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OPERANT CONDITIONING METHODS APPLIED TO RESEARCH IN CHRONIC SCHIZOPHRENIA*

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WE SEE in the method of free operant conditioning probably one of the most rigorous technics yet devised by experimental psychology for the development, maintenance, modification, and analysis of acquired motor behavior in an experimental setting. B. F. Skinner 8 perfected this method, and he and his collaborators have been using it successfully for the past twenty-five years in analyzing the behavior of laboratory animals.¹⁰ In application, an animal is placed unfettered and alone in a small enclosure where he is free to make any response at any time-hence the term "free." If the animal operates a small lever, wheel, key, plunger or similar device, he is promptly rewarded or reinforced-hence the term "operant." Through varying the nature and conditions of the reinforcement, complex behaviors have been developed and measured which are similar to symbolic behavior, "superstition," time-telling, counting, fear, anxiety, competition, cooperation, and so on. The method has produced high degrees of control: for example, animals have been taught what are for them very unusual forms of behavior (rudimentary ping-pong, high jumping, or weight lifting) in less time than it takes many circus animal trainers to teach similar skills. Such complex behaviors have been maintained for very long periods of time by automatic reinforcing devices without the constant attendance of an experimenter.

The free operant method can be used, with very little modification, to measure the behavior of any animal from a turtle to a normal genius. Since neither instructions nor rapport with the experimenter are demanded, the method is particularly appropriate in analyzing the behavior of non-verbal,

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lowly motivated, chronic psychotic patients. (We can argue that the first place to study an unknown phenomenon is in its stable state, and the chronic psychotic is usually more stable than the acute.)

During the past two-and-one-half years we have constructed a laboratory and have successfully applied the method of free operant conditioning to the study of the behavior of 60 chronic and acute psychotic children and adults. We have also studied the behavior of 15 normal people, to provide controls and to show that the method is applicable to a full range of human behavior.

This paper will give a glimpse of the theoretical and historical background of this method, show the modifications necessary in applying it to psychotic patients, and give a summary of some of our results. We shall also point out some of the advantages and disadvantages of the method in analyzing the behavior of psychotic patients.

THEORETICAL BACKGROUND

Four general assumptions are useful in proceeding to analyze any form of behavior, and we have appealed to them in the special 'case of psychotic behavior.

1. We must often increase the precision of the measurement of the behavior before we can determine the conditions under which the behavior occurs. Diagnostic and therapeutic studies are naturally facilitated by more objective and more sensitive measurement of psychotic behavior. Today there are many explanations of how patients became psychotic, many suggestions about how to cure them, but surprisingly few quantified descriptions of exactly how and under what conditions they are psychotic.§

2. Sigmund Freud was among the first to stress the point that *all* behavior has physical causes, and that no behavior is capricious. This assumption leads us to look for physical events, in the immediate or historical environment, which might control the disturbed behavior of our patients. Freud's explanatory terms satisfy us less than would the actual discovery of causal events in the physical environment.

3. A profitable investigation of psychotic behavior can gain much from the application of the experimental method in its most rigorous and objective manner. Ideally, one environmental variable should be manipulated at

[§] The studies recently performed by King² of the Tulane group represent the sort of basic methodological research that is so sparse. Their study would have been enhanced by the use of free operant methods. Recently, Peters^{6,7} has used problem solving and multiple choice tests with acute schizophrenics. More recently, King, Merrell, Lovinger and Denny (in an unpublished study) have used the free operant method and obtained rates of response similar to ours. They studied acute patients undergoing insulin therapy and did not find the correlation between rate of response and severity of psychosis that we had suggested might be present with chronic patients.

a time while the changes in behavior are recorded as objectively as knowledge, time, and funds permit. In defense of rigorous experimentation over the "real-life" experiment, Kurt Lewin, an important theoretician of social psychology, has said: ". . . [The investigation of] those cases, impossible to produce experimentally, in which the most important decisions of life are made . . . is a requirement which, if transferred to physics, would mean that it would be incorrect to study hydrodynamics in the laboratory; one must rather investigate the largest rivers in the world. . . ." (³ p. 158).

