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2

**COGNITION AND PERFORMANCE: THE RELATION
TO NEURAL MECHANISMS OF CONSEQUENCE,
CONFIDENCE, AND COMPETENCE**

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INTRODUCTION

In 1968 at a UNESCO meeting on brain and human behavior, Skinner stated that he was interested in the environmental contingencies that produce reinforcement. I remarked that if this were so, then reinforcement must be conceived as a process whose locus could be nowhere else than the brain. In contributing this chapter, then, I take the opportunity in examining some of the issues that have made the concept of reinforcement, from a structural point of view, so central in behavior theory. Skinner (1976) has clearly opted for a descriptive functionalism in his search for the laws governing behavior. Those of us contributing to this volume are, for the most part, searching for process and mechanism. This approach shows kinship with cognitive psychology, and one of the staples of cognitive psychology is the distinction between surface and deep structure, between performance and competence. Thus one of the aims of this chapter will be to bridge the current chasm between functional behavior theory and the structures of cognitive psychology. These "structures" are conceived as patterns describing processes (see, e.g., Saussure, 1922; Miller, Galanter, & Pribram, 1960; Merleau-Ponty, 1963). Thus, the keystone to the bridge between behavioral performances (processes of organism-environment interaction) and structural competence (neural processes) may well be furnished by the concept of reinforcement, a concept that was originally invoked to explain learning, i.e., sustained changes in behavior.

The burden of an earlier paper, *Reinforcement Revisited* (Pribram, 1963), was to point out that the framework of functional learning theory was inadequate to explain the effects of reinforcers in a variety of conditions. The proposal was made that in addition to learning theory—or encompassing it—we need a structural theory of performance. As research has developed, performance theory has in fact been formulated: It now makes up the bulk of cognitive psychology. However, cognitive theorists rarely resort to the concept of reinforcement. It is therefore useful to trace once again the experiments that establish the relationship of reinforcement to performance, not only to changes in performance but to the stabilities that give rise to such concepts as confidence and competence.

CONSEQUENCE

Operant Conditioning

“Reinforcement increases the probability of recurrence of a response.” This simple definition, proposed by Skinner, has provided an excellent beginning and a steady guide to those who use operant techniques in the study of behavior. Because of its tight circularity, however, the definition leaves something to be desired when the question is asked: What is the neurological process concerned in reinforcement? But even here, experiments of the operant type can fruitfully initiate the inquiry.

Much has been done in this direction. According to the definition, behavior occurs and is followed by a contiguous event. This may be called the outcome or consequence of that behavior (which may be the case or may be acted on by the subject as if it were the case, i.e., as in a superstition). The contiguous event may “shape” the behavior. When this happens, the probability of recurrence of the contiguous response increases (and in many instances the probability of recurrence of other responses in the subject’s repertoire in that situation decreases). Whenever this constellation of environment-organism interactions is observed, the event consequent to the behavior is described as reinforcing the behavior. Note that whenever this same constellation of events occurs and the event that increases the probability of recurrence of a response *antecedes* it, the event is called a discriminative stimulus. One property of reinforcers, therefore, is that they are *consequent* to responses, and are often consequences of actions.

But reinforcing events per se do not affect behavior in a completely predictable fashion. To take an extreme case, one can set up an operant conditioning experiment in such a way that the number of reinforcers obtained during two equal-length testing sessions is the same, though in one the reinforcers are programmed according to a fixed ratio, and in the other, according to a fixed interval schedule. The behavior displayed by the organism in these two situations is strikingly different. On the ratio-controlled task, the subject shows a continuous, linear, and stable performance curve. Performance controlled by the fixed interval program is cyclical, the curve showing scallop due to a crescendo of activity

that reaches a maximum at the moment reinforcement is due. Reinforcers, therefore, have a second important property related to the first: They control behavior through their temporal organization, that is the way they are scheduled or programmed. Reinforcers are *consequences*.

Productive experimental analysis of reinforcement based on the initial definition has been undertaken by David Premack (1959). Premack begins by measuring the rate of response in a given situation (e.g., the rate of eating) and comparing this rate with another, obtained independently (e.g., the rate of lever pressing per se). He suggests that reinforcement occurs whenever the response with the lower independent rate (lever pressing) coincides, within temporal limits, with the stimuli that govern the occurrence of the response with the higher independent rate (eating). An ingenious set of experiments has been presented in support of this view. One of these is of special interest (Premack, 1962):

Parameters were identified for the rat which both made drinking more probable than running and running more probable than drinking. In the same subjects, depending upon which parameters were used, running reinforced drinking and drinking reinforced running. This relationship suggests that a "reward" is simply any response that is independently more probable than another response (p. 255).

Specifically, an activity wheel equipped with a brake and a retractable drinkometer were used:

Drinking contingent upon running was arranged by retracting the drinkometer, freeing the wheel and making availability of the drinkometer contingent upon running. Conversely, running contingent upon drinking was arranged by locking the wheel, moving in the drinkometer, and making release of the wheel contingent upon drinking (p. 255).

Other instances of such reversals among reinforcers will be discussed below in relation to the means-ends problem. Here, I should rather turn to two other matters. First, Premack's experiments and his analysis clearly establish that a response sequence is reinforcing to the extent that it occurs in the context of another response sequence (of lower independent rate). This contextual relationship adds a new and important dimension to the definition of reinforcement.

Second, Premack discusses only the relation between responses. He fails to define fully the immediate operations that define response. Response, in an operant situation, is the indicator of behavior, the indicator that the organism has acted in and on the situation. The action includes not only the patterned muscular contraction (movement) of the organism but the consequences of that movement. (In fact the response, the indicator of the action, is one of these consequences.) The response rates studied by Premack refer not so much, therefore, to the rapidity with which the movements of the organism take place, but to the rapidity with which some reliably observed consequences of these movements can be recorded. For instance, in one set of experiments, a Cebus monkey was used. The monkey might well have been smacking his lips, circling in the cage, or turning somersaults. These were irrelevant movements—and not recorded in the situation as responses, since manipulation of lever, door, and bin were the actions under study. And the particular movements involved in these actions

are also pretty much irrelevant—the monkey could use his right or left hand, his feet, or even his head to accomplish the response.

What I want to emphasize is that the response, as used in the operant situation, is an indicator of the stimulus aspects of the action, that is, the consequences of that action. Premack's contribution, that response sequences occurring in the context of other response sequences are reinforcing, may thus be more generally restated: Reinforcers are *consequences* of behavior, that is, event sequences that occur in the context of other event sequences.

