The history of 2-process learning theory is described, and the logical and empirical validity of its major postulates is examined. The assumption of 2 acquisition processes requires the demonstration of an empirical interaction between 2 types of reinforcement contingencies and (a) response classes, (b) reinforcing stimulus classes, or (c) characteristics of the learned behavior itself. The mediation postulates of 2-process theory which argue that CRs are intimately involved in the control of instrumental responding are emphasized, and 2 major lines of evidence that stem uniquely from these postulates are examined: (a) the concurrent development and maintenance of instrumental responses and conditioned reflexes, and (b) the interaction between separately conducted Pavlovian conditioning contingencies and instrumental training contingencies in the control of instrumental behavior. The evidence from concurrent measurement studies provides, at the very best, only weak support for the mediational hypotheses of 2-process theory. In contrast, the evidence from interaction studies shows the strong mediating control of instrumental responses by Pavlovian conditioning procedures, and demonstrates the surprising power of Pavlovian concepts in predicting the outcomes of many kinds of interaction experiments.

The procedures which the experimenter (E) carries out in the Pavlovian, or classical, conditioning experiment are quite different from those he carries out in a Thorndikian, or instrumental, training experiment. In the Pavlovian conditioning experiment, E ideally has full control over all experimental events; he determines the time of occurrence and the duration of a trial without any regard to the animal's behavior. That is, E arranges relations between stimulus events which

Irwin, and Vincent M. LoLordo for their extensive comments on an earlier draft of this paper.
he controls. In contrast, in the Thorndikian training experiment, E only arranges it such that the animal's behavior at specified times will yield predetermined environmental changes; E arranges relations between the animal's behavior and future stimulus events.

Because the laws of learning are stated as interrelationships between experimental operations and consequent behavioral changes, the laws of conditioning and those of learning must be different at a descriptive level. This would be so even though the behavioral changes were identical in the two cases.

On the other hand, if some theoretical system could be developed to unify the different empirical laws, to reduce them to the same general underlying principles, then the laws of behavioral modification would deduce the outcomes of both types of experiment. In an important sense, the history of learning theories is a succession of attempts to specify the relation between the outcomes of the two types of experiment.

Most learning theorists have attempted to reduce the outcomes of these two experimental procedures to a common underlying learning principle. Such attempts led to a period of vigorous experimenting, in order to see which of several competing theories of learning would survive the data of both conditioning and training experiments. Pavlov's (1932), Hull's (1943), Tolman's (1932) and Guthrie's (1935) theories are well enough known in the history of learning theory to excuse us from detailed discussion of them.

Suffice to say, these single-process theories challenged each other during the period 1930-1950. Then, in recent years, interest in the all-encompassing, "single, sovereign principle" theories declined as E's more and more explained their findings in terms of limited, more specific "miniature models." Thus, for example, theories of the partial reinforcement effect have multiplied and have been refined to account for a single phenomenon rather than all learning phenomena. In the same way, theories of extinction have proliferated, until now there are at least seven distinct accounts of the phenomenon. Grand theory testing, in the sense of seeking a crucial experimental test of whole theoretical systems, has clearly subsided.

In contrast, two-process learning theory has persisted as a systematic influence since 1928, and interest in it has increased rather than decreased. Lacking the elegance and simplicity of a postulated, single learning process and the parsimony of a single reinforcement principle, as well as the proselytizing influence of a vigorous "school of thought," two-process learning theory nevertheless has been a major heuristic tool in the stimulation of new conditioning and training experiments.

**History**

How did two-process learning theory arise, and what stages of development has it undergone? Two Polish investigators, Kornorski and Miller, stated in 1928 that the facts of Pavlovian conditioning and Thorndikian learning required the postulation of two underlying associative processes for adequate explanation; the facts of one could not be explained by the inferred processes of the other (Miller & Kornorski, 1928). They distinguished between responses yielding rich sensory feedback and those yielding little or no sensory feedback. They assumed that Pavlovian conditioned reflexes yield poor sensory or proprioceptive feedback; but, in contrast, Thorndikian response learning involves extensive and intricate feedback mechanisms. The associative processes operating for responses with poor feedback were postulated to be those of an S-S nature: the linking of afferent processes set up by the conditioned stimulus (CS) and the unconditioned stimulus (US). In contrast, for responses yielding rich feedback, the feedback itself was postulated to be a part of the associative process, and subjects (Ss) learn an S-R relationship only insofar as the feedback
from R is distinctive and powerful. There was, however, no postulation of a law of effect for such feedback-rich responses (Miller & Konorski, 1928).

Thorndike (1932) believed that Pavlovian conditioned reflexes do not reflect the general laws of ordinary trial-and-error learning. Perhaps, he speculated, Pavlovian conditioned responses (CRs) are a special case of some subclass of learning? Writing in this vein in the early 1930s, Thorndike had, however, no alternative to his own law of effect to propose in order to account for Pavlovian phenomena. Relegating such phenomena to a limited subclass did not solve the theoretical problem, and he candidly said so.

Skinner (1935) arrived at a two-experiment and two-response classification, emphasizing that the operations of E differ between the Pavlovian and Thorndikian experiment. He proposed that there are two types of conditioned reflex, Type S and Type R, and two types of response, the operant and respondent. However, Skinner did not postulate two separate associative processes to explain the two sets of conditioning facts, nor did he infer two distinctly different theoretical reinforcement processes for them. His distinction between the respondent and the operant paralleled, but was not identical to, Miller and Konorski’s (1928) distinction between poor and elaborated feedback.