4. It is much wiser for exploratory investigators to use operational, behavioristic descriptions of the patient's behavior than to use explanatory terms which may turn out to be mere fictions. It was Ivan Pavlov's choice of this path that led to his rewarding investigations of conditioned reflexes, as he points out in the following quotation from the introduction to his published lectures: ". . . Now when we proceeded to explain and analyse this [phenomenon] . . . we had to deal with the feelings, wishes, conceptions, etc. of our animal. The results were astounding, extraordinary: I and one of my collaborators came to irreconcilable opinions. We could not agree, could not prove to one another, which was right. . . . It seemed probable that we were not on the right track. . . . I finally reached the ground of pure objectivity. We absolutely prohibited ourselves (in the laboratory there was an actual fine imposed) the use of such psychological expressions as the dog guessed, wanted, wished, etc. Finally we came to look in another light upon all the phenomena with which we were concerned. What then is our view? Is not this a form of nervous activity which was established long ago by physiology. . . . Is it not a reflex?" (5 p. 264).

HISTORICAL BACKGROUND

A confusing variety of apparatuses has been used by American psychologists to measure behavior. Well-trained psychologists often use very different devices to measure what is supposedly the same thing. Almost as often, conflicting results are obtained and the conflict is resolved only when later studies show that two different behaviors were being measured, or that one apparatus was inadvertently measuring the effect of an additional, confounded variable. Since psychology has not yet accepted a characteristic instrument, many students design new instruments, or modify old instruments, in the hope that their design will become universal. This modification only adds to the confusion, and few experiments are exactly repeated. When cross-species comparisons are made, the difference between the apparatuses is often so profound that it is impossible to identify the single thing the two devices were presumed to be measuring:

Over the past sixty years the development of these devices has shown a consistent trend towards simplicity of design and automatic control. Although

some persons lament this trend, it continues. The "problem box" was introduced in 1898, the maze in 1901, the two-choice discrimination apparatus in 1907, the delayed response in 1913, the multiple-choice apparatus in 1916, the spring-mounted cage for measuring activity in 1918, the obstruction apparatus for measuring different degrees of motivation in 1924, the detour problem for measuring insight in 1925, the matching methods for discrimination learning in 1928, and the jumping stand in 1930. Most of these devices measure relatively complex behavior which is difficult to analyze, and quantitative comparison from one apparatus to another is almost impossible. In Figure 1, four stages in the evolution of the maze are presented to show how the attempts to obtain a device which would produce more easily interpretable data resulted in simplification. It is noteworthy, also, that the evolution proceeds from a device with high social interest (the 1901 copy of the recreational maze of Hampton Court, England) to a device with low social interest (the austere Graham-Gagné runway found only in experimental laboratories).

Probably the American tendency towards practicality and social utility, which led to Functionalism, mental testing, and Behaviorism, led psychologists a bit astray towards the design of experimental devices with high social interest. Pavlov remarked on this tendency in 1923, to quote from his lectures on Conditioned Reflexes: ". . . The American psychologists proceeded to their laboratory experiments on animals. From the character of the investigations, up to the present, one feels that both the methods and the problems are derived from human interests" (5 p. 40).

Even today, devices with high social interest and similar to "real-life" situations are more popular with many experimental psychologists, though the social interest is purchased at the expense of interpretative simplicity. The physical scientists are indeed fortunate today that they are not as bothered by the pressures of social interest as are the behavioral scientists. In the days of the Aristotelian interpretation of physical events, the physicists were, of course, less fortunate.

Not until 1938 did an experimental device which had the properties of simplicity of design and analysis, and which, at the same time, was appropriate for the study of almost all types of operant or "volitional" behavior, appear on the American scene. At that time, Skinner⁸ described an instrument which other writers have called the "Skinner box." Similar devices had been used by the Russians many years earlier. Moreover, the enclosure is not necessarily a box; it could be a room, an aquarium, or an aviary. Since the innovation was more methodological than architectural, it is more appropriate to speak of "the method of free operant conditioning."

In Figure 2 is shown an apparatus for the free operant conditioning of dogs.

The essential parts of the apparatus are: (1) a suitable enclosure, which



FIGURE 1.—Four stages in the evolution of the maze from complexity [and high social interest] to simplicity [and low social interest, but easier interpretation and analysis]. The names of the experimenters and the first date of use appear above each maze diagram. "S" indicates the starting box and "G" the goal box of each maze.

excludes undesired variables; (2) a manipulandum for recording the desired response; (3) a reinforcement magazine to present standard quantities of the reward used to maintain the response being studied; (4) a stimulus panel for presenting the stimuli used for discrimination purposes; (5) recording equipment for the automatic recording of the responses; and (6) controlling equipment for the automatic scheduling of the various stimuli whose effects are being studied.

