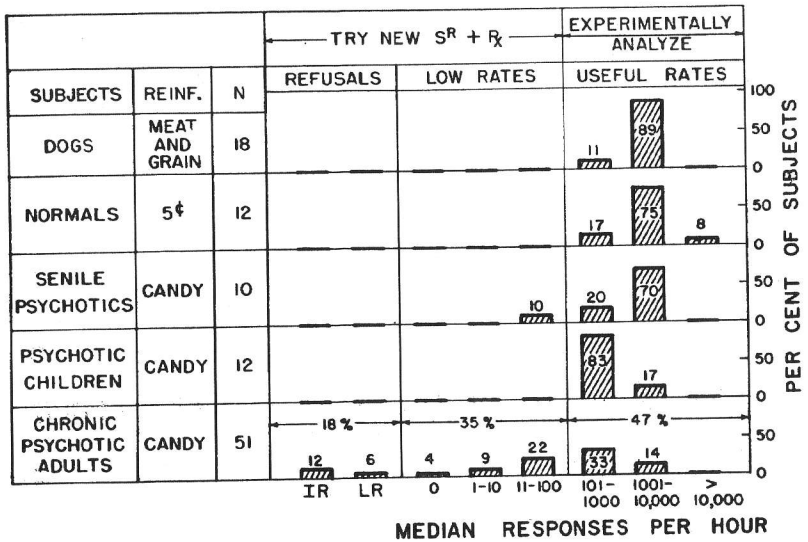

Fig. 2. Frequency distributions of median responses per hour of five classes of subjects for first 10 hours on a 1-minute variable-interval schedule of reinforcement.

These free-operant nonspecific measures of psychosis are more sensitive than other nonspecific measures (*e.g.*, the pursuit rotor, wiggley-block test), because of the high environmental control and continuous and automatic recording. However, these measures are still quite primitive because they indicate the *presence* of disease by the *absence* of behavior which can also be lost through other disease or by inappropriate reinforcement.

Data from an acutely and severely psychotic young woman throughout her recovery and up to the day of discharge are plotted in figure 3. For treatment she received four different tranquilizers, electroshock therapy at the points marked "X", and insulin coma therapy shown by the number of units of crystalline insulin and the number of minutes the patient was in coma each day. Her diastolic and systolic blood pressure and body weight, taken in our laboratory before each experimental session, are also plotted. At the beginning of her treatment she was so severely psychotic that she could not stay for an hour in the experimental room with the door closed. Since this inability to stay within the experimental enclosure also indicates severe psychosis, it is plotted on the graph. The ΣIRT indicates the total number of pauses greater than 10 seconds after each response during a 1-hour experimental session. Prior to her recovery this patient was spending most of the hour without responding. Up to the fortieth experimental session she was reinforced with candy on a 1-minute variable-interval schedule. After that the reinforcement was changed to nickels on the same schedule. The "H's" at the top of the graph indicate times that she went home for weekend visits. Note that her rate of response rose to the unhospitalized range more than 6 weeks before her discharge.