Contiguity as Readiness

As a definition then, reinforcement can be seen as a consequence of behaviors. But what about mechanisms? Is it so, as many would hold, that reinforcement occurs by contiguity? Assuredly, the proponents of contiguity could not simply mean just this. And yet when one reviews Guthrie and Estes, contiguity is exactly what they mean and hope to mean. Let us listen for a moment to Guthrie: "A stimulus pattern that is acting at the time of response will, if it recurs, tend to produce that response" (Guthrie, 1942, p. 23). Estes' (1958) analysis of the drive-stimulus explanation of drive is certainly in this vein. Guthrie and Estes differ, however, on one point. For Guthrie, "we learn only what we do" (p. 24), and "a student does not learn what was in a lecture or in a book. He learns only what the lecture or book caused him to do" (p. 55). For Guthrie, behavior becomes "its own chief guide" (p. 37) by way of its consequences (movement produced stimuli). For Estes, behavior (i.e., the probability of any response) is guided by sets of stimuli sampled probabilistically, each with its own weight (a parameter determined from the data). However, Estes does not do away with conditions of reinforcement—these "are such that drive cues and experimentally controlled signals will become conditioned (associated) to the same responses" (p. 46). More of this later. Here the point is that we meet contiguity again and again, yet there is a definite difference in emphasis! Guthrie emphasizes response consequences; Estes, stimulus association. Perhaps in this difference lies the heart of the problem of what constitutes contiguity.

What happens when experimentally controlled signals are repetitiously presented to an organism in a constant situation? The organism habituates.

Habituation has received a good deal of attention from neurophysiologists and psychophysicists during the past decades, altering our conception of the process radically. One critical experiment was performed in Moscow by Eugene Sokolov (1960). A tone beep of specified intensity and duration was presented at irregular intervals to a subject whose electroencephalogram, galvanic skin response, and plethysmographic record were traced. At the onset of such an experiment, characteristic changes in these traces are observed. These accompany behavioral alerting and are known as the orienting reaction. As the experiment proceeds, these indices of orienting become progressively more attenuated until the beep of the tone no longer seems to have any effect. This is habituation. At

this point Sokolov reduced the intensity of the tone without changing any of its other characteristics. Immediately, the electrical traces from the subject signaled an orienting reaction. Sokolov reasoned, therefore, that habituation could not be simply some type of fatiguing of sensory and neural elements. Rather, a representation of the input must be set up in the central nervous system against which incoming sensory signals are matched. Any *change* in signal would result in the orienting reaction. He tested his idea by habituating his subjects anew and then shortening the tone beep. Now the orienting reaction occurred at the moment the shortened beep ended. The electrical traces showed the alerting reactions to the period of *silence*.

The neural mechanism involved in the orienting reaction and its habituation has been the subject of psychophysiological experiments on man (Luria, Pribram, & Homskaya, 1964) and nonhuman primates (Kimble, Bagshaw, & Pribram, 1965; Bagshaw, Kimble, & Pribram, 1965; Bagshaw & Benzies, 1968; Pribram, Reitz, McNeil, & Spevak, 1974). The results of these experiments delineated a system centering on the amygdala, which is critical to phasic visceromotoric concomitants of orienting. In the absence of such phasic "arousal" responses, behavioral habituation of orienting is delayed and even precluded. The conclusion was thus drawn that visceromotoric responses were intimately involved in the setting up of a neural representation of input as a function of orienting.

There is thus ample evidence for the occurrence of some representation of input in the central nervous system and its appendages against which incoming signals are matched. The representation is gradually built up; it may be conceived as a neurally coded model of prior signals generated by organism-environment interaction; it is subject to alteration by signals of mismatch. (i.e., a partial match); it leads to "expectancies" of the environment by the organism; its implications for psychology (e.g., in perceptual readiness) have been detailed (Bruner, 1957). Here it is necessary only to point to the facts of the process and to ask what its existence means for the contiguity position.

Contiguity theorists work on the assumption that behavior can be predicated from lawful relations between simultaneously occurring stimulus events and between these and responses. The facts of habituation show that a stimulus event arises from a partial match between a central process and an environmental occurrence. The central process in turn has been formed by the prior occurrence of partial matches between central process and environmental events. Another way of stating this is to say that at any moment in time the central process provides the context in which stimuli arise. Contiguity of stimuli comes to be seen not as some vague "association," but a process occurring as a context-content relationship. And if this is so, stimulus contiguity theory and expectancy theory become brothers under the skin—that is, in the central nervous system. In short, contiguity depends on the readiness of the organism to process an input.

Let us return to Guthrie and Estes. The emphasis in both the "behavior is its own guide" and the "stimulus sampling" approach must, in the light of these results, begin to stress the importance of the *temporal* organization of contiguity.

Organisms do not respond to *any* occurrences that happen simultaneously, contiguously. Their behavior is guided by *stimuli*, including those consequent to behavior. And stimuli are context-determined events, "sampled" on the basis of a central process (a neural "set") determined by *prior* experience and by other central events. An organism's behavior is thus context determined, and is, as well, context determining: Response-produced events, the outcomes of behavior, consequences, are more than likely (i.e., have a high probability) to partially match a central process and thus act as stimuli, behavior thus becomes its own guide.

In summary, the organization of contiguity is a progressively differentiating context-content structure. For the contiguity position, therefore, reinforcements come to be response sequent events occurring in context, that is, consequences.

CONFIDENCE

Perceptual Reinforcement as Information Processing

In 1960 I offered the suggestion that the differentiation of structure by way of reinforcement is "the reverse of the coin of similarity" and, of course, many others including Tolman (1932) and Postman (1953) have conceived of reinforcement as providing "information."

But perhaps the model has its greatest power in the description of what constitutes reinforcement for the organism. The posterior intrinsic mechanism, because of the hierarchical nature of its selective control over its own modification, allows a change in the representation to occur by trial and error. Whenever the error signal is such that the corrective change is not uniquely specified, the representation is modified to include this information, and trials continue. Thus an organism that possesses this mechanism can, given a relatively unchanging or slowly changing environment, search that environment for the additional information that is needed to make the organism fully informed. The neural model would thus account for the search through negative instances as these are defined in the stimulus-sampling type of stochastic learning theories (Bush & Mostellar, 1951; Estes, 1950, 1955; Green, 1958), search by an information-hungry organism reinforced or satisfied only when corrective change of the representation is immediate and can be deduced uniquely from the error signal. Stated in this way, reinforcement becomes one side of the coin of similarity (Pribram, 1960, p. 18).

There I was concerned with what Bruner (1957) has called perceptual readiness and Postman calls the arousal of perceptual response dispositions (1953, p. 86). Here I have been discussing reinforcement as a process that progressively differentiates a context-content structure.

The evidence that perceptual differentiation takes place need not be reviewed here. The work of the Gibsons (1955) is well known, as are Hebb's (1949), Piaget's (1955), Postman's (1953), and Bruner's (1958) contributions. I should rather address myself to two questions: (1) Is the concept of reinforcement tenable in this area of problems; and (2) what is the connection between progressive differentiation, hierarchy, and the model of the biased homeostat?