[#]Automatic controlling and recording equipment are not essential for the use of the free operant method, but many of the important advantages are lost if such automatic devices are not used.



FIGURE 2.—An apparatus for the free operant conditioning of dogs. The enclosure is labelled #1, the manipulandum #2, the reinforcement magazine #3, the stimulus panel #4. The recording and controlling equipment are not shown.

The apparatus shown in Figure 3, which was used by Pavlov and his collaborators as early as 1906, is similar in many respects to Skinner's. The Pavlovian Camera, or experimental enclosure #1, the reinforcement magazine #3, and the stimulus panel #4, are all very similar to that used by operant conditioners today. Pavlov's response recorder #5 and manipulandum #2 were, of course, very different since he recorded glandular secretion, but Bechterev, Kalischer, and Ivanov-Smolenski had used the method to study the motor responses of dogs and human beings prior to 1927. The biggest difference in the two methods is found in #6, the controlling equipment. An experimenter in an adjoining room was in constant attendance and presented the stimuli in a series of trials. One response was recorded and reinforced in each trial.

Skinner⁸ was the first to stress the value of the *free operant*, wherein the animal is free to respond at any time, and the rate of occurrence of this response is recorded. As a consequence, the method dispenses with "trials," which are burdensome, time-consuming, and often reduce the sensitivity of the method by adding sources of variability between the trials.



FIGURE 3.—Diagram of Pavlov's apparatus for classical conditioning. The enclosure is labelled #1, the manipulandum #2, the reinforcement magazine #3, the stimulus panel #4, and the recording equipment #5. No automatic controlling equipment was used.

Skinner ¹⁰ also stressed the use of schedules of intermittent reinforcement. Under the conditions of reward which previously were used (they are now called continuous reinforcement), the animal was reinforced every time he made the desired response. Under the conditions of intermittent reinforcement, only a few responses are reinforced (for example: every twentieth response might be reinforced). Skinner and his co-workers found that intermittent reinforcement produced: i) a wide range of rates of response; ii) a responding which was less dependent upon the deprivation and satiation associated with the reinforcing stimulus; iii) a greater resistance to experimental extinction; and iv) a more sensitive response measure (in part because the animals spent less time eating, etc. between responses).

The use of the *free* operant and of intermittent reinforcement pushed the generality of the method of operant conditioning beyond that of the Pavlovians motor CR investigations. Yet it is still amazing that the Pavlovians exerted such a high degree of experimental control in the first decade of the twentieth century. Figure 4 shows a diagram of Pavlov's laboratory. The experimental rooms or "cameras" are separated from each other and from the rest of the building by pillars of sand for controlling vibration. Possibly no psychological experimental control. (Let us suggest this moral: Individuals who ridicule extensive experimental control should be careful not to quote Pavlov.) American psychologists in the early part of this century imitated Pavlov's verbal behavior, but they did not imitate his experimental behavior.



FIGURE 4.-Diagi im of Pavlov's laboratory, constructed in 1925.

in terms of conditioned reflexes, but they continued to use poorly controlled experimental situations with high social interest.

MODIFICATIONS FOR APPLICATION TO CHRONIC PSYCHOTICS

When the method of operant conditioning is applied to a new organism, the biggest problems are always those of apparatus design and construction. Appropriate experimental enclosures, manipulanda, and reinforcement magazines must be designed and constructed. There are a few additional problems concerning the handling of the animals, but the recording and controlling devices and experimental design come intact from the earlier work. The apparatuses and procedural modifications we have developed for use with chronic psychotics are described below under the appropriate headings.[‡]

1. Experimental enclosure: Ideally the experimental rooms should be sound-proofed, indestructible, pleasant, and easily cleaned, and should provide for one-way observation, the yoking of two rooms for social experiments, and a means of presenting reinforcing and discriminative stimuli. Those who have been concerned with the designing of hospital furnishings for violent patients will realize that this is no small order. For over two years we have successfully used six-by-six-foot rooms constructed of concrete block. The

[‡] With the exception of the experimental rooms all of this equipment is now commercially available from Ralph Gerbrands, Arlington, Massachusetts, and Grayson-Stadler, Inc., Concord, Massachusetts. rooms are illustrated in Figure 5. The doors are solid wood, metal-clad, and the floors are covered with linoleum. Apertures for visual communication between two rooms are covered with $\frac{3}{8}''$ plexi-glass sheets. Our first rooms had plexi-glass-covered silk pictures on the walls, and through these the experimenter could observe the patients from an adjoining darkened room. Our later rooms have a mirror-and-lens-system, and this provides hidden observation facilities through a metal screen in the ceiling of the experimental rooms. We can mount speakers and microphones behind the screen, and these are accessible from the adjoining apparatus area. The manipulanda and magazine panel, which has an open back accessible from the apparatus area, are located on one wall.