From this graph we do not know whether this patient recovered

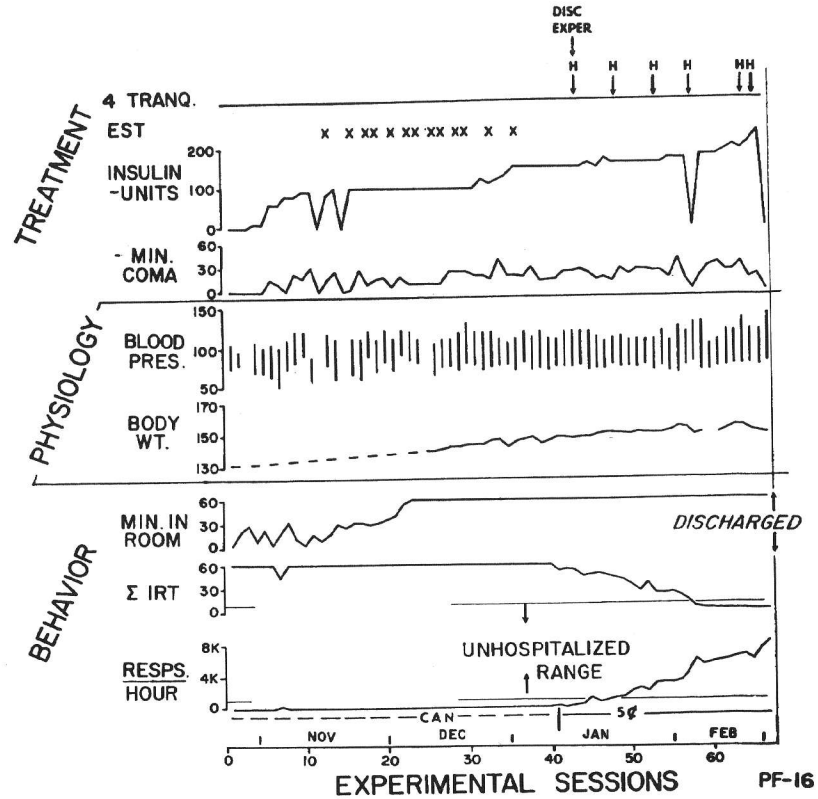

Fig. 3. Daily evaluations of recovery of an acutely psychotic woman receiving various kinds of treatment, up to day of discharge.

spontaneously or as a result of electroshock coma, insulin coma, one of the four tranquilizers, the various types of psychotherapy administered in the admissions unit at that time, or some combination of these. The graph does show, however, that the nonspecific free-operant response rate provides a useful quantification of the severity of a psychosis and can be used to monitor and predict recovery.

SPECIFICALLY DEFICIENT FREE-OPERANT MEASURES

Slightly more complicated modifications of the free-operant technique can be used to screen for specific rather than general behavioral deficiencies. These specific behavioral deficiencies more narrowly define the nature of the behavioral disturbance in a given patient. To date we have developed devices which screen for specific deficiencies in motivation, in discriminative ability, and in social behavior.

By using a different and more specific reinforcing stimulus, *specific motivational deficiencies* can be detected. For example, Kodachrome slides can be projected on the back of a translucent screen on the wall of

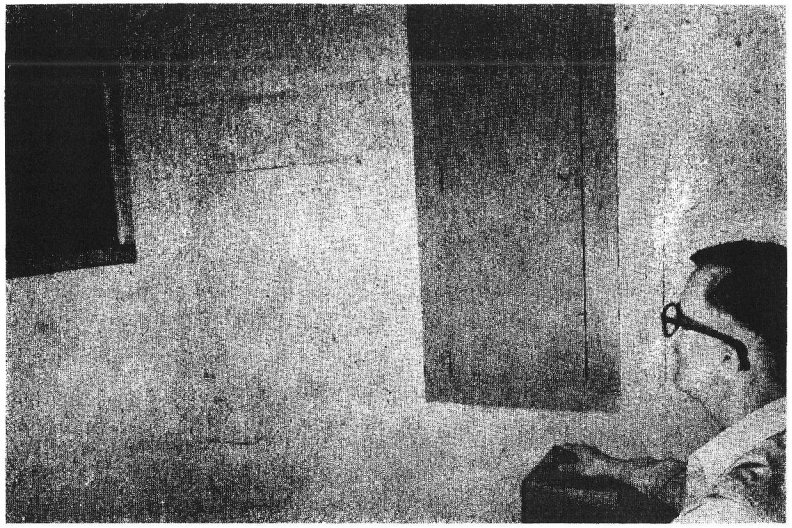

Fig. 4. Experimental room for presenting visual stimuli as reinforcers.

an experimental room. Different visual themes can be presented as 5-second episodes of reinforcement. Travel pictures, religious pictures, animal pictures, female nude pictures, and male nude pictures have thus been used as reinforcers. The experimental room used for this purpose is shown in figure 4.

In figure 5, an apparatus for presenting a social reinforcer is shown. The patient's plunger pulling is reinforced by the opportunity to observe a hungry kitten drink milk from a dipper which is presented to the kitten contingent upon the patient's plunger pulling. This device experimentally measures the desire to succor or the charity the patient has for the kitten.