If reinforcement is conceived as differentiating the consequences of behavior, what is the behavior involved in perceiving? Operant conditioning has admitted "looking responses" to its repertoire. Looking certainly involves muscular contractions, the muscles of the eye must move it to make and maintain contact with the exciting energy. Focusing the retinal image also involves the muscles of accommodation. In hearing, the muscles of the middle ear have been shown important to the process of habituation in this modality. And sniffing is certainly a part of perceiving olfactory cues. Further, the experiments of Ivo Köhler (1964) and of Held (Held & Hein, 1958; Held & Schrank, 1959) have shown that perceptual performance depends in good part on more general performance experience in the situation. Finally, there is the well-known fact that passive pushing of the eyeball leads to blurring of vision, while active movement "pre-sets" the perceptual mechanism in such a way that vision is possible. Evidence of this sort has been collated by Teuber (1960) and given a theoretical base. A somewhat similar model for the process has recently also been detailed by MacKay (1957a, b; 1958a, b). And the model is essentially the model of reinforcement with which we are concerned (Pribram, 1960). The consequences of looking must involve events subsequent to context, context which is active in moving the eye. This context must be some self-adapting error-sensitive mechanism that has control over its own input; in other words, a biased, settable, homeostaticlike feedback structure. However, I need not detail anew such a model here. Floyd Allport (1955), after his classic, critical, and comprehensive review of theories in perception, was led by his analysis to propose the outlines of a structural model. Let us look in on his event-structure theory of perception:

The first step of the theory is the conceptualization of a complete and potentially repetitive cycle of ongoings and events Both these effects [positive interaction and inhibitory interaction between cycles] might be present in one . . . system, as in the principle of negative feedback, if the main line production is also considered as a cycle

We now proceed to a further step. The closed chain of ongoings and events, since it is neither open-ended nor indefinitely extended in space, but a real (cyclical) entity, can be used as a unit of a structure of a larger or "compounded" type The total structure is the "including" structure In other words we can build a "higher order" of structures made up of a cycle of cycles of ongoings and events. Still higher orders can be structured as cycles of these larger cycles, and so on. This development of the model will be called the property of "order." It should now be noted that the principle of ordering is not limited to event-cycles; it can apply also to event-systems [pp. 635-636].

Allport presented his theory of event-structure as a way of looking at the problems of perception, not as a definitive theory. The similarities of his view to those expressed in the last section leaves little doubt that event-structures in perceptual theory and reinforcement (viewed structurally) in learning and in performance have many essential properties in common. So conceived, event-structuring is a process through which the consequences of perceptual acts (e.g., looking) become ordered, much as this ordering takes place in the development of skills. Perceptual problems can, in this light, be approached as if they were sensory performances. Differences between motor (i.e., instrumental) and

perceptual performances would quickly show themselves—for sense organs and the striped musculature of the organism are differently related to their environment.

But it remains now to be shown that the neural organization of perceptual performance partakes of the properties assigned to reinforcing events. In discussing the structure of contiguity, the facts of the orienting reaction to “novel” stimuli and of habituation were presented. There is now direct evidence that these processes take place in a neural mechanism closely connected to sense-organ function. Lettvin *et al.* (1961) described the following reactions of cells in the frog’s optic tectum:

“Newness” neurons: These cells have receptive fields about 30° in diameter . . . They are distributed so as to map continuously the visual field with much overlap. Such a neuron responds a little to sharp changes in illumination. If an object moves across the receptive field, there is a response whose frequency depends on the jerkiness, velocity, and direction of the movement, as well as on the size of the object. There is never an enduring response [p. 773].

“Sameness” neurons: Let us begin with an empty gray hemisphere for the visual field. There is usually no response of the cell to turning on and off the illumination. It is silent. We bring in a small dark object, say 1 to 2° in diameter, and at a certain point in its travel, almost anywhere in the field, the cell suddenly “notices” it. Thereafter, wherever that object is moved it is tracked by the cell. Every time it moves, with even the faintest jerk, there is a burst of impulses that dies down to a mutter that continues as long as the object is visible. If the object is kept moving, the bursts signal discontinuities in the movement, such as the turning of corners, reversals, and so forth, and these bursts occur against a continuous background mutter that tells us the object is visible to the cell.

When the target is removed, the discharge dies down. If the target is kept absolutely stationary for about two minutes, the mutter also disappears. Then one can sneak the target around a bit, slowly, and produce no response, until the cell “notices” it again and locks on [p. 774].

My interest in “perceptual readiness” and a model that would account for it stems from the results of a series of neurobehavioral experiments. Some years ago, in our analysis of the functions of the posterior “association” cortex of monkey, we discovered an area on the inferolateral surface of temporal lobe that functions in vision (Blum, Chow, & Pribram, 1950). Additional work showed that lesions in this locus disturbed visual behavior only—somesthetic, taste, and auditory functions could be assigned elsewhere. Further, all sorts of visual choice behaviors were disrupted: Choices among colors, patterns, objects, luminances were equally affected, provided the task was equally difficult (number of trials to learn) for unoperated, normal monkeys (Pribram, 1954). Finally, vision was not affected if *choice* was not involved: The monkey could groom, pick a gnat out of midair, and gauge his rate of lever pressing according to the level of illumination in a “ganz-field” (Ettlinger, 1959). The variables that influence choice were also investigated: Stimulus object similarity (Mishkin & Hall, 1955) and factors influencing response difficulty (Pribram & Mishkin, 1955) were found important. But in a test of importance of the amount of information processed by the monkeys, i.e., the effect of varying the number of alternatives in the situation, an interesting fact came to light. The performance difficulty of the

lesioned monkeys was related not to the amount of information, the number of alternatives in the situation, but to the number of alternatives sampled, the lesioned group of monkeys consistently made their choices from among a smaller set of stimulus objects than did the control subjects (Pribram, 1961).

The anatomical relations of this inferolateral portion of the temporal lobe are therefore of interest. There is no direct visual input to this area as far as is known today. The area is three neurons removed from the striate optic-cortex—and no further away from the auditory cortex of the supratemporal plane, and not much further, neuronwise, for that matter, from the postcentral somatosensory areas. Also, severance of the connections between striate and inferotemporal cortex by circumsection of the occipital lobe fails to affect permanently visual choice behavior (Pribram, Spinelli, & Reitz, 1969; Christensen & Pribram, 1977; Ungerleider & Pribram, 1977). On the other hand, there is an efferent feedback that originates in the inferotemporal cortex and influences visual function (Spinelli & Pribram, 1966, 1967; Lassonde, Ptito, & Pribram, 1975) via the basal ganglia (Reitz & Pribram, 1969; Buerger, Gross, & Rocha-Miranda, 1974; Pribram, 1977). A mechanism exists, therefore, that can explain the restricted sampling and related effects on visual choice behavior produced by intertemporal lesions. A defect produced in the readiness mechanism that presets the visual mechanism would result in a defect in information processing by a failure of establishing the context within which a subsequent event can become consequent, that is, reinforcing.