The room is furnished with a small chair and plastic ash tray for the comfort of the patient. In handling extremely violent patients we have only lost some chairs and ash trays, and two of the doors. The patients often urinate or defecate during experimental extinction but the floor is not hard to clean. The cinder-block walls are a cleaning problem, but they are easily repainted when they become dirty. Exhaust fans in the ceilings continuously move



FIGURE 5.—Diagram of the experimental rooms now in use for the free operant conditioning of psychotic patients. The plexi-glass windows between the rooms can be made transparent for visual communication in social experiments. The enclosure is labelled #1, the manipulandum #2, the reinforcement magazine #3, the stimulus panel #4, and the automatic recording and controlling equipment #5.

fresh air through the rooms. With rooms of this size and design, we have met with no permanent case of claustrophobia. Tendencies to withdraw from the rooms usually subside after a few reinforcements have been delivered.

2. Manipulanda: We began with a modified cigarette vending machine, but when the levers were operated six hours per day at rates up to 10,000 pulls per hour they soon showed signs of wear. The children were especially destructive, and constantly tore the apparatus apart in attempts to get the candy that was used as reinforcement. We have designed a standard manipulandum constructed of angle iron and half-inch brass rod which remains operative even when struck with chairs. It requires a pull of 300 grams through one centimeter to close the operating circuit. Patients responding on our apparatus at maximum rates perform from $\frac{1}{5}$ to $\frac{1}{12}$ the amount of work of an average typist typing 60 words per minute on a standard typewriter. The manipulanda can be mounted in banks, and springs can be added to study various response parameters.

3. Reinforcement magazines: We use a standard vending device which will hold 100 objects varying in size from a jelly bean to a nickel candy bar. This vending device has been used for the automatic delivery of penny candies, cigarettes, coins, and food morsels through an aluminum chute into an illuminated delivery tray within the experimental rooms, during a chosen period of time. An apparatus that presents colored slide images on the back of a translucent plexi-glass screen on the wall of the room was used to measure the degree of "interest" or motivation that various forms of pictorial material offer. We have also used devices to present fluids and musical materials as reinforcing stimuli.

4. Stimulus panel: We can present visual stimuli under plexi-glass screens above the manipulanda, as well as auditory stimuli from speakers hidden behind the metal screen in the ceiling.

5. Recording equipment: We use standard Harvard cumulative response recorders and reset counters to record the responses. Each experimental hour is characteristically reported in a cumulative response record, in counter readings, and on a clinical data sheet. In addition to the patient's and experimenter's names, the time and date of the session, and the counter readings, the data sheet has space for recording the patient's body weight and body temperature; results of a cursory physical examination; descriptions of the patient's behavior on leaving the ward, in the waiting room or in the experimental room and upon returning to the ward. The qualitative data are difficult to analyze and obviously are subject to the experimenter's bias. However, these data provide a measure of the patient's physical health. In some cases, the behavioral descriptions show significant relations to some of the experimental manipulations.

6. Controlling equipment: Standard electrical devices available are used for controlling the delivery of reinforcements, the presentation of stimuli, and the duration of the experimental session. The whole experiment is automatically conducted. The experimenter conducts the patient to the room, closes the door, and throws the appropriate switches. At the end of the experimental session the experimenter is signalled, the patient returned to the waiting room, and the permanent records of the experimental behavior are available for later analysis.

7. Experimental session: We have not yet fully investigated the ideal length of the experimental session. We use a standard duration of one hour per day, five days a week. Some patients have responded in as many as four rooms for one hour each day for many days without showing signs of fatigue or boredom. Holiday and week-end interruptions do not seem to produce noticeable changes in the behavior of the patients at this stage of our investigation.