Figure 6 contains motivational profiles of 5 chronic psychotic male adults. The median number of responses per hour for the first 10 hours on a 1-minute variable-interval schedule of reinforcement for 5 different reinforcers is plotted for each patient. The line across the graph at 800 responses per hour represents the lowest rate of response recorded during any session with 12 non-hospitalized normals responding for nickels. "EXT" shows the rate of response for 10 sessions without any reinforcement (extinction). "FK" represents the rates to feed the kitten; "5¢" marks the rates for nickels; "FN", the rates for female nude pictures; "MN", the rates for male nude pictures, and "CAN", the rates for candy. All 5 patients responded at low rates for female nude pictures (FN). Two of these patients (P20 and P35) responded at significantly higher rates for male nudes (MN), showing a homosexual pictorial interest. Both of these patients have been observed engaging in homosexual practices within the hospital. These motivational profiles indicate how the simple free-operant technique can be used with several different reinforcing stimuli in order to differentially determine a patient's interest, motivation, or needs.

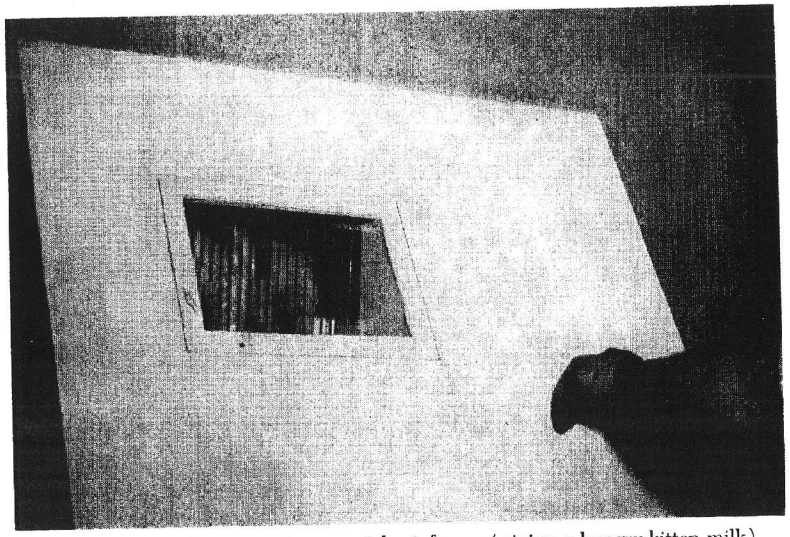

Fig. 5. Device for presenting a social reinforcer (giving a hungry kitten milk).

A device for diagnosing *specific deficits in discrimination* is shown in figure 7. Two plungers which can be pulled separately or simultaneously and two lights are mounted on the panel. There are two different stimulus configurations: the right light on for 1 minute, as shown in the figure, and the left light on for 1 minute immediately following. These configurations alternate throughout the experimental session. With two stimulus configurations and two available responses, there are four possible reflexes. If only one reflex (pulling the left plunger with the left light on) is reinforced, then discrimination (telling the lights apart) and differentiation (telling the responses apart) can be separately and simultaneously measured. For example, if a patient eventually learns to pull the left plunger only when the left light is on, does not pull the right plunger at all, and does not pull the left plunger with the right light on, then he must obviously have discriminated the lights and differentiated the plungers. This would show that he is capable of both discrimination and differentiation at the time of measurement. However, if the patient pulls both plungers undifferentially only when the left light is on and does not pull either plunger when the right light is on, he has discriminated the lights but not differentiated the plungers. If he learns to pull only the left plunger regardless of which light is on, he has not formed a discrimination of the lights but has formed a response differentiation.