Konorski and Miller felt that Skinner’s distinction was superficial. In 1937, they argued that Skinner had not completely specified all of the differences between the two types of conditioned reflexes, and they pointed out that Skinner’s operant conditioned reflex “... is confined exclusively to striped muscles, while the classical type has no restrictions laid on effectors and includes among them, besides striped muscles, smooth muscles and glands [Konorski & Miller, 1937b, p. 271].” They further argued that: “Being a glandular reaction, salivation cannot by any means be made a conditioned reaction of the new type [p. 271].” Konorski and Miller were thus speculating that respondents cannot be brought under the control of the law of effect. It is one matter to argue that temporal contingency between CS and US onsets is sufficient for conditioning, or that the response-reward temporal contingency is sufficient for instrumental learning. Here, however, Konorski and Miller were arguing for a strong two-process law: that the contingency sufficient for law of effect learning cannot reinforce a CS-CR relationship of the Pavlovian type. Though the converse was not stated at the time, we might suppose that Konorski and Miller believed it to be so (i.e., instrumental responses cannot be conditioned by a Pavlovian procedure). Their emphasis was on Pavlovian conditioning, and, indeed, they anticipated Mowrer (1947) in thinking that Pavlovian CRs might strongly influence instrumental responding; however, they did not have in mind a concept like that of mediation.

The first explicit statement of a complete two-process learning theory came in 1937, in a paper by Schlosberg entitled, “The Relationship between Success and the Laws of Conditioning.” This paper was the basis for most of the more recent elaborations of two-process learning theory. In it, Schlosberg distinguished between (a) the experimenter operations of Pavlovian conditioning and Thorndikian training, (b) the postulated associative processes set up by the two different procedures, and (c) the theoretical reinforcement mechanisms appropriate for the two processes. He argued that the empirical laws of Pavlovian conditioning implied that the associations formed are those between stimulus-related or contiguous perceptual processes, and that the reinforcement mechanism is brought into play by the initiation of a US. He further claimed that the empirical laws of Pavlovian conditioning are the laws of conditioning of diffuse, preparatory responses of an emotional type. In contrast, he stated that the empirical laws of Thorndikian learning imply that the major associative process is that linking stimulus and precise, adaptive, motor response, and that the reinforcement process is that of “success” or an improvement of the hedonic state of the S.

Actually, even though Schlosberg was aware of Konorski and Miller’s two-response idea, Skinner’s operant and respondent, and Type S and Type R conditioning procedures, he was much more influenced by W. J. Brogden’s 1936 APA paper than he was by the published papers of Konorski and Miller and of Skinner. Brogden, at that time, reported on the work later to be incorporated into the article by Brogden, Lipman, and Culler (1938), the widely cited work showing that omission of shock could reinforce running by guinea pigs in a running wheel, in contrast to the poor and unreliable running obtained with a Pavlovian, inevitable presentation of the shock. Brogden suggested that the underlying reinforcing mechanism for Pavlovian conditioning might
be different from that for Thorndikian learning. He contrasted forepaw conditioning, relatively successful with a Pavlovian procedure, with the conditioning of running, relatively unsuccessful with a Pavlovian procedure, and speculated about possible theoretical reasons for such a discrepancy.

Schlosberg developed a novel theoretical explanation for the discrepancy. He pointed out that some diffuse motor responses are composed of reflexes within an emotionality pattern. These are conditionable only by Pavlovian methods. If one tries to make use of such motor responses as operands, one will not be able to train them as such because the law of effect will not "work" with such reflexes. Pavlov's laws will. (Konorski & Miller, 1937a, 1937b, at about the same time, made the same claim about visceral, glandular reflexes.)

Schlosberg's (1937) clearly stated two-process theory was listened to, digested, and acknowledged. Yet it did not effectively enter into the arena of the theory-testing giants, those single-process theories struggling against each other during the 1930s and 1940s. There was no two-process "school" to match the Hullian, Yale-Iowa group, or the Tolmanian group at Berkeley, or the Guthrie group at the University of Washington. Instead, due note of the reasonableness of the two-process idea appeared here and there, in sporadic fashion. For example, Hilgard and Marquis (1940) in their influential book, Conditioning and Learning, distinguished between classical and instrumental conditioning, preferring to use the term "conditioning" for both the Pavlovian and Thorndikian experiment. Maier and Schnirer (1942) espoused a distinction between two acquisition processes, but preferred to classify the Pavlovian processes as those for perceptual reorganization and the Thorndikian processes as those for biologically adaptive behavior. Later Tuttle (1946), in a rarely cited paper, argued for the existence of associative conditioning and law of effect learning as two completely distinct processes. Birch and Bitterman (1949) noted the usefulness of the two-process distinctions.

Mowrer (1947) published what was at the time the longest, most tightly reasoned, and most persuasive argument for two-process theory. He added precision to Schlosberg's (1937) specifications, refined the theoretical relationships between inferred processes and experimental operations, and developed the conception of CRs as motivational mediators of instrumental responding. Mowrer argued that the laws of Pavlovian conditioning are applicable only to