8. Patient selection: The majority of the patients were male and were diagnosed schizophrenic at admission. The adult patients' ages ranged from 18 to 63 years, with a median age of 40 years. Total hospitalization for mental illness ranged from 1 to 47 years, with a median of 12 years. We selected patients who were preferably not on parole, not working in hospital industries, not receiving active therapy, not receiving visitors, and not going on home visits. We did this in order to minimize extraneous variables and to facilitate patient handling. We have not yet completed our own clinical testing of the patients. We used no other criteria in selecting patients.

9. Patient handling: Our standard procedure is to go up to the patient, for the first time, on the ward and ask him if he wants to come with us and get some candy or cigarettes. Those who do not answer are led, if they do not follow us, to the laboratory. If at any time a patient balks or refuses, he is left on the ward. Approximately 10% of the patients we approached have refused to leave the wards. A few of these have been conditioned to come with us when we gave them candy or cigarettes each time they came closer to the laboratory, but this is time-consuming, and we are content to study the patients that come without special training at this time.

A new subject is led into one of the rooms and told: "This is a candy machine. If you pull the knob you will get candy that you can eat or keep, but you will not get candy every time you pull the knob." If he asks why we are doing this, we say: "We are studying how patients work, and the machine will give you candy." Under no condition is the patient told more. After a careful analysis of the differences between the behavior of patients who had various degrees of information about the experiments, we were able to find no correlations between what the patients "knew" about the experiments and how they behaved.

If the patient has not made a response within 15 minutes, the experimenter enters the room and pulls the knob and ingests a reinforcement with obvious relish. He then leaves, saying nothing. If no response is made for 15 minutes after this demonstration, the experimenter again enters and places the patient's hand on the knob and helps him pull it. The reinforcement is given to the patient. Although we initially tried to condition the patients who did not spontaneously respond by reinforcing movements closer and closer to the knob (the method of successive approximation ⁹), we have since discontinued this procedure. It is time-consuming; we are not primarily interested in response acquisition, and, in one case, it produced a strong "superstitious" response of tapping the apparatus that was very difficult to extinguish. If at any later time a patient refuses to leave the ward, to enter the rooms, or asks to leave the room, his request is granted and the fact recorded. (These refusals increase significantly during experimental extinction when the patients are not reinforced for responding.)

Since our only contact with the patient is through positive reinforcement, we cannot, theoretically, "hurt" a patient. The patient may be made unhappy by some procedures or schedules (for example, extinction). In that case the situation becomes aversive rather than positively reinforcing, and the patient withdraws from the room. Since our patients are free to leave the rooms at any time, we cannot study avoidance or escape behavior in the same fashion as with lower organisms. However, we have found that we can sandwich small slices of mild aversion between thick slices of positive reinforcement without producing withdrawal from the rooms. We have used pure tones as aversive stimuli. They are not initially disturbing, but after a few minutes some patients will respond to turn off the tones.

10. Sample apparatuses: Figure 6 is a diagram of our first apparatus, the modified vending machine. The patient is shown getting a reinforcement. A piece of candy has fallen into the chute below the manipulanda, and the chute is illuminated for five seconds while the room is darkened. This illumination and darkening is called a conditioned reinforcing stimulus and is designed to increase the effect of the reinforcement by shortening its delay. Experiments with lower organisms have shown that reinforcements have a greater effect in strengthening responses the more closely they follow the responses in time. A piece of candy cannot be delivered much quicker than one second after a response, but the flash of light (a conditioned reinforcement) can be delivered milliseconds after a response. Although we have not made direct experimental test, this immediate, conditioned reinforcement is probably also important in human operant conditioning. On the other side of the cinder-block wall, the counters have registered 969 responses and 11 reinforcements so far in this experimental session, and the cumulative response recorder has drawn an automatic graph of the responses plotted against time. The paper moves at a rate of 11 inches per hour (except when the magazine is operating, the eating time being subtracted from the record). The pen moves across the paper, one small step each time a response is



FIGURE 6.—An apparatus for the free operant conditioning of psychotic patients, using small objects (candies, cigarettes, coins, or food morsels) as reinforcing stimuli.

made, and takes 500 responses to traverse the paper; then it is automatically reset. When a reinforcement is delivered, the pen makes a short diagonal "hatch" mark on the paper. In this manner an automatic, permanent, and continuous record of the patient's responding and the delivery of each reinforcement is obtained.#