Normal adults form the discrimination and differentiation very rapidly in this situation. However, with chronic psychotic adults who have previously responded at useful rates on a single plunger (thus showing that their psychosis was not severe enough to interfere with simple responsivity and that an appropriate reinforcer was being used) the following results were obtained. Out of 15 patients, 4 (27 per cent) who responded above 100 responses per hour on a single plunger stopped responding when faced with this complicated task. Five (34 per cent) responded at high rates on all four reflexes. Two (13 per cent) formed

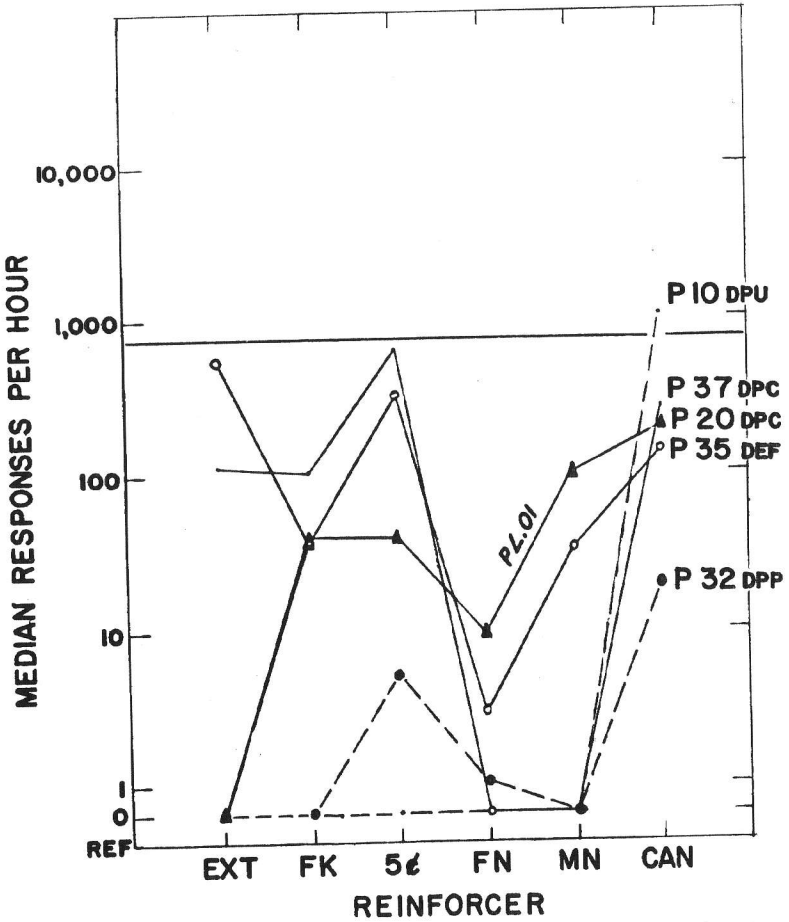

Fig. 6. Median responses per hour of 5 chronic psychotics during first 10 hours on a 1-minute variable-interval schedule for 5 reinforcers.

the differentiation but not the discrimination. Another two (13 per cent) formed both the differentiation and discrimination but had perfect performance limited because what they learned was to pull the plunger under the light, even though it was only the plunger under the left light which was reinforced. Their performance was limited by excessive reflex generalization with extremely poor reality testing. Two patients (13 per cent) acquired the differentiation and discrimination without limitation by excessive generalization as did all the normal adult subjects.[11] The patients with differentiation deficits tended to be the most severely psychotic. Many also had mental retardation or senile psychosis. Two patients who showed excessive generalization and lack of reality testing were extremely paranoid. Clearly, this device for measuring discrimination and differentiation has great potential for use in the direct behavioral diagnosis and analysis of mental retardation and senility.

