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Normal Sources of Pathological Behavior

Animal experimentation shows that certain combinations of adaptive responses can result in nonadaptive behavior.

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While they were once held to be incompatible, clinical and experimental medicine have lived together so long and so harmoniously that they are now recognized to be at least common-law partners. The bond that united them was the thesis, ably demonstrated and eloquently expounded by Claude Bernard, that pathological states may be manifestations of normal processes—normal, not according to any statistical criterion, but in the sense that they carry on a lawful existence independently of their pathological manifestations. The study of disease and the study of normal physiological functions have thus come together within a deterministic framework. Clinical medicine has developed a truly experimental foundation and looks to basic science for future progress.

With respect to pathologies of behavior, however, clinical practice and laboratory experimentation have yet to achieve a satisfactory working partnership. The origin of pathology in normal behavioral processes is beginning to be recognized (see, for example, *1*), but in a not very large segment of current experimental or clinical practice. Experimental and clinical psychologists alike seem to equate the two terms *abnormal* and *disorderly*. Thus, when an experimenter isolates a lawful behavioral phenomenon, he is likely to consider that its very lawfulness removes it from the realm of clinical interest. Similarly, the clinician who does venture into the laboratory will, more often than not, try to demonstrate the absence of lawfulness in some behavioral phenomenon. Neither worker seems to give much thought to the possibility that maladaptive behavior can result from quantitative and qualitative combinations of processes which are themselves intrinsically orderly, strictly determined, and normal in origin.

I shall try to demonstrate a case of this sort here. The clinician may not have available, when I have finished, any new diagnostic or therapeutic tool, but if he can relate the events in my story to these introductory remarks, we may move somewhat closer to an experimental foundation for clinical psychology. The point of view must generate a practice before it can show practical results. The course that has proven so fruitful in medicine should also yield rich dividends in psychology.

Estes-Skinner Experiment

In a paper on "Some quantitative properties of anxiety" (*2*), published in 1941, W. K. Estes and B. F. Skinner described the changes produced in the lever-pressing activities of a rat by the sounding of a tone and administration of an electric shock when the tone ended. Observation by Estes and Skinner of the world about them—clinical observation, so to speak—had led these investigators to suspect that the term *anxiety* was often applied to behavior occurring during sequences of events similar to the tone and shock. The authors selected the laboratory rat as the subject for their experiment; but it was assumed that under similar circumstances other animals would behave in a similar fashion, and this assumption has subsequently been confirmed to a remarkable extent.

In the experiment, a rat is placed in a small chamber. The rat is first trained to press a lever projecting from the wall; as reinforcement it gets small food pellets from a tray underneath the lever (see Fig. 1). Next, the mechanism connecting the lever to the food-delivery system is scheduled so that lever pressing produces food only once every 4 minutes. As established by earlier experiments (*3*), on this schedule, a hungry rat will press the lever at a fairly steady rate.

The investigation proper is now begun, with experimental sessions lasting 1 hour. During each session the tone is sounded (through a phone in the chamber) once or twice, for 3 minutes at a time, and at the termination of the tone the rat receives a brief, unavoidable shock through the grill on which it stands. The food-reinforcement schedule remains in effect at all times, including the period when the tone is sounding. After a number of sessions the effect of the tone is to diminish greatly the rate at which the rat presses the lever. This phenomenon is called conditioned suppression.

We repeated the Estes-Skinner experiment in our laboratory, using a rhesus monkey as the subject and making the food pellets available at irregular intervals. Again, the result was conditioned suppression. As the record reproduced in Fig. 2 shows, when the

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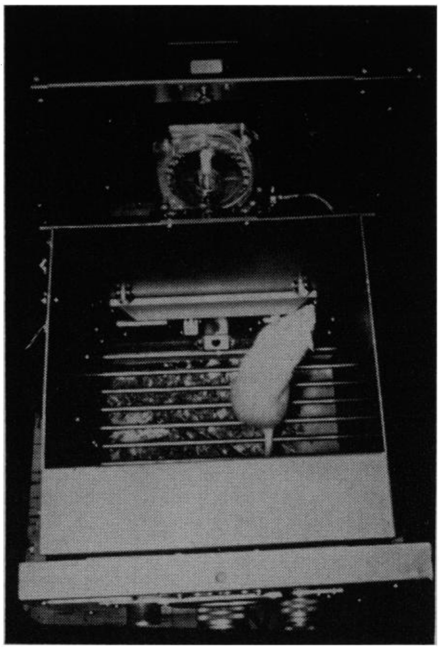

Fig. 1. An experimental chamber similar to the one used by Estes and Skinner.

tone sounded the monkey pressed the lever at a much slower rate. After the shock was administered, the monkey pressed the lever at its usual rate.

The disruption of ongoing activity is quantitatively reproducible for the same animal, for animals of the same or different species, and for animals in tests of behavior other than lever pressing. Yet this lawful phenomenon has pathological characteristics. As the animal reduces the rate at which it presses the lever, there is a resultant loss of food; this response would seem to have no adaptive value. Instead of pressing the lever, the animal displays other forms of behavior, which may range from complete immobility to agitated, intense, and apparently aimless locomotor activity, all accompanied by signs of autonomic upset.