In the record shown, the patient may be seen to have responded at a fairly steady rate for approximately thirteen minutes, to have stopped responding for five minutes, and then to have continued responding at the previous rate for five minutes. During such periods, when responding ceases, a patient often engages in his particular psychotic behavior pattern: pacing, laughing, swearing, staring, destroying objects within the room, etc. Under certain experimental conditions, excessively long pauses appear to indicate severe psychosis. We quantify pauses by automatically counting and summating all inter-response times; a normal either responds at a fairly steady rate or else leaves the room. The measurement of long inter-response times seems to provide a measure of the frequency and duration of those psychotic outbursts which are strong enough to interfere with the particular response,

#A one-minute variable-interval schedule of reinforcement was used. Schedules of reinforcement have been described in detail by Skinner.¹⁰

reinforcement, and deprivation being used at the time. The technique of measuring a topographically different series of events in terms of their effect on a stable system is well known to the physicist. Although we must proceed with caution, the same technique may prove useful in the investigation of psychosis.



FIGURE 7.—An apparatus for the free operant conditioning of psychotic patients, using pictorial material as reinforcing stimuli.

Figure 7 shows a diagram of a second apparatus which presents various pictorial themes to the patient. A patient is shown being reinforced by the projection of a colored slide image on the wall of the room. Although most patients will respond for pictorial reinforcement, their rates of response vary depending upon the theme of the pictures. Some patients, for example, have responded at higher rates for male nudes than for female nudes. In contrast with the adults, the children did not respond very long for pictures of animals, cartoons, etc. They made remarks like "lousy movies," or "just a bunch of pictures," and showed relatively rapid satiation. In adult patients, the rate of responding for candy or cigarettes. This variability in rate suggests that, although the pictorial reinforcements might have great value in diagnosis or motivation testing, they are not so valuable for the maintenance of the behavior of psychotics as candy or cigarettes.

In Figure 8 an apparatus for the free operant conditioning of an altruistic response is presented. We thought that some of the patients who responded at very low rates in getting candy or cigarettes for themselves, for example, because they "had excessive guilt" and "felt they did not deserve good things," might respond at higher rates reinforcing some other organism. We therefore constructed a small apparatus to present milk to kittens. Kittens were conditioned to drink milk immediately on presentation of a dipper. The kitten was safe in a cage placed in front of the patient, securely behind $\frac{3}{8}$ inch-thick plexi-glass. The patient could watch the kitten drink the milk that had been produced by his response. To date, only two out of fifteen patients have responded at higher rates feeding the kitten than they did producing candy for themselves. Some patients seem to be stimulated by the presence of the kitten to violence or hallucinatory verbal behavior directed at the kitten.

Such patients often strike the kitten cage with the ash tray or with the chair, but the kittens have learned to sit calmly behind their screens and "meow" for milk. We plan to use a similar procedure to measure interhuman altruism, by having patients reinforce other patients whom they will be able to observe through a plexi-glass screen. The effects of drugs, shock therapies, or psycho therapy on altruistic behavior should be readily ascertained with such a highly controlled, objective, and continuous measure of altruism as the operant method has provided.

SUMMARY OF RESULTS TO DATE

In two and a half years we have collected approximately 4,500 hours of data from 60 psychotic patients. Since this is the first application of the method to psychotic material, we have spent much time on methodological research problems. We have studied patients for very long periods of time



FIGURE 8.—An apparatus for the free operant conditioning of an altruistic response of human subjects. The reinforcement consists of producing a few drops of milk for a hungry kitten and watching the kitten drink the milk.

(over 400 hours or two calendar years) to see how long this sort of experimental behavior can be maintained without change. Interrupting an experiment for six months, such as would be demanded by neuro-surgical research, does not significantly change a patient's rate of response. Studies of interand intra-patient variability have shown that, although the variability of a given patient's response rate appears to be characteristic of the patient, there is a wide range of day-to-day and within-the-hour variability between patients. Approximately 30% of the patients had very low rates of response and these were not increased by the reinforcements we have used to date. The low rates appear to indicate a general loss in motivation and/or a severely debilitating psychosis. (A stronger reinforcement would be substantial food delivered under conditions of hunger, but although we have not been able to arrange hunger schedules to date.)

Analysis of inter-response times has shown that the normal and psychotic individuals are spread along a continuum, with the most normal individuals at the low end (no inter-response time over 10 seconds) and the severely disturbed patients at the high end (inter-response times over 60 minutes). Although such quantitative continua do not fit the popular Aristotelian dichotomy of "normal" and psychotic," they are more useful for comparison with other quantitative measures.

Significant changes have been observed in the experimental behavior as a result of half-hour unstructured interviews with the patients, routine ward assignment changes, changed parole status, and other extra-experimental variables. These observations suggest that, in using such a sensitive method for research purposes, variables of this nature should be controlled. Insulin therapy has produced effects on rates of response reinforced by the feeding of the kitten, which are presumably not directly related to hypoglycemia. Chlorpromazine and dexedrine administrations have both produced rate increases in some patients and rate decreases in others. Lysergic acid administration to normal individuals produced more psychotic-like records than the pre- and post-lysergic control records. Taken together these results suggest that the method may be used to advantage in diagnostic and therapeutic studies.

In the experimental analysis of the behavior deficits found in psychotics we have not fared so well. The problem is very complex. Many peculiar and hitherto little-known behavior deficiencies have been discovered, but they occur so infrequently in the patient population that each patient has to be experimentally treated as though he were a unique case. Since the method is reliable enough for single individual studies, it presents no insurmountable problem, but it means that research must proceed slowly and carefully. Large numbers of patients with a particular behavior deficit are difficult to accumulate.

One behaviorial peculiarity we have observed is strong response pattern stereotypy similar to that reported by Peters 7 with chronic schizophrenics. When more than one manipulandum was used and responding on any one was reinforced, three out of 20 patients developed very strong stereotyped response patterns in the first few hours of experimentation. These persisted over 100 hours and resisted experimental change when we selectively reinforced only one manipulanda or locked all but one.

Another behavior deficit was an extreme resistance to experimental extinction discovered in only two out of 20 patients. In Figure 9 is presented a plot of the number of responses per hour against the experimental sessions for one patient that has this extreme resistance to extinction. He made approximately 5,000 responses per hour when reinforced by female nude pictures in room #2. After 50 hours of intermittent reinforcement (one-minute variable interval), the pictures were no longer presented but the experiment was continued to see how long he would respond without reinforcement. After 50 hours of extinction he was still responding at rates above 5,000 per



FIGURE 9.—Median responses per hour plotted against experimental sessions under conditions of intermittent reinforcement by projected slide images. The patient was still responding at a high rate after 100 hours of extinction. This high rate did not generalize to another similar room with no previous history of reinforcement.

hour. Other patients and the normals show fairly sharp decreases in rate of response within the first ten hours of extinction after 50 hours of intermittent reinforcement. When placed in room #6, where the patient had never been reinforced, his median rate of response was never over 2,000 responses per hour. Evidently this patient can acquire responses that are reinforced, but if they are no longer reinforced the responses persist without a noticeable reduction in frequency for extremely long periods of time. However, this non-adjustive responding does not generalize to a similar room without a previous history of reinforcement. Note that there is a very slow reduction in rate over the 110 hours of extinction we have recorded to date. We will continue this extinction for another 100 hours to see if the rate continues to slowly decrease. One other patient has shown this same resistance to extinction, but his high rate generalized to similar rooms.

Failure to discriminate, to respond to rate-increasing schedules of reinforcement, and to count have also been discovered in certain patients. We have not yet been able to relate these behavior deficits to each other or to any clinical measures.

The primary purpose of our investigations has not been to produce therapy through automatic reinforcement of an isolated segment of a patient's behavior, although such a development would be more than welcome. Our purpose has been to develop a basic research tool for the measurement of



FIGURE 10.—Median responses per hour plotted against experimental sessions under conditions of intermittent reinforcement by candy and cigarettes and extinction. The patient was placed on parole for the first time in 19 years of hospitalization at the first arrow and taken off parole at the second arrow.

the simple and complex, individual and social behavior of psychotic patients, and then to proceed with an analysis of behavior anomalies found in psychosis. However, a few patients have shown evidence of clinical improvement since we started working with them. In Figure 10 is presented a plot of the number of responses per hour against the experimental sessions for the patient who showed the most striking hospital improvement. Note that his rate of response for candy reinforcement gradually increased over a period of more than 150 hours. After 180 hours of experimentation (36 weeks) he was placed on parole (given grounds privileges), and the rate of responding rapidly increased thereafter until it reached over 8,000 responses per hour. After 260 hours, the reinforcements were no longer delivered (experimental extinction). The rate of response rapidly declined, and the patient became more untidy and uncommunicative in the experimental rooms and on the wards. At 350 hours he was taken off parole and sent to the surgical ward for treatment of an ulcer he had produced by constantly picking his leg. It is not clear that the experimental treatments produced the changes in his hospital status, but it is clear that his changed hospital status was followed by an increased rate of response in the experimental room. We are currently having the ward attendants fill out behavior rating scales in order to obtain quantified measures of the patients' ward behavior for comparison with the experimental behavior.

DISADVANTAGES OF METHOD

The method has some disadvantages. Since time is spent in training and stabilization, the method is apt to test the patience of investigators used to less sensitive measures and to quick, parametric studies. If it is desired to correlate the results with another measure that depends on a very large "N" for its reliability, the free operant method probably should not be used since it would take too long to generate the large sample demanded by the less reliable measure. Since relatively large financial and temporal investments (by psychological standards) are made in laboratory facilities, the method is probably inappropriate for short-term investigations. A skilled technician is needed to trouble-shoot the controlling and scheduling equipment. So far we have obtained useful rates of response from only 70% of the back-ward population of the hospital without special training. We hope to increase this percentage by reinforcing with substantial food in relation to hunger schedules. However, few other psychological methods can be successfully applied to so large a percentage of the chronic population of the large state mental hospitals.

ADVANTAGES OF METHOD

The advantages of the method can be summarized under five methodological characteristics:

1. *High experimental control:* The exclusion of unwanted variables produces more stable behavior and higher sensitivity. The simplicity of design makes for analytical and interpretive ease.

2. Automatic recording and scheduling: Since the behavior is automatically recorded, no problems of experimenter bias and error are involved in the collection of the raw data. Permanent, continuous records are available for later analysis and interpretation. Presumably any two experimenters in any two laboratories should be able to collect similar records just by arranging the appropriate experimental conditions and finding two similar patients.

3. High generality: The wide range of situational variability within a common methodological schema permits the study of different response topographies by changing the properties of the manipulanda, the study of different motivations by changing the nature of the reinforcing stimuli, and the study of discriminative functions by associating stimuli with various conditions of reinforcement. Psychophysical thresholds have been successfully obtained without recourse to verbal instructions. If visual communication is permitted between patients in separate experimental rooms, and the reinforcements are delivered only when the patients respond together, cooperation can be developed without any verbal instructions.¹ By different modifications of the reinforcement circuits for two such visually linked rooms,

imitation, altruism, sadism, and competition can be studied. Since the basic situation with an individual alone in a room can be used as a baseline, the effect of the addition of the slightest social variable can be determined (*i.e.*, the voice of another person played over a speaker in the background). By changing the enclosure, manipulandum, and reinforcing stimulus, a wide range of species can be studied. To date the method has been applied to reptiles, fishes, birds, and mammals. Of the mammals, the behavior of rats, cats, dogs, monkeys, and chimpanzees has been studied successfully. Since the other properties of the method are not altered, inter-species comparisons are simplified, which would be of great aid in the investigation of extreme neurosurgical and pharmacological variables not initially feasible with human material.

4. Free operant nature: The free operant nature of the method eliminates variability introduced by trials between responses and permits the experimenter to collect more data per unit of laboratory time. This increased sensitivity is especially important in the study of psychotics because the interpatient differences are so great that a method that must resort to averaging to gain reliability often loses the important differences between the patients of which the clinician is so acutely aware. Experimental case studies are not only possible but appear to be what we are forced into at the finer levels of analysis. The continuous nature of the records provides a measure more in keeping with the notions of probability of responding and gives a finer temporal sensitivity than measures which contain trials or recovery periods (for example, mental tests).

5. Lack of instructions: The lack of verbal instructions permits the investigation of non-verbal behavior and the study of patients who do not communicate. We have discovered patients who respond in a normal fashion when alone in a room, but have a psychotic response when the experimenter or another patient enters the room. This sort of behavior anomaly is beyond the scope of methods that demand the immediate presence of an experimenter.

As we continue to perfect the application of the method of free operant conditioning to the analysis of psychotic behavior, we discover more and more promising research leads. There seems to be no doubt that the method should be considered along with the other promising basic research tools by investigators of chronic schizophrenia.

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