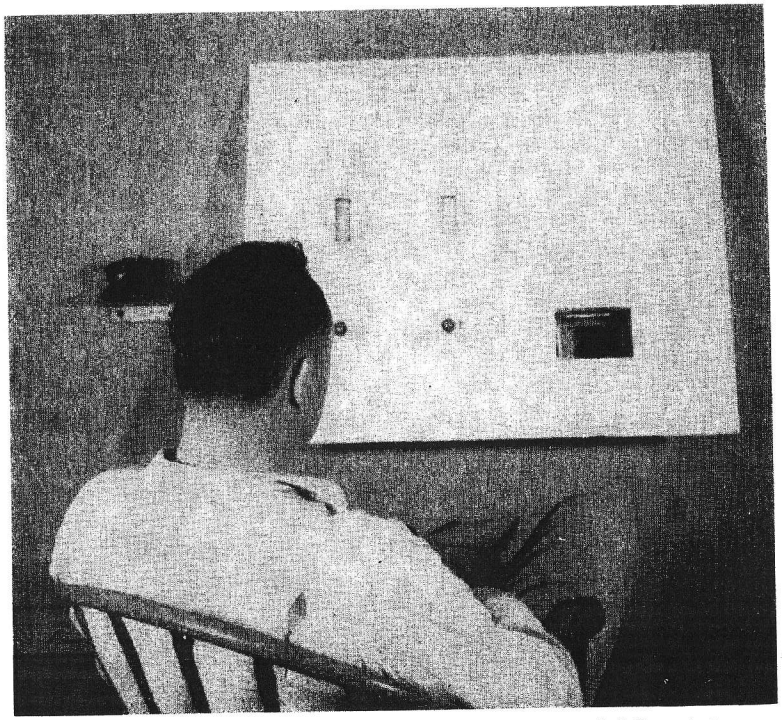

Fig. 7. Device for diagnosing deficits in discrimination and differentiation.

By placing two patients in adjoining rooms connected by a window, we can determine *deficits in social behavior.* In a cooperative situation, both patients must pull their plungers and both are reinforced. When patient A pulls his plunger and patient B follows within ½ second, reinforcers (pennies) are dispensed into both rooms. The same thing happens when B pulls first and A follows within ½ second. In order to produce and measure competition, we require both patients to pull their plungers but reinforce only one of them. If A and B pull their plungers within ½ second of each other, the follower receives the reinforcement. If, however, A manages to "catch B asleep" (*i.e.*, B pulls his plunger after ½ second has passed), A receives the reinforcement. B would be similarly reinforced for "catching A off-guard". By differential reinforcement of these leader-follower relationships we can determine specific deficits in both cooperation and competition, as well as in leadership displayed in these social situations.[1, 13]

SPECIFICALLY EMERGENT FREE-OPERANT MEASURES

To date we have measured three different types of emergent properties of psychosis. The first, described above in the section on discrimination, is *excessive generalization,* a reflex pattern emitted by certain psy-

chotics and not found in normal adult subjects. The second is the emission of *vocal hallucinatory responses*. The third is highly stereotyped *hypermotilic* responses so often observed in excited catatonics (pacing, rocking, etc.). The construction of devices which automatically record these two psychotic symptoms permits their direct measurement and the determination of the relationship between these symptomatic responses and the nonsymptomatic or normal plunger-pulling free-operant responses.

In figure 8 a schematic diagram of the apparatus for simultaneously recording both vocal responses and plunger pulling responses is presented. The plunger pulls are recorded in the usual way through a response definer, which converts a pull on the plunger to an impulse in order to eliminate "lever holding" responses. These impulses are then conducted to a cumulative response recorder, where each impulse raises the pen a small step up the recording paper which moves continuously in time. After 500 responses have been made, the pen is reset to the bottom of the paper where it is ready to record another excursion. The presentation of a reinforcing stimulus is marked on the cumulative response record by a movement of the pen diagonally downwards to the right. Hidden behind a perforated metal screen at the ceiling of the experimental enclosure is a microphone. The output of this microphone feeds into a voice key with adjustable frequency and intensity filters. This voice key is operated by bursts of sound above prespecified intensities and within the human voice range. The output of the voice key is in impulses, so that sustained sound does not continuously record. The voice key impulses are correlated most closely with grammatical stresses. Therefore, this output is closely related to frequency of speech within the experimental room. The vocal responses are recorded on a cumulative response recorder, as are manual plunger pulls.