Drive Structures

Perceptual stimuli are not the only ones to influence behavior, however. Stimuli also rise from the metabolism of the organism and these are ordinarily classed as physiological drive stimuli. Paradoxically, the neural organization responsible for drive stimuli has been better understood than that involved in perception, while the relationship of drive to the organization of behavior the problem of motivation has been one of the most controversial topics in psychology.

Thus, the most recalcitrant problem regarding reinforcement is probably its relationship to drive. Initially this relationship was conceptualized as the drive-reduction hypothesis. This hypothesis was based on a two-factor theory of drive—that physiological needs set up tensions in the organism (these, as a rule, are manifested in increased general activity); that behavior which reduces such tensions is reinforced. Some have argued (e.g., Sheffield *et al.*, 1955) that organisms seek tension increase, that reinforcement thus accompanies tension increase. This argument does away with the need for the second factor. Drive and reinforcement are still considered covariant, however. Meanwhile, Estes (1958) has convincingly stated the case for a drive-stimulus rather than a drive-tension theory of drive. The question remains, what happens to reinforcement if drive stimuli are conceived to guide behavior directly and not via some tension-state mechanism. With respect to external stimuli, an answer has been given in

the last section: What constitutes a "stimulus" is not as simple as it seems on the surface, that is, external to the organism. The occasion for an input to become a stimulus demands an organism ready, because of an internal representation, to respond. What constitutes a drive stimulus may be similarly determined.

First, therefore, some comments on the organization of a drive stimulus. This structure is well worked out in many instances. Essentially, it results from the operation of a feedback mechanism, the homeostat (Cannon, 1929; Pribram, 1960; Von Euler, 1961), and of course the very conception of homeostasis was derived from data concerning such physiological stimulations. Such an apparatus has a sensitive element, a receptor. Specialized areas sensitive to temperature, osmotic equilibrium, estrogen, glucose, and partial pressure of carbon dioxide are located around the midline ventricular system; these areas are connected to mechanisms that control the intake and output of the agent to which they are sensitive. The areas are embedded in a reticulum (the famous reticular-activating systems), which can act to set the level (a bias) at which the sensitive mechanism throws the system into operation. As will become clear, other biases also come to regulate drives. In addition, the entire homeostat is often supplied with secondary, peripherally sensitive mechanisms that aid the more finely calibrated regulations of the agents in question (e.g., to shunt the blood in vessels of the finger tips so as to provide greater cooling or to avoid extreme cooling, on the basis of a blood-finger temperature differential biased by the body's main thermostat).

Electrodes placed in the area sensitive to glucose show an increase in neural activity to occur not when the organism is deprived, but when he has just completed a meal (or has been given intravenous glucose). On the other hand, when electrodes are placed in a region lateral to the sensitive area, the converse is found. Stimulation of the sensitive area inhibits the activity of the lateral region to which it is connected. Whereas deprivations around the sensitive mechanism lead to overeating, those in the laterally placed region produce an animal who will not eat at all. And it is the amount of electrical activity that can be recorded from this lateral region that correlates directly with the amount of deprivation of the organism (see Grossman, 1966, for review). This region is largely composed of several crossing tracts of fibers in passage, which suggests that their origins are distributed among several locations in the central nervous system. A remarkable set of neurochemical and neurobehavioral experiments (Ungerstedt, 1975; Phillips, Carter, & Fibiger, 1976; Teitelbaum, 1955) has shown that the fibers in question are the dopaminergic nigrostriatal system of the basal ganglia. These structures have long been known to be involved in determining postural set. As noted in the previous section, they are now also known to be involved in the determination of sensory sets. Thus, the finding that they are important in setting the appetitive homeostats simply generalizes their function to include all readiness mechanisms.

But the most striking contribution to the neuropsychology of the drive-related theories of reinforcement has not been in the specification of drive

stimuli but in producing reinforcement directly with central electrical excitations. Olds and Milner (1954) discovered that an animal would press a lever in order to electrically excite certain parts of its brain. Olds (1955) distinguished between physiological need, drive, reward, and punishment, and stated that the last three might all covary, or that any two might, or that each might require separate treatment. His own view was that reward and punishment were probably separable and that each would have a drive component. For Olds, physiological needs were drive stimuli; drive resulted in general activity of the organism; reward and punishment served as response selectors.

Deutsch (1960) also examined the self-stimulation effect in the light of his own theory, which also demands separation of drive and reinforcement (i.e., reward and punishment) factors. In Deutsch's theory, drive is directly derived from need and therefore can be equated with Estes' and Olds' drive stimuli. However, in the Deutsch mechanism, excitation derived from drive stimuli and that derived from reinforcing stimuli (initiated in peripherally located receptors) are apt to display different properties. These have been comprehensively reviewed (Deutsch & Howarth, 1963). Essentially three sets of experiments are reported: (1) Extinction of lever pressing and maze running was found to be a function of time from the last brain excitation, and not of the number of unreinforced lever presses or maze runs; (2) extinction of lever pressing (and maze running) was found to be delayed or interrupted by interposing conditions that would "normally" produce lever pressing (or maze running) e.g., by an aversive stimulus; (3) extinction was delayed by low voltage or low frequency, but hastened by high voltage or high frequency trains of excitation, administered to the electrode independent of response. These results show that the central nervous system referents of drive and reinforcing events can be separately manipulated, that any exclusive definition of one in terms of the other (as in the drive related theories) is difficult to maintain.

What then is the relation between reinforcement and drive? Deutsch suggests that afferent excitation derived from peripheral sensory receptors converges on a neural "link" that has already been connected to the drive stimulus. Another way of stating this is that the reinforcing event acts on a neural mechanism preset by the drive stimulus. M. D. Egger and Neal Miller (1963) have reported a series of experiments that they interpret in somewhat similar terms: The reinforcing event gives information about the drive state. In both statements the drive structure is conceived to preset the organism, to provide the context within which the reinforcing events are to operate.

Drive, structured as a biased homeostat, thus serves in turn as the bias or setting for the consequences of behavior. These, as will be described in the following section, have a structure of their own, a structure not dissimilar to that of the biased homeostat. For the present, it suffices to make clear that the drive structure can, and does in the experiments cited, bias the consequences of behavior.

To turn again to the nervous system, Olds (1955) detailed the anatomical systems of the forebrain from which self-stimulation could be obtained in his

hands. These systems, formerly called rhinencephalic, have become more widely known as the limbic areas since their relation to olfaction is relatively limited. Olds reviews the evidence:

As we mentioned earlier anatomical and physiological evidence can be cited to indicate that structures related closely or remotely to olfaction are divided into three systems: System I has direct connection with the olfactory bulb. It contains none of the structures we have discussed. System II, including septal area and some amygdaloid nuclei, is connected with system I but not with the olfactory bulb. Further, it is related to the anterior hypothalamus. This system has been implicated in diverse functions: olfactory, gustatory, metabolic, socioemotional.

Finally, system III is defined by having connections to system II but none to the first system or to the olfactory bulb. It includes the hippocampus, and the cingulate gyrus; and it is connected anatomically to the posterior hypothalamus and the anterior thalamus.

Now, the interesting fact is that our Skinner box tests, which were not even conceived when Pribram and Kruger (1954) classified limbic structures, validate the distinction between second and third system [pp. 120-121].

The validation to which Olds refers is that the rate of lever pressing increased over 50% when electrodes were implanted in system II; when the implant location was system III, rates increased from 20-32%. No endbrain stimulations in locations other than these reliably gave an increase in response rate, of 86 electrode placements there were only two (one on the edge of the lateral geniculate nucleus, the other in the white matter of the cerebrum) from which a spurious increase in response rate occurred, and this sporadically (not every day).

Our interest here centers on system II. As noted in the previous section, the amygdala is centrally involved in the orienting reaction, the phasic arousal to input. There is ample evidence that this input need not be exteroceptive. Regulation of drive stimulus is also well documented (for review, see Grossman, 1966). And although included in the limbic forebrain, the earlier neuroanatomists classified the amygdala as one of the basal ganglia. Further, there is some doubt as to whether the septal nuclei are necessary structures in mediating the reinforcing effect. It appears likely that the mesencephalic dopamine systems, the nigrostriatal (involving the caudate-putamen complex), mesolimbic (projecting to nucleus accumbens), and mesocortical pathways play an important role in the reinforcing effect (Mora & Myers, 1977; Routtenberg & Malsbury, 1969; Routtenberg, 1971; see Clavier & Routtenberg, this volume). Thus, it appears likely that the basal ganglia of the limbic system are responsible for arousal and readiness with respect to drive stimuli and that these functions are reflected in changes of bias (set) produced in the homeostatic structures of drives by the self-stimulation effect.

Finally, there is some evidence that other than drive stimuli are involved in this biasing function. The stimuli in question may perhaps be only those close relatives of drive stimuli such as olfaction (Freeman, 1960) and taste (Bagshaw & Pribram, 1953; Pfaffmann, 1960); but behavioral evidence suggests that the stimuli affected are of a still wider range (Hearst & Pribram, 1964); Bagshaw & Pribram, 1968). The full meaning of this relationship among drive stimuli, per-

ceptual stimuli, and the consequences of behavior (action-produced stimuli) is the topic of the concluding section of this paper.

Uncertainty and Risk

What then are the similarities and differences between the central processing of perceptual and metabolic (drive) stimuli? Whenever reinforcement involves the processing of stimuli, whether perceptual or metabolic, neural feedback mechanisms are apparently engaged. The processing of external stimulation involves differentiation of alternative reinforcing contingencies. Alternatives are measured as information and its obverse uncertainty (as these are defined in information measurement theory, Shannon & Weaver, 1949). The differentiation of alternatives most likely involves the joining of feedback loops in parallel (the development of "and" gates, Pribram, 1971, Chapter V) to produce an open loop, helical, feedforward mechanism. Such parallel information processing mechanisms do not merely respond to discrepancies between a bias (or set) and an input but also generate changes in set point by virtue of the interactions among biases. The interactive set of biases (set points) serves as the context into which the input must be fitted. Differentiation of alternatives, as when a discrimination task is engaged, begets uncertainty because of the enlarged set (context) about which any input must provide information. Thus the organism becomes information-hungry, uncertainty providing the "drive" that "needs" satisfying.

With regard to metabolic stimulation, the situation is similar but not identical. Once again, the processing of physiological drive stimuli involves feedbacks. However, metabolic homeostatic regulations do not appear to be joined in parallel. Rather, the join is multiple and complex (involving the development of "or" gates, see Pribram, 1969, 1971, Chapters 9, 10, 15). This results in ultrastability (Ashby, 1960) and exquisite sensitivity to error perceived as potential upset (disequilibrium). Stability in processing involves the structure of redundancy and is measured as assurance. When stability is assured, risk of error is minimal. When such assurance is lacking because reinforcing contingencies continuously vary (as in probability matching experiments), risk is high.

The neural mechanisms that are involved in the processing of information and assurance are reasonably well worked. Information processing in the visual mode, for example, depends on a circuit involving the inferior temporal "association" cortex and its corticofugal efferents to the putamen of the basal ganglia. The anatomical route to the visual system from the basal ganglia is now under study, but the effects of electrical stimulation of the circuit on visual physiology is well documented (Spinelli & Pribram, 1966, 1967; Lassonde, Plito, & Pribram, in press).

The processing of assurance depends on the limbic forebrain and its connections to hypothalamus and mesencephalic receptors as described above. Once again the basal ganglia are involved, this time their limbic representatives, the amygdala and nucleus accumbens. Further, neurochemical, neurobehavioral,

neurophysiological, and psychophysiological evidence has been reviewed elsewhere (Pribram & McGuinness, 1975; Pribram & Isaacson, 1976; Pribram, 1977) to the effect that the hippocampal formation acts to coordinate the phasic arousal processes served by the amygdala with the more tonic readiness to continue habitual modes of behavior controlled by the caudate nucleus of which the nucleus accumbens is a part. This coordination apparently joins the two feedback mechanisms (phasic arousal and tonic readiness) in parallel, so that even in limbic system function a feedforward process becomes initiated. This limbic mechanism differs from that served by the information processing mechanism of the convexity of the cortex in that control over information processing rather than the processing itself is involved.

Uncertainty and risk (or information and assurance) associated with reinforcing contingencies thus determine the *confidence* with which an organism behaves. Brain research has provided initial evidence for dissociation of these two aspects of confidence. Behavioral analyses of the structure of confidence would be timely and tests to validate this dissociation welcome.

COMPETENCE

Addictionance

There is of course still more to the problem of reinforcement. Lawrence and Festinger (1962), faced with an impasse in the learning theory derived from animal experiments, have made a statement about rat behavior in the context of a theory designed to cope with the behavior of man.

The impasse is this: Response strength, that is, the probability that a response should recur, ought to be, according to learning theory, proportional to the occurrence and immediacy of appropriate reward and inversely related to the effort expended to obtain that reward.

Recently, there has accumulated a considerable body of experimental evidence suggesting that these common assumptions underlying learning theory fail to give an adequate description of changes in response strength. In fact, there is the suggestion that under some circumstances the variables of reward, temporal delay, and effort may have just the opposite effects from those predicted by the assumptions . . . [p. 6].

This impasse is not a new one for those working in a physiological orientation. Miller, Bailey, and Stevenson (1950) found that the lesions of the ventromedial region of the hypothalamus that produce the syndrome of hypothalamic hyperphagia (overeating) do *not* induce the subject to work more for food; on the contrary, these animals will work *less* than their controls under similar conditions of deprivation. The conditions that determine this dissociation have been fully explored (e.g., Teitelbaum & Epstein, 1962). In another series of experiments, performed in our laboratories, the variables that determine the response sequence displayed in the "fixed interval" reinforcement situation were analyzed.

Overall rate of response, dependent on deprivation, was found to be sensitive to limbic system lesions, but the distribution of per cent of responses in a "scallop" was unaltered by either deprivation or limbic area destructions. Frontal isocortical lesions, on the other hand, altered the "scallop" without changing overall rate of response (or, for that matter, the rate of reinforcement, Pribram, 1961).

The evidence to which Lawrence and Festinger address themselves, however, concerns what happens during extinction. In essence, the more the effort, and the fewer and more delayed the rewards, the slower the learning, but the more resistant the behavior will be to extinction. In operant situations, behavior established under conditions of continuous reinforcement extinguishes almost immediately; behavior established under conditions of variable schedules of reinforcement is more resistant to alterations of scheduling.

In their experimental and logical analysis, Lawrence and Festinger dispose of several prior explanations forwarded to resolve this impasse. The resistance to extinction cannot be simply conceived as dependent on a failure in discrimination, and insufficiency of information, or the development of competing responses. Rather, they propose that, when "competing," "incongruent," "dissonant" sets of information are supplied to the organism, its behavior persists beyond the point expected if either set were alone operative: An animal that, during a nonchoice situation, experiences a set of conditions he is shown to choose *less* frequently in a free-choice situation will show increased resistance to extinction. In man, the "dissonant" state is stated to arise when two cognitions, that is, two sets of information, would suggest two incompatible actions. Most of the body of experiment and, I believe, much of the spirit of the argument, is concerned with the state aroused when such dissonant sets occur *in sequence*. For instance, dissonance is aroused when the result of taking some action does not lead to consequences that sufficiently "justify" the action taken. If the set of information consequent to the action were available beforehand, and choice were free, the action would not have been undertaken. Another way of stating this is to say that expectations were not met by consequences, that antecedent and reinforcing events do not match, that dissonance results from this mismatch.

Dissonance reduction can come about in two ways: (1) The organism "can convert the consequences of the act into something that 'justifies the action'" or (2) it "can change its behavior so that it becomes consonant with the consequence experienced (e.g., the animal may, during extinction, refuse to run, provided this does not lead to consequences still more dissonant). The question remains as to what consequences "justify" action (Lawrence & Festinger's "extra attractions") and what it means when behavior "become consonant with the consequences experienced."

A few observations are in order. It is common knowledge among morphine addicts that very often the strength of the addiction is proportional to the amount of "hustling" that is required to obtain the drug. In fact, in most cases, patients who have had prolonged morphine therapy and who go through with-

drawal symptoms when treatment is discontinued have an (understandable) aversion to the drug and addiction is not a particularly severe problem. Recent experiments with rhesus monkeys suggest that the situation is not much different here (Clark & Polish, 1960; Clark, Schuster, & Brady, 1961). ("Personality" variables, of course, play a considerable role; yet the overall observation holds sufficiently to affect the laws regulating morphine distribution, e.g., in the British Isles.) The similarity to the dissonance producing paradigm is unmistakable (thus the term "addictionance" theory). And the observation thus leaves us with the same unsettled and unsettling questions.

Effectance

Could it be that activity per se is rewarding? This makes little sense, for it would not account for the difference between, say, hustling and unordered, random hyperactivity. And here we may have a clue: Could it be that *ordered* activity per se is rewarding? And again, what can be meant by "ordered activity?" Certainly not patterned muscular contractions, since these are equally manifest when we observe random activity. No, clearly, when the *consequences* of action become orderly, consonant, that is, sequences appearing *in context*, then and only then is activity ("judged") rewarding, that is, reinforcing.

Support for this view comes from the experiments on autoshaping (see Schwartz & Gamzu, 1977; Dunham, 1977; Hearst & Jenkins, 1974, for reviews). Even more critical perhaps is the fact that even in infancy such essential functions as sucking can be maintained without any usual "drive-reducing" reward such as milk (Koepke & Pribram, 1967).

But what might be the process by which ordered activity per se ordinarily achieves its own reward? Mace (1962) has called attention to the fact that, in an affluent society, man and beast tend to reverse the means-end relationship.

What happens when a man, or for that matter an animal, has no need to work for a living? . . . the simplest case is that of the domesticated cat—a paradigm of affluent living more extreme than that of the horse or the cow. All the basic needs of a domesticated cat are provided for almost before they are expressed. It is protected against danger and inclement weather. Its food is there before it is hungry or thirsty. What then does it do? How does it pass its time?

We might expect that having taken its food in a perfunctory way it would curl up on its cushion and sleep until faint internal stimulation gave some information of the need for another perfunctory meal. But no, it does not just sleep. It prowls the garden and the woods killing young birds and mice. It *enjoys* life in its own way. The fact that life can be enjoyed, and is most enjoyed, by many living things in the state of affluence (as defined) draws attention to the dramatic change that occurs in the working of the organic machinery at a certain stage of the evolutionary process. *This is the reversal of the means-end relation in behavior.* In the state of nature the cat must kill to live. In the state of affluence it lives to kill. This happens with men. When men have no need to work for a living there are broadly only two things left to them to do. They can "play" and they can cultivate the arts. These are their two ways of enjoying life. It is true that many men work because they enjoy it, but in this case "work" has changed its meaning. It has become a form of "play." Work is characteristically activity in which effort is

directed to the production of some utility in the simplest and easiest way. Hence the importance of ergonomics and work study—the objective of which is to reduce difficulty and save time. In play the activity is often directed to attaining a pointless objective in a difficult way, as when a golfer, using curious instruments, guides a small ball into a not much larger hole from remote distances and in the face of obstructions deliberately designed to make the operation as difficult as may be. This involves the reversal of the means-end relation. The “end”—getting the ball into the hole—is set up as a *means* to the new end, the real end, the enjoyment of difficult activity for its own sake [pp. 10-11].

A somewhat similar statement has been presented by Robert W. White (1960). He emphasizes the role played by the progressive achievement of competence in the maintenance of behavior, and makes a strong case that the “feeling of efficacy” is an important guide to behavior.

Effectance is to be conceived as a neurogenic motive, in contrast to a viscerogenic one. It can be informally described as what the sensory-neuro-muscular system wants to do when it is not occupied with homeostatic business. Its adaptive significance lies in its promotion of spare-time behavior that leads to an extensive growth of competence, well beyond what could be learned in connection with drive-reduction [p. 103].

White is concerned with the implications of effectance in clinical psychology; here our concern is with what the sensory-neuromuscular system “wants.”

According to the foregoing analysis, the common problem for dissonance theory, addiction theory, means-end theory, and effectance theory is that activities of a certain type appear to be self-maintaining in the face of situations which in a drive-reduction frame of reference would be predicted to extinguish the behavior. In the previous section, the relation between drive and reinforcement was shown to be one of sequentially occurring events set in context (context provided either by the drive stimuli or the environmental stimuli, “comparison” taking place in the limbic systems). In the present section, the relation between action and reinforcement has been found to be somewhat similar, in the case of action, however, the consequences of the actions must provide their own set within which a subsequent event will be consequent, that is, reinforcing.

In many respects, what has been discussed in the latter half of this section is the development of behavior differentiation, that is, skill. Effectance and competence, play and gamesmanship demand precise timing of actions within larger sequences of actions, so that consequences, sequences in context, will form a harmonious production. And a great deal is known about the neurology of skill. Here, perhaps, more than anywhere else, the model of “sequence in context” can be realized in tissue, and, in fact, the model was originally devised to handle some new neurological facts in this area (Miller, Galanter, & Pribram, 1960).

At the reflex level, control of muscular contraction can no longer be conceived simply in terms of the reflex arc (some excitation of receptors, transmission of the signal aroused by such excitation to the central nervous system, and back again to the muscle in question). The change in conception is necessitated by the discovery that the activity of the γ efferent fibers, fibers that transmit signals from the central nervous system to the receptors in the muscle (muscle spindles), acts as a feedback, that is, controls the amount of activity recordable from the

afferents that signal the state of the receptor to the central nervous system. The presence of this feedback loop makes it difficult at any moment in time to assess the origin of a particular amount of activity in the afferent nerves, and thus the state of the receptor. That state could reflect the state of contraction (isomorphic or isotonic) of its muscle group or it could reflect the amount of activity of the γ efferent system, or both. Only a comparison between states at successive moments, in the context of γ efferent activity, will give a signal of the state of contraction of the muscle group. The γ efferent activity provides the setting, the context, the bias on the muscle receptor. (On occasion, the reverse may well be the case. The bias may be set by the muscle contraction and changes in γ efferent activity computed.) The feedback model, very similar to the biased homeostat, applies, therefore, not only to behaviors where drive stimuli are involved, but also to behaviors where the consequences of muscular contractions per se are under consideration.

Sherrington, in his classic lectures on the integrative action of the nervous system. (1947) was not unaware of the problem, and his statement of it is worth repeating (though his solution is cast in simple associative terms, reinforcement for Sherrington occurs through immediate spinal induction [summation through increased intensity and coextensity of convergent inputs]):

We note an orderly sequence of actions in the movement of animals, even in cases where every observer admits that the coordination is merely reflex. We see one act succeed another without confusion. Yet, tracing this sequence to its external causes, we recognize that the usual thing in nature is not for one exciting stimulus to begin immediately after another ceases, but for an array of environmental agents acting concurrently on the animal at any moment to exhibit correlative change in regard to it, so that one or other group of them becomes—generally by increase in intensity—temporarily prepotent. Thus here dominates now this group, now that group in turn. It may happen that one stimulus overlaps another in regard to time. *Thus each reflex breaks in upon a condition of relative equilibrium, which latter is itself reflex.* In the simultaneous correlation of reflexes some combine harmoniously, being reactions that mutually reinforce. [p. 120; italics supplied].

At the cerebral level, also, neurology has a great deal to say about skill. Removals of the precentral "motor" cortex of primates (including man) certainly results in awkward performance (Pribram *et al.*, 1955, 1956). Equally disruptive are lesions of the cerebellar hemispheres, those portions of the cerebellum that are directly connected with the precentral cortex through the ventrolateral portion of the dorsal thalamus. The functional relationship between precentral cortex and cerebellum has been the subject of considerable work. An overbrief summary runs as in the following paragraph.

Each part of the precentral motor cortex controls the muscles, movements, and action of a portion of the body. This part of the cortex also receives a direct input from the portion it controls. In addition, this same portion receives an input via the cerebellum. The assumption has been that a match between these inputs is made and that the signal resulting from this match activates the pyramidal tract through which muscle control is effected. And there is ample evidence

to support the assumption. Awkwardness due to cerebellar lesions results in "intentional tremor"—smooth performance is converted to a jerky sequence (almost as if a biased homeostatic mechanism were thrown into oscillation). And the effect of precentral cortex removals has been suggested to be a change in facilitation of reflex actions, in some experiments, disinhibition resulting in spasticity (Denny-Brown, 1948), in others, defacilitation (Lashley, 1924).

The suggestion is that the organization of action resembles the biased homeostat, the structure of drives. It follows that the bias of the neural mechanisms in control of action should be resettable, much as is the bias of the drive homeostats to produce the phenomenon of self-stimulation. This has been accomplished by John Lilly (1959). Prolonged trains of excitation (subliminal to those that would produce movement) were delivered to the precentral motor cortex whenever the lever was depressed by subject (a monkey). Lever pressing had to be paced so that the on-off nature of the excitation could be maintained. The monkey learned to do this, however, and spent many (perhaps "happy"?) hours at this occupation.

Obviously, the interrelations among the neural systems that regulate skilled, highly differentiated action are complex. It may be that careful perusal of the literature and a few critical experimental results could make out a clear hierarchical arrangement among systems in such a way that each locus of match between inputs serves as a setting within which the occurring events must operate. This is not the place for such an extensive analysis, but the work of the Brelands (1966) has shown how it can be approached. In their work, each response class appears to become "contaminated" by its reinforcers, indicating that perhaps response classes, in fact, prescribe their reinforcers and thus their ever-differentiating competencies. It suffices to pose the problem and to point out in summary, that a neural mechanism does exist whereby order can be achieved among actions and their consequences, again the brain is as it must be, since skilled behavior is possible.

This has been a long road from dissonance to effectance to skill. The point is simply that these areas of interest pose a common problem: How is it that selective behavior is maintained in the absence of guides from drive or external stimuli, or, in the extreme, when behavior apparently goes in a direction contrary to one plausibly related to drive and external stimuli? The suggestion made in this section is that the consequences of actions are truly stimulus events that occur in sequence and that, once some order has been initiated in this sequence of stimuli, this order per se can provide the set or context for the occurrence of the next or subsequent event. Actions have consequences and the consequences of actions are reinforcers. Behavior, thus, becomes its own guide.

CONCLUSION

The theme is reinforcement. Each of the preceding sections is a variation on that theme, that variation produced by a set of techniques and problems. In this

section I hope to draw out the theme itself more fully.

Reinforcements are considered consequences of instrumental, motivational, and perceptual acts, event sequences that occur in the context of other event sequences. The model of event structure presented is the biased homeostat, a closed loop feedback unit which, during learning, has the capacity to differentiate into a helical open loop feedforward mechanism. This model has been spelled out in a variety of ways: One way is a set of test-operate-test-exit units, hierarchially organized into a branching program or Plan, suggested by George Miller, Eugene Galanter, and myself (1960). This formulation has the advantage of analogy with computer information processing, so that problems generated can be tested by hardware as well as brainware operations.

The suggestion has also been made that once stable performance has become established, reinforcing events provide the mechanism whereby confidence becomes established. Further, the development of skill, i.e., the differentiation of performance and of motivation and perception has been attributed to the differentiation of the confidence mechanism, the reinforcing process. Is there any direct support for equating reinforcement and confidence? I believe there is.

Whalen (1961) has used a situation similar to that already described in which drive and reinforcing stimuli were teased apart. In Whalen's experiment, reinforcement resulted not from electrical self-stimulation of the brain, but by sexual activity. Whalen showed that the choice between two alleys of a maze depends on the occurrence of an intromission, but running speed in the maze increases with the number of such occurrences.

Spence (1956, p. 127-148) has reported a similar result when pellets of food are used as reinforcers. These results are congruous with Miller's (already mentioned) proposal that choice, and the rate of learning of that choice, depend simply on the information given by the reinforcing event. But Whalen's and Spence's results demonstrate that, once performance is established, reinforcing events display another property: An increase in the number of reinforcements causes performance rate to increase monotonically (over a range). Another way of stating this effect on performance is to say that reinforcers place a value on the performance, reinforcement biases the confidence with which the performance will be executed.

In *Plans and the Structure of Behavior* (Miller, Galanter, & Pribram, 1960) we discussed two aspects of motivation: Plan and value. Plan clearly directs performance, that is plans program choices. Value played some other, less well-specified role in the initiation and the "seeing through" of plans. When value is stated to be a bias on performance (and of course, this includes perceptual performance), a clearer conception is attained.

However, another problem is immediately raised. If reinforcers bias performance, place values on them, how are reinforcers then informative? The solution to this problem lies in the reversal of the context-content relationship. When, during learning, reinforcers give information they must operate, by the definition of the term information, within a set or bias already established. When, on

the other hand, reinforcers bias performance, they establish the set within which other events become informative. Thus the consequences of actions and perceptions are informative *or* valuative according to whether they take place within another context or they themselves serve as the context.

Some of the conditions that govern the occurrence of context-content reversals have been detailed in each of the earlier sections. Much more could have been added. When mechanisms of drive serve as context, utility theory applies: Preferences form the contextual matrix within which the consequences (outcomes) of actions and perceptions are informing. When, due to affluence, the means-ends reversal has taken place, "futility" and performance theory must take over, the consequences of action become the context within which other consequences, drive, and perceptual stimuli give information about the gamesmanship or skill. And when perceptual stimuli provide the context, values are recognized to bias the operation of both drives and actions.

Finally, new insights into the relationship between performance and competence have been derived from this analysis of the structure of the reinforcing process. These insights are perhaps best reviewed in a summary of the similarities and differences between the structure of reinforcement proposed here and the conceptions of others working in each of the areas covered by a section.

Experimentalists working in the tradition of operant conditioning have pointed the way to a descriptive definition of reinforcement and have demonstrated the reversibility of the response relationships that result in reinforcement. However, they have blurred the distinction between a "response" as an indicator of action and a "consequence" of an action conceived as a stimulus event. This blurring has led to the confusion that reinforcement is composed by the concatenation of muscular events. Once consequences of actions are seen for what they are, stimulus sequences, the confusion is no longer possible.

Contiguity theorists have depended heavily on the simple idea that stimulus events, whether of muscular, perceptual or metabolic origin, must somehow come into contact in order to guide behavior. Neurophysiological and psychophysiological research have shown, however, that a stimulus event becomes constituted *only* when there is a partial match between some coded neural representation of prior inputs to the organism (or some innately operating mechanism awaiting "release"). A stimulus thus is shown to arise within the context of an already established process. Readiness determines a context-content contiguity, thus stimulus sets become temporally ordered. And so theoretical distinctions between contiguity and expectancy theory vanish. A reinforcing event is any consequence of behavior that alters the context-content relationship, that is, any consequent stimulus. The proposal here presented should allow better specification of what constitutes a stimulus (reinforcing or otherwise) by those who hold the contiguity position, perhaps the central problem for their theory and for behavior theory in general.

Drive theorists have been concerned primarily with physiological need-produced tension states. Estes' analysis cleared the air considerably by demonstrating

that many of the problems faced could be solved by considering drives as stimuli. The conception of drive as tension was not done away with, however. Tension accompanies the operation of feedback mechanisms and drive stimuli were seen to arise from the feedback operations of homeostats, mechanisms that control the production of the physical or chemical substances to which they are sensitive. The level at which these mechanisms become sensitive can, within limits, be set, that is, biased. Self-stimulation by electrical currents delivered to the brain was suggested to operate by setting this bias.

Neural organization according to feedback principles is not limited to physiological drive systems, however. Perceptual performance and effective action are also organized by way of feedback mechanisms. Perceptual and motor skills as well as drive structures develop, by way of reinforcement, a progressive differentiation of biases that connect neural feedback loops in parallel to produce helically organized (open loop) feedforward mechanisms. These constitute the competencies that underlie the performances of organisms.

A concluding thought. Pfaffman (1960) has stated the case for the *pleasures* of sensation elegantly. Perhaps *this* paper has brought us a bit closer to understanding *happiness*. Classically, happiness is conceived as "entelechy," that is, "self-actualization" (Maslow, 1955), the achievement of competence and not hedonistically. Cyclically recurring phases have been described to characterize achievement (Tomas, 1960; Erikson, 1962): During each cycle, progressively more control is gained over a set of events; when this control reaches a certain level, new sensitivities develop. Then satiety sets in, reorganization (of context-content relationships?) takes place, and the cycle starts afresh. This cyclic process is, of course, most clearly apparent in behavior related to physiological competences.

The suggestion is that happiness is slowly achieved through the progressive gain in control over stimulus events, through the structuring of competences by way of confidence in regulating consequences. Consequences are reinforcements: the language of operant learning can be mapped into the language of cognitive psychology to constitute a much needed theory of performance.

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