Applications of the Estes-Skinner Technique

The small perturbation in the cumulative response curve of Fig. 2 may not correspond to one's favorite definition of anxiety. As Schoenfeld has noted, ". . . anxiety in its multifarious nonoperational meanings is a perfectly bad word. . . ." (*4*). But that is not the issue here. The fact remains that we have a simple technique for producing a profound change in an organism's behavior, a change that appears to be characteristic of a pathological condition. The simplicity of the manipulation should not deceive us. Whenever a simple operation is found to exert a powerful behavioral effect, we may suspect that the phenomenon can be widely generalized. In the present case, furthermore, the simple operation of exposing an organism to the stimulus-shock sequence leads to behavioral consequences of an exquisite complexity.

After it was first described, in 1941, the Estes-Skinner experiment received almost no experimental attention for a period of 10 years. It was finally resurrected by Hunt and Brady (*5*), who, with their collaborators, made it the basis of a productive research program. At first Hunt and Brady were interested in conditioned suppression not so much for its own sake as for its potentialities as a tool in studying other things. Their initial investigations, for example, dealt with electroconvulsive therapy. After their subjects, white rats, had developed a full-blown conditioned suppression, ceasing to press a lever when they heard the clicking noise which preceded shock, they were given a series of electroconvulsive "treatments." On being returned to the experimental chamber they no longer reacted to the clicker. Instead of being disrupted, the animals behaved normally during the warning stimulus. Electroconvulsive shock had "cured" them of their anxiety.

A long and revealing series of experiments followed, elucidating additional aspects of electroconvulsive shock treatment (*6*). In these experiments, Brady and Hunt employed conditioned suppression in much the same way as the physiologist, for example, utilizes the techniques of chemistry to investigate metabolic processes. Little more was learned of the behavioral processes themselves. But as additional uses were developed for the Estes-Skinner technique, greater attention was given to the behavioral processes, the initially silent partner in this study of a "cure." It is instructive both for the experimentalist and the clinician to follow at least part of the course of this development.

Another problem to which the suppression technique was applied was that of the effects of certain types of damage to the central nervous system. For example, if a clicking noise of mild intensity is sounded while a thirsty rat is pressing a lever to obtain occasional small drops of water, and an unavoidable shock is delivered to the rat when the clicker stops, the animal will eventually cease pressing the lever while the clicker is on. We then make a surgical lesion in the rat's septal forebrain region. When placed in the experimental situation again after it has recovered from the operation, the rat presses the lever for water in the same way as it did before. But when the clicker sounds, the animal does not reduce its rate of lever pressing to the degree that it did prior to the operation. The septal lesion tends to attenuate the conditioned suppression in much the same way as electroconvulsive shock does (*7*).

Certain drugs also change the reaction of both monkeys and rats to the warning clicker. Animals given reserpine over a long period, for example, gradually resume their normal rate of lever pressing during clicker stimuli which precede electric shock (*8, 9*). Like electroconvulsive therapy, reserpine apparently cures their disturbed behavior.

There is a similar effect when rats and monkeys are rewarded for lever pressing not by food but by intracranial electrical stimulation via permanently

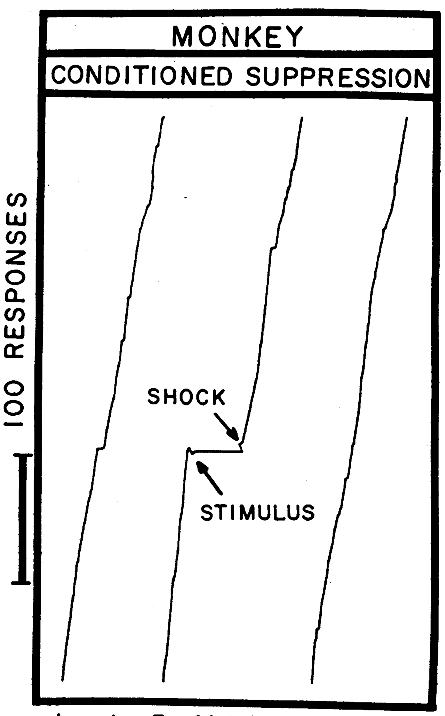

Fig. 2. An illustration of the Estes-Skinner conditioned suppression phenomenon. Responses are recorded cumulatively, with the pen automatically resetting to the base line after every 450 responses. The introduction of the clicking noise is indicated by the slight oblique downward displacement of the pen at the first arrow. The shock, which immediately follows termination of the tone, occurs at the point where the pen displacement is rectified, indicated by the second arrow.

implanted electrodes. (Intracranial electrical stimulation seems to function as a reward for the animal. The basic observation is that the animal will work for electrical stimulation in certain brain areas just as it will work for food; it is not necessary to assume that the animal derives pleasure from the electrical stimulus.) But, whereas an animal working for food will cease its lever-pressing activities after a series of clicker-shock experiences, the same animal, when working for electrical stimulation of the brain, will continue to press the lever while the clicker sounds (*10*). Though both function as rewards, brain stimulation and food cause animals to react differently in an anxiety situation.

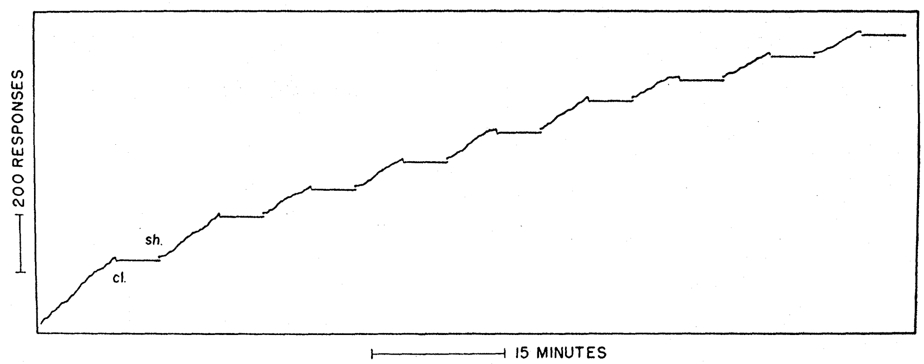

Fig. 3. Cumulative record of lever pressing. Five-minute periods of clicking alternated with 5-minute periods of silence. The introduction of the clicking noise is indicated by the slight oblique downward displacement of the pen and is marked *Cl* at the first presentation. The shock occurs at the point where the pen displacement is rectified. The first shock is marked *Sh*.

As far as the behavioral processes were concerned, we had not, at this point, progressed much beyond the original Estes-Skinner phenomenon. But the behavioral perturbation that often accompanies the warning stimulus shows both an order and a complexity which help us to understand behavioral pathology. One more application of the technique will show how we were led to consider conditioned suppression as of interest in its own right.

A research program was under way to test the notion that behavioral phenomena and the functioning of the pituitary-adrenocortical system are correlated. On the endocrine side, John Mason and his collaborators had developed a reliable technique for measuring blood levels of 17-hydroxycorticosteroids in monkeys (*11*) and were engaged in a series of studies to determine the anatomical and physiological properties of the system. On the psychological side, we set out to determine whether this system could be activated by behavioral methods. One of our successful ventures involved the Estes-Skinner technique. When blood samples were taken from monkeys before and after their exposure to the Estes-Skinner procedure we found that a marked elevation had occurred in the plasma level of 17-hydroxycorticosteroids (*12*). But in this application we were forced to depart, to a certain extent, from the original procedure. All of the departures were dictated by practical necessity, but they had revealing systematic consequences.

A first change was required when we found we could not use the laboratory rat. Nearly all previous work on conditioned suppression had been performed with this useful animal, but unfortunately it did not have a sufficient quantity of blood for repeated steroid measurements. We therefore turned to the monkey. In the initial experiments with the monkey, as in previous work, we combined stimulus and shock only once or twice during any given session. While our subjects did display elevation of steroid levels in these first tests, the elevations were not as consistent as we felt requisite for further investigation. Following a procedure developed by Azrin (*13*) we therefore subjected the monkeys to a large number of stimulus-shock sequences during each experimental session and, when this procedure showed signs of success, went on to a schedule in which stimuli of 5 minutes' duration were programmed every 10 minutes. Findings under these conditions gave us clean and reproducible base lines; the animals ceased to respond during each stimulus but began to press the lever again almost immediately after each shock (see Fig. 3). Correlated with this relatively stable behavior was a reliable and large elevation in steroid level.

Was this, however, a pure example of behavioral stress, or was the shock a necessary part of the picture? In order to answer this question we attempted to run test sessions in which we gave the subjects the warning stimuli as usual but no shock. Would the stimuli alone, without shock, increase the output of 17-hydroxycorticosteroids? The procedure, unfortunately, did not allow us to answer this question. When the shock was discontinued the animals pressed the lever at their usual high rate during the warning stimuli. There was no longer any conditioned suppression or any rise in steroid level.

We solved the problem by following the stimuli with shock only intermittently. The monkeys received shock after 25 percent of the warning stimuli in each session; the remaining stimuli were not followed by shock. Then, in subsequent test sessions, we again presented the warning stimuli to the subjects without shock. Consistent with the general principle that intermittent reinforcement prolongs the process of extinction was the finding that a diminished rate of lever pressing and a rise in steroid level were elicited by the warning stimuli alone.

But the story is not a continuous chronicle of success. It was necessary to keep each monkey working consistently for extended periods of time, pressing the lever steadily but ceasing to press when the clicker sounded. Stable behavior was required if further investigation was to continue. But when the modified Estes-Skinner procedure had been in effect for some time, the monkey's behavior began to deteriorate. An example may be seen in Fig. 4. The contrast with the regularity shown in Fig. 3 is striking. The subject now presses the lever at a very uneven rate between stimuli, with suppression sometimes continuing even after the clicker is silent. Occasionally, as at the points marked *a*, the animal ceases lever pressing immediately before the noise is introduced. During the stimulus period there is evidence of temporal discrimination: as indicated at *b*, the animal continues pressing the lever during the early minutes of the stimulus; then suppression occurs. Another strange phenomenon is indicated at *c*: after a period of suppression, the monkey begins to press the lever at a low, steady rate which continues until it receives the shock.

This breakdown of the behavioral

base line is the kind of phenomenon that suggests pathology. We may well conclude that the behavior is pathological but not on the grounds that it is disorderly. The anomalies which began to appear in the behavioral records appeared to be disorderly only because we were not at the time able to identify the controlling variables. Unless we could gain some understanding of the behavioral processes at work here, we could not apply the technique to the problem of behavior-endocrine interaction. Out of our investigations, then, there emerged a new appreciation of the behavioral complexities with which we had been working. Our first attempts to unravel these complexities seemed to multiply them, producing behavior which, if not pathological, was certainly bizarre, but we were eventually able to show that even the most bizarre performances were under the control of orderly and manipulable factors. In no sense did they represent deviations from lawful behavior.

Some Fruits of Basic Research

Reinforcement cost. From the several changes we had made in the basic Estes-Skinner procedure, we selected two temporal variables for further study. These were (i) the period during which the clicker sounded and (ii) the period during which the clicker was silent. Using white rats as subjects, we systematically manipulated these two periods (*14*). Much to our surprise, we found that such manipulation reproduced several of the phenomena shown in Fig. 4. The most general finding, however, was that both temporal variables controlled the degree of conditioned suppression, but only when they were considered in relation to each other. An animal would press the lever at a very slow rate during a clicking period of a given duration only if there were relatively long intervals of silence between clicking periods. An example may be seen in the upper two curves of Fig. 5. With 24-minute periods of silence, the subject makes only a few responses during a 6-minute clicking period (at *a*). Suppression is nearly complete. But when the periods of silence are reduced to 2 minutes, the animal responds considerably more often during a 6-minute clicking period (at *b*). Similarly, as may be seen further down in Fig. 5, with 2-minute periods of silence and ½-minute clicking periods the subject again fails to respond (at *c*). Complete suppression reappears.

We now knew how to maintain a stable conditioned suppression in the subjects of our steroid studies and in other applications of the Estes-Skinner technique, but the real plum was another observation which illuminated the process through which the animals' behavior was controlled by the temporal variables. The subjects of the experiment had been deprived of water, and the reinforcement for lever pressing was a small drop of water. We noticed that the number of drops of water the animals received was relatively constant, about 90 percent of the maximum possible, regardless of the effectiveness of the clicker in diminishing the rate at which they pressed the lever. But, it will be recalled, conditioned suppression causes the animal to miss reinforcements, for it is only by

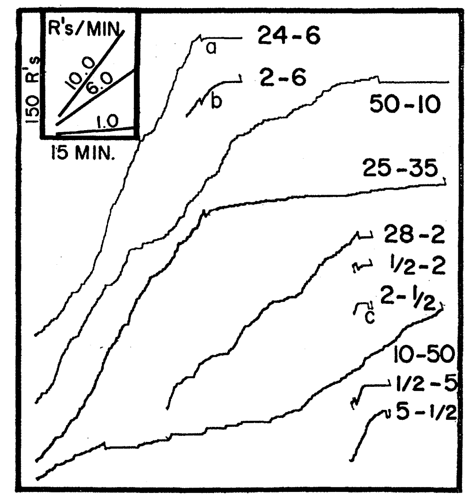

Fig. 5. Sample cumulative records made in tests with periods of clicking and of silence of various lengths. The first number of each pair designates the number of minutes of silence; the second, the number of minutes of clicking. The oblique downward displacement of each curve indicates the point at which clicking was introduced.

pressing the lever that a drink can be obtained. In other words, the animals displayed conditioned suppression only to the extent that they could do so without missing more than 10 percent of their drinks. Thus, if the clicking period was short relative to the period of silence, the animal could cease pressing the lever during the clicking and still miss relatively few drinks in the course of an experimental session. On the other hand, if the clicking period was relatively long, complete cessation of lever pressing would cause the animal to lose most of the available drinks.

Although more work must be done before the phenomenon is entirely clear, we might say, at this point, that the animals manifest anxiety only to the extent that they can afford to do so in terms of reinforcement cost.

Aversive interactions. A unique feature of the Estes-Skinner technique is its use of changes in the organism's ongoing behavior to measure the consequences of an independent but concurrent experimental operation. The effect of the warning stimulus may be described, in most general terms, as a disturbance in the pattern of behavior in progress at the time the stimulus appears. As we have seen, one form of disturbance is complete cessation of the behavior. It seems reasonable to suppose that the variables which control the base-line activity also have a role in determining the effect of the

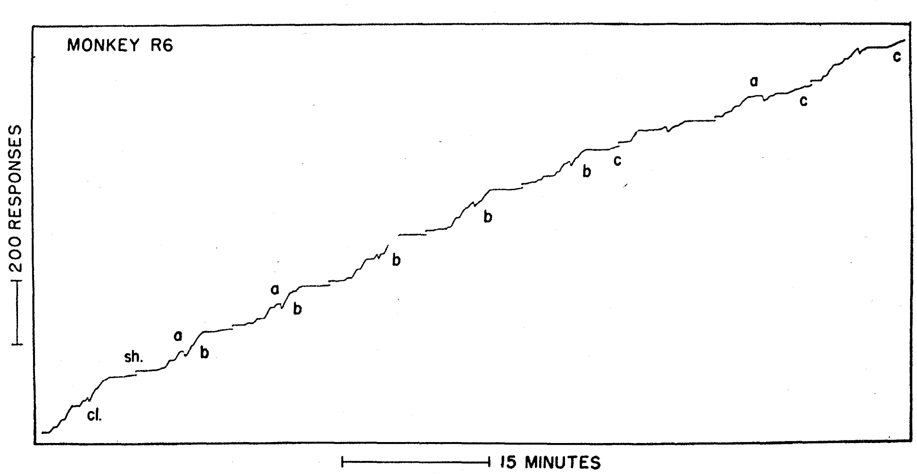

Fig. 4. Cumulative record obtained under the same conditions as those of Fig. 3, but at a later stage. See text for explanation of *a, b,* and *c.*

warning stimulus. In one of the few attempts yet made to verify this supposition, Brady found that rats reacted to a warning stimulus with conditioned suppression even when they received their water in accordance with several different types of schedules. However, when the stimulus was then presented without any shock, it was found that the type of reinforcement schedule did influence the length of time it took the animals to resume their normal rate of lever pressing (*15*). The variables controlling the normal behavior pattern, then, did affect the temporal course of the animals' "rehabilitation."

All demonstrations of conditioned suppression up to this point had one feature in common. Food or water reinforcement was always used to maintain the subjects' base-line behavior. What would be the consequence of presenting the clicker-shock sequences while the subjects were pressing a lever to avoid electric shocks?

In the experiments described below, monkeys were the subjects, and the experimental space was similar to, but larger than, that previously described for the rat (see Fig. 1). We first conditioned the monkeys to press a lever by the simple expedient of giving them a brief shock whenever 20 seconds elapsed without a lever depression. Each time they pressed the lever they postponed the shock for 20 seconds (*16*). After the animals had settled down to a relatively stable rate of avoidance responding we introduced the clicker and unavoidable shock sequence, using the earlier schedule of 5-minute clicking periods alternating with 5-minute periods of silence.

The immediate result was that the animals pressed the lever at approximately three times their normal rate, both when the clicker was on and when it was silent. In fact, they responded sufficiently often to avoid all avoidable shocks; the only shocks they received were the unavoidable ones (*17*). The monkeys then gradually slowed down to their normal rate of lever pressing. But they returned to their normal rates more rapidly when the clicker was silent than when it was sounding. There was, therefore, an intermediate phase in which they pressed the lever at a higher rate during the clicking periods than during the periods of silence. This reversal of the Estes-Skinner observation caught our interest.

We eliminated the avoidable shocks but continued to administer the unavoidable ones. The monkeys ceased lever pressing, as was to have been expected, during the periods of silence. But for a long time they persisted in lever pressing during the clicking periods. Figure 6 shows the striking reversal of the usual conditioned suppression; the animal practically never responds during periods of silence or during the initial minutes of the clicking periods. But as the time approaches for shock, the monkey begins to press the lever rapidly and continues until it receives the shock. Immediately after the shock, it again ceases pressing, and another cycle begins. This phenomenon is called conditioned facilitation.

Does conditioned facilitation during the clicking period represent a breakdown of the lawfulness to which we have become accustomed in our experience with the Estes-Skinner technique? From an adaptive point of view, the facilitation of lever pressing makes no more sense than does suppression. The shock is inevitable, and the animal's high response rate during the stimulus represents only so much wasted energy. It would take very little stretching of the imagination to class this behavior as pathological. Yet, as we shall see, it results from normal processes at work in a slightly unusual setting.

When an animal that is pressing a lever for food is first exposed to the clicker-shock sequence it may initially cease pressing both when the clicker is on and when it is silent, even though it receives shock only while the clicker is on. This may be thought of as a generalized effect of unavoidable shock. A corresponding generalized effect, an over-all increase in response rate, is initially observed when the lever pressing has served to postpone shock. In their first stages, then, the two effects are opposite in direction but similar, perhaps, in origin.

A second stage occurs when the initially generalized effect of shock is channeled into the clicking period. A monkey working for food returns to its normal rate of lever pressing during periods of silence but continues to display suppression during the clicking periods. Similarly, a monkey pressing the lever to avoid shock returns to its normal response rate during periods of silence but continues to display conditioned facilitation during the clicking periods.

If this were the whole story, both the suppression and the facilitation might well be construed as emotional reactions to the unavoidable shock, the precise form of the reaction depending upon the subject's past experience of shock. Perhaps some such formulation could encompass the observations thus far discussed. But one additional observation does not fit. Under appropriate conditions, some of which I discussed above, the conditioned suppression becomes fixed at the second stage. The conditioned facilitation, on the other hand, goes through a third phase. It disappears. It is really a transitory phenomenon, though its life span and magnitude are sufficiently great to merit

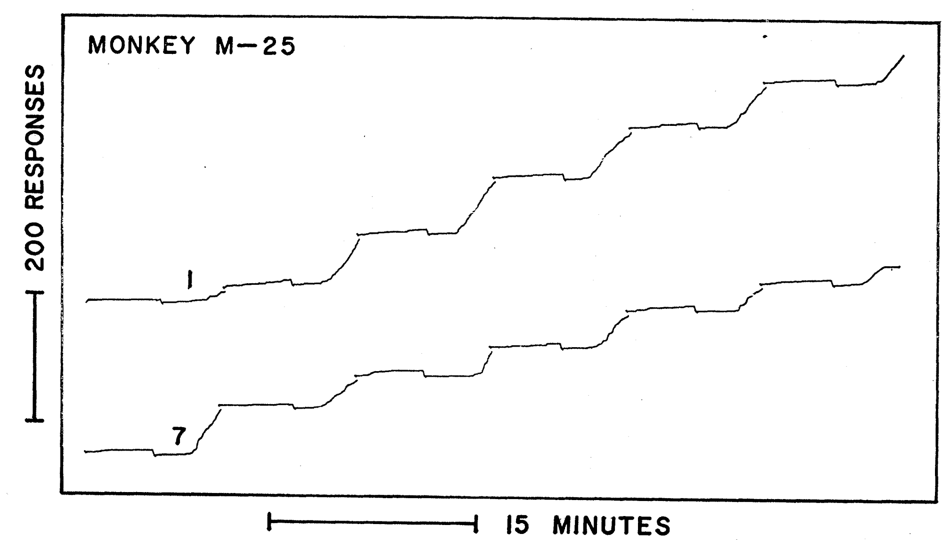

Fig. 6. Response facilitation during the period of clicking prior to shock. The introduction of clicking is marked by the downward displacements in the record. The lower curve is actually continuous with the upper one, but has been displaced for compact presentation. The first and seventh clicking periods of the session are labeled.

both experimental and clinical attention. The impermanence of the facilitation places it in a different category from the suppression.

We can, however, hold on to the notion that avoidance conditioning is a prerequisite if the animal's rate of lever pressing is to increase, rather than decrease, during the clicking periods. If an organism has learned a successful shock-avoidance response, what is more appropriate, in a situation in which shocks occur, than that very response? The source of control of the facilitation may be the normal processes which govern the subject's previously acquired avoidance behavior. But we are still faced with the fact that the animal actually cannot avoid the shocks. On many occasions the monkey is almost immediately punished by the shock for its increased rate of lever pressing during the clicking period. How can we reconcile the inevitability of the shock with an explanation based upon the normal and orderly processes that underlie successful avoidance behavior?

The difficulty is more apparent than real, but I have not simply been building up a straw man. I have examined the problem in detail because its simple solution reveals a form of behavioral control which, because of its subtlety, one might easily overlook. In the actual relations between the shock and facilitated lever pressing two facts are to be noted. First, the monkey receives only one shock during each 5-minute clicking period; hence, only an extremely small proportion of its lever-pressing responses are actually punished. From the subject's point of view, lever pressing, by which it has in the past effectively avoided shocks, seems to remain largely successful. Avoidance of shock still reinforces lever pressing, even though the relation is a spurious one. The monkey's behavior during the clicking period is nonadaptive because the rules of the environment have changed and the changes have not yet elicited appropriate response modification. The occasional shocks only serve as false discriminative cues to keep the animal behaving in a fashion appropriate to the former circumstances.

The second point concerns the temporal relation between response and shock implied by the term *punishment*. The time interval that elapses between an unavoidable shock and the immediately preceding lever response is variable. In other respects the situation is exactly the same as that during the original avoidance conditioning. Originally, the monkey postponed the shock for 20 seconds each time it pressed the lever. Now, the shock sometimes occurs 2 seconds after a response, sometimes 200 seconds after, sometimes 20 seconds after, and so on. We have already demonstrated that animals will continue to avoid shock successfully when we systematically vary the amount of time they postpone shock with each lever press (*18*). In the present case, the variation is governed not by the experimenter but by the vagaries of the subject's own lever-pressing. The contingencies are spurious, but the control they exercise is real.

In its late stages at least, facilitation during the clicking period may properly be understood as avoidance behavior which the monkey continues to manifest because of a combination of historically real and currently adventitious contingencies. It is not nearly as general a phenomenon as conditioned suppression; it requires an organism with a particular type of behavioral history, and it requires a unique set of current circumstances which serve to perpetuate the processes that stem from this history even after they are no longer relevant to the demands of the environment.

Direct manipulation of the monkey's behavioral history in a subsequent experiment effectively demonstrated its relevance. In the first phase of the experiment we conditioned the monkey to press the lever by reinforcing it with food. Once the monkey was pressing the lever at a steady rate, we introduced the clicker-shock sequences until a conditioned suppression developed during the clicking period.

The next step was to add an avoidance component to the subject's behavioral repertoire. We disconnected the food-delivery mechanism, the clicker, and the mechanism that delivered the unavoidable shock. Pressing the lever now served to postpone shocks for 20 seconds. Finally, the monkey was again given the opportunity to procure food by pressing the lever without receiving shocks at any time. The variables were the same as in the first phase of the experiment, but the monkey's experience with shock was different.

When we again introduced the clicker-shock sequences the avoidance history proved to be dominant. Whenever the clicker sounded the monkey pressed the lever at a much higher rate, even though it was working for food (*19*). By interpolating a period of avoidance conditioning between the two stages of the Estes-Skinner procedure we had changed conditioned suppression to facilitation. The conclusion seems inescapable that the facilitation represents a form of avoidance behavior, irrational perhaps, certainly ineffective, but nonetheless derived from identifiable and orderly sources of control.

A final set of experiments provided us with an unexpected view of the twisted fashion in which normal behavioral processes can manifest themselves (*20*). Our initial aim was simple enough. We had seen that the effect on a given response of a stimulus that precedes a shock will depend upon the history of that response. If we now select for simultaneous observation two different responses, one of which the monkey has used to procure food and the other of which it has used to avoid shock, will a warning stimulus generate two concurrent but opposite reactions in a single animal?

To answer this question, we made two opportunities simultaneously available to the monkey. Hanging down from the ceiling of the chamber was a chain, and pulling this chain occasionally paid off with food, while pressing a lever mounted on a wall of the chamber postponed shocks for 20 seconds. Both the food schedule and the avoidance program were in effect concurrently. The monkey adjusted appropriately to the contingencies, sometimes pulling the chain and sometimes pressing the lever.

Clicker-shock sequences were then introduced, and the avoidable shocks—shocks previously governed by lever pressing—were eliminated. The only shocks the monkey received were the unavoidable ones that followed the clicking periods. In line with previous findings, we expected the monkey, during the clicking period, simultaneously to reduce its rate of chain pulling, displaying conditioned suppression, and to increase its rate of lever pressing, displaying conditioned facilitation.

In fact, the animal's rates of response for both chain pulling and lever pressing rose during the clicking periods. There was no evidence of suppression. Rates for both types of response were relatively low during periods of silence. This was the pattern for a response with an avoidance history, yet we had not provided the food-reinforced response with such a history. Did this mean that the lawfulness revealed in the prior experiments is missing when two response systems within a single organism are simultaneously exposed to the Estes-Skinner procedure? Such an interpretation would be consistent with the classical view of behavior pathology, and, if we had accepted it, we should have stopped work at that point. As it turned out, however, our resistance to the classical view permitted us to round out the story. The final experiments not only revealed orderly processes but, in addition, permitted us to explain some material classically considered pathological.

We found that our monkey's two concurrent responses were not entirely independent. For example, we returned the animal to the initial training procedure in which it produced food occasionally by pulling the chain and avoided shock by pressing the lever. We then disconnected the feeding mechanism. But even though no food was forthcoming, the animal continued to pull the chain at a relatively high rate. The monkey stopped pulling the chain only after we had also disconnected the shock, thereby causing it to stop pressing the lever. Only with the cessation of avoidance behavior did the monkey cease pulling the chain. It seemed clear that the food-reinforced behavior was being controlled in some way by the avoidance contingency, even though no such control was demanded by the experimental arrangements. The process through which this control developed is a most fascinating one, for it takes us, in a manner of speaking, into the "inner life" of our animal subjects.

We have already described the facilitating effect of the warning clicker as a case of adventitiously reinforced, or "superstitious," avoidance behavior. (I use the term *superstitious* in the operational sense in which Skinner uses it, to describe a situation in which a particular response is correlated only by chance with a reinforcing state of affairs (*21*). Even though the behavior may not actually produce the reinforcement, and though the correlation may not even be advantageous to the organism, the reinforcing effect is not thereby weakened.) The monkey's behavior during the stimulus period is reinforced by the seeming avoidance of shocks. We, as experimenters, know that the animal would not have received shocks anyway, even if it had not pressed the lever, but our monkey is a prisoner of its behavioral history.

The subject was free to make the two possible responses in any sequence. If it frequently pulled the chain and then pressed the lever, the pattern might become established as superstitious avoidance. If the monkey could speak, it might well tell us that it was avoiding the shock by first pulling the chain and then pressing the lever. The chain-pulling response, though reinforced with food, might also develop an avoidance component, which would explain the increased rate of chain pulling during a clicking period.

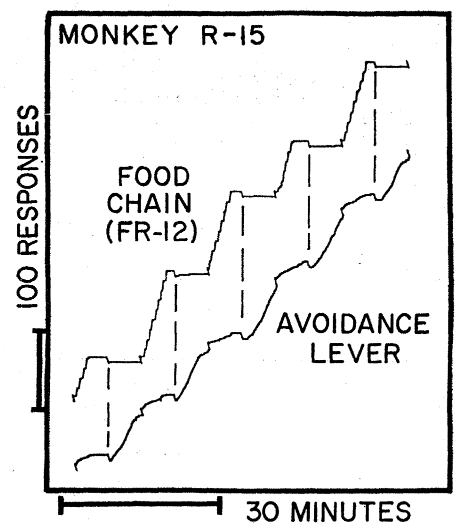

Fig. 7. Concurrent cumulative records for chain pulling and lever pressing. The portions of the records displaced obliquely downward denote clicking periods that preceded shock. The broken lines connect temporally corresponding points (introduction of clicking) on each curve.

Being both unable and unwilling to rely upon the verbal report of our subject, we made an experimental search for adventitious reinforcement processes. We found that the monkey was actually making the two responses in sequences of the sort that would favor the development of a superstitious avoidance pattern. There was only a low probability that the animal would pull the chain twice without pressing the lever in between; the vast majority of chain-pulls were followed by lever presses. There was abundant opportunity for chain pulling to be correlated accidentally with the avoidance of shock.

There remained only the task of breaking up the alternation pattern and thereby eliminating the avoidance component of the food-reinforced response. This was accomplished by utilizing a bit of behavioral technology. Up till now only an occasional chain-pull had paid off on a temporal schedule. The schedule was changed so that the animal had to pull the chain a fixed number of times to procure food. Since such a schedule favors the reinforcement of rapid bursts of responses (*3, 22*), there should be a tendency for the monkey to make several chain-pulling responses in succession before switching to the lever.

The new schedule accomplished its purpose. The likelihood that the animal would press the lever after only a single chain pull decreased markedly. Instead, the monkey showed a marked tendency to pull the chain several times before pressing the lever. The typical pattern of bursts and pauses may be seen in the upper curve of Fig. 7.

Figure 7 also indicates that we eliminated the superstitious avoidance component of the food-reinforced response. For now, when we introduce the clicker-shock sequence there is no increase in the monkey's rate of chain pulling. The clicking simultaneously suppresses the food-reinforced response and facilitates the avoidance response. Although both forms of response exist simultaneously in the same organism, each is affected by the clicking according to its own history.

It has been necessary to report the experiments in such detail in order to illustrate the complete normality of the processes underlying our initial finding of facilitation in both responses. In tracking these processes down, we have seen how they may act to produce some bizarre manifestations. Thus, behavior which has no real connection with the shock must nevertheless be diagnosed as avoidance behavior, spuriously maintained as part of an avoidance pattern. Then, this behavior, already under spurious control, perpetuates itself during the clicking period by seemingly permitting the animal to avoid shocks that would not have occurred anyway. Such behavior may be called "second-order superstition." If this is "sick" behavior, the processes that generate and maintain it are healthy enough.

Whether these particular experimental phenomena are indeed basic to the understanding, diagnosis, and treatment of clinically observed behavior pathology remains an open question. But there can be no doubt that such experimental manipulation has the necessary power and subtlety to uncover processes relevant to clinical observations. The clinical psychologist need no longer seek his experimental foundations among demonstrations of behavioral chaos. The experimentalist, too, would do well to cultivate an interest in pathology as a source of insight into normal behavioral processes (*23*).

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Science and Human Welfare

The AAAS Committee on Science in the Promotion of Human Welfare states the issues and calls for action.

For nearly two decades, scientists have viewed with growing concern the troublesome events that have been evoked by the interaction between scientific progress and public affairs. With each advance in our knowledge of nature, science adds to the already immense power that the social order exerts over human welfare. With each increment in power, the problem of directing its use toward beneficial ends becomes more complex, the consequences of failure more disastrous, and the time for decision more brief.

The problem is not new, either in the history of human affairs or of science. What is without past parallel is its urgency.

Four years ago, the report of the AAAS Interim Committee on the Social Aspects of Science (*1*) stated: "We are now in the midst of a new and unprecedented scientific revolution which promises to bring about profound changes in the condition of human life. The forces and processes now coming under human control are beginning to match in size and intensity those of nature itself, and our total environment is now subject to human influence. In this situation it becomes imperative to determine that these new powers shall be used for the maximum human good, for, if the benefits to be derived from them are great, the possibility of harm is correspondingly serious."

The Interim Committee also concluded that "there is an impending crisis in the relationships between science and American society. This crisis is being generated by a basic disparity. At a time when decisive economic, political, and social processes have become profoundly dependent on science, the discipline has failed to attain its appropriate place in the management of public affairs."

In the last few years the disparity between scientific progress and the resolution of the social issues which it has evoked has become even greater. What was once merely a minor gap now threatens to become a major discontinuity which may disrupt the history of man.

Recent events have lent substance to the conviction of our committee and of its antecedent groups—and we believe to that of scientists generally—that scientists bear a serious and immediate responsibility to help mediate the effects of scientific progress on human welfare, and that this obligation should be reflected in the program of the AAAS.

In the present report we endeavor to translate this conviction into action by suggesting a general approach and some specific procedures which may serve as a guide for the development of a AAAS program on the role of science in the promotion of human welfare.

Now, as in 1956, our premises are these (*2*):

1) We are witnessing an unprecedented growth in the scale and intensity of scientific work.

2) This growth has been stimulated by an intense demand for the practical products of research, especially for military and industrial use.

3) The public interest in, and understanding of, science is not commensurate with the importance that science has attained in our social structure. It cannot be said that society provides good conditions for the proper growth of science.

4) For reasons such as those just cited, science is experiencing a period of rapid but rather unbalanced growth. Basic research, which is the ultimate source of the practical results so much in demand, is poorly supported and, in the view of some observers, lacks vigor and quality.

5) The growth of science and the great enhancement of the degree of control which we now exert over nature have given rise to new social practices, of great scope and influence, which make use of new scientific knowledge. While this advance of science has greatly improved the condition of human life, it has also generated new hazards of unprecedented magnitude.

Members of the committee are Barry Commoner, Washington University, *chairman*; Robert B. Brode, University of California, Berkeley; Harrison Brown, California Institute of Technology; T. C. Byerly, Agricultural Research Service; Laurence K. Frank, 25 Clark Street, Belmont, Mass.; H. Jack Geiger, Harvard Medical School; Frank W. Notestein, Population Council, New York; Margaret Mead, American Museum of Natural History (ex officio Board representative); and Dael Wolfle, AAAS (ex officio).