Using this appartus, we have found that hallucinogenic vocal responding of psychotics strongly competes with concomitant reinforced manual responding. However, drug-induced vocal hallucinatory responding in normals does not compete with their reinforced manual responding.[14] The severity of the hallucinosis is indicated not only by the frequency and duration of vocal output, but more importantly by the amount of suppression of the simultaneously recorded reinforced manual responding. The more attention a patient pays to his vocal responses and the less he is able to manipulate the environment for reinforcement, the more severe is the psychotic hallucinosis. The development of this technique for recording vocal output permits fully automatic and objective screening of individuals for the presence of psychotic auditory hallucinosis. After such hallucinators are selected, the technique can be used for screening hallucinogenic and anti-hallucinatory drugs. This measure has high clinical relevance because it is useful not only for drug screening, but also for psychiatric evaluation. It has face validity, for the criteria used by the psychiatrist in determining the presence of hallucinations are here put to laboratory use. We have merely automated and objectively recorded the easiest and most dramatic criteria that the psychiatrist applies in his diagnosis of hallucinosis. This automation and objective recording raises the diagnosis of a subgroup of hallucinators to the level of laboratory science. Hallucinosis of this type can now be

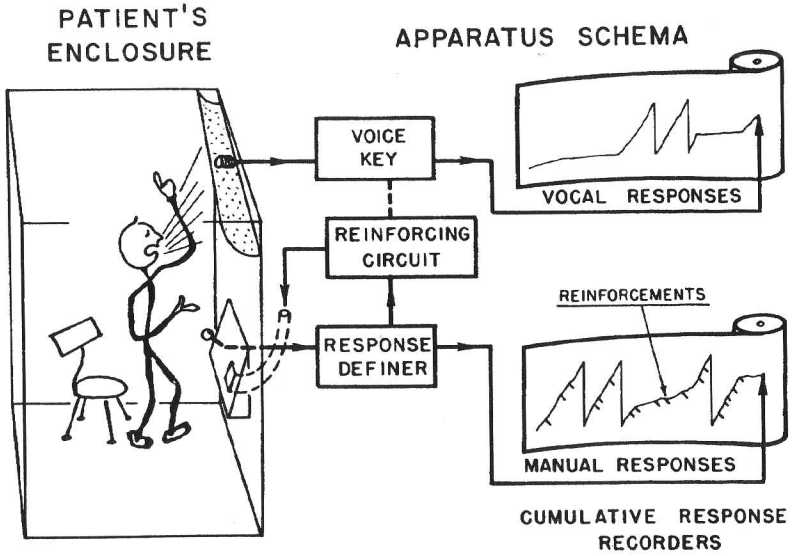

Fig. 8. Schema of apparatus for simultaneous recording of vocal output and plunger pulling responses.

accurately evaluated by technicians operating standard laboratory apparatus.

In a similar way, we have recently constructed a device consisting of pressure sensitive mats on the floor of an experimental room, which record a patient's pattern of movement about the room. By summating the operation of these mats, the frequency of responses can be recorded on a cumulative response recorder. Since this device was put in operation only recently, we can not report definitive data at this time. However, our first records have shown that the pacing symptoms do not suppress the manual adjustive responses. On the contrary, as was not the case with the vocal symptomatic responses, the pacing responses occur at their highest frequency at the same moments that the manual responses are occurring at their highest frequencies. This result surprised us and reversed a conclusion we had drawn from nine years of daily visual observation, *viz.*, that pacing competed with lever pulling as did vocal hallucinatory activity. The reversal of our conclusion based upon visual observation shows dramatically the value of automatic apparatus for measuring patients' behavior.

CORRELATIONS OF FREE-OPERANT WITH OTHER DIAGNOSTIC MEASURES

The nonspecific free-operant measures correlate highly with ability to work in hospital industry, with ward assignment, and with hospital management criteria. These nonspecific measures also correlate with some of the more descriptive rating scales, such as the Lucero-Meyer

Behavior Scale, the Tulane Behavior Scale, and the Hospital Adjustment Scale.[10, 12, 15] However, these rating scales rapidly lose their sensitivity if used repeatedly at a frequency of about once a week. The ratings after repeated administration appear to be more a function of the previous ratings than of the patient's current behavior. Others have found significant correlations between the nonspecific free-operant measures and standard rating devices.[3, 4, 5, 8] These nonspecific free-operant measures do not correlate with differential psychiatric diagnoses. They indicate the general severity of psychosis but do not indicate the specific sub-types.

The specific free-operant measures correlate fairly well with most descriptive classification systems. The best correlations appear to be found with the classification system of Leonhard.[7, 9] It appears that this system, with 3 major groupings and 27 sub-types, is more descriptive and hence correlates more closely with objective measurement than the more interpretive and dynamic classification systems that are currently more popular in America.

LIMITATIONS OF EARLIER DIAGNOSTIC METHODS OVERCOME BY FREE-OPERANT MEASURES

Psychiatric evaluations, although the most inclusive and most clinically relevant of earlier methods, contain a maximum of observer bias and of lack of objectivity. Such evaluations are extremely wasteful of valuable psychiatric time which could be much more efficiently spent in evaluating the results of laboratory tests and selecting, prescribing, and conducting therapy.

Psychological tests, although less inclusive and less clinically relevant than psychiatric evaluations, in most cases suffer from the same problems of observer bias. The tester is in the same social situation with the patient, presents the discriminative and reinforcing stimuli, and records the data. Furthermore, in the case of chronic psychotic patients, from 20 to 50 per cent are untestable, depending upon the patience and skill of the psychologist.

Rating scales, even though they can include the total population of chronic psychotics, suffer from the same problems of observer bias as do psychological tests. Rating scales are inappropriate for situations in which a given patient should be regularly evaluated every week for a period of months. As previously suggested, when repeated ratings are made by the same rater on the same patient, the ratings are more a function of the previous ratings than of the patient's current behavior. Our graphs of such repeated ratings show the loss of sensitivity of the rating scale as the rating-to-rating variability disappears and the changes in the ratings become less frequent and more abrupt. It would be uneconomical to attempt to solve this problem by using a large number of raters.

SUMMARY

The properties of direct, continuous, and automatic measurement afforded by free-operant techniques solve many problems of psychiatric diagnosis and evaluation.

Direct measurement solves the problem of validity. It is only when

indirect measurements are made that the problem of validity arises. The direct recording of catatonic hypermotility (pacing) needs no follow-up validity studies.

Continuous measurement permits the direct recording of moment-to-moment variability and of irregularities in the behavior of the patients, which emerge as data rather than as between-group variance.

Automatic measurement and full environmental control qualify the method as a laboratory technique which can be conducted by intelligent trained technicians with little formal education. This would relieve the professional staff for selection of therapies. The automatic property also removes the interpersonal aspects of other diagnostic techniques and permits the changing of diagnostic and evaluative personnel without bringing individual differences in evaluative bias and technique into the results. This would greatly facilitate seeing a case through a long period covering vacation periods of staff or the direct comparison of patients from different hospitals. This aspect also permits culture-free measurement so that international comparisons will be valid. Since there is no immediate observer bias, there is no need to do double-blind evaluative studies.

The fear that if these laboratory measures became popular one would regularly need an inordinately expensive, large battery of tests is not based on common sense. A large battery of laboratory tests is currently used in physiological medicine, and the larger the battery the more successful the medicine. However, in most cases the physician isolates a problem area before he refers his patient to the laboratory. He then asks the laboratory to do a selected and economically small number of appropriate tests from the large number that the laboratory is equipped to perform. Only very rarely does the physician refer a patient to a hospital or laboratory for a complete battery of physiological tests. When this does occur the patient usually enters the hospital and stays a week or so for "observation."

Psychiatric medicine is facing today the same challenge and opportunity that physiological medicine faced in the mid-nineteenth century when Claude Bernard[2] made his magnificent and successful appeal for laboratory medicine. Today I make a similar if less magnificent appeal. For our patients' sake, I hope this appeal will meet with some success. The prototype techniques and devices are now available. They only await further refinement by the skilled clinical researcher. And then, some day soon, we will have a *laboratory psychiatry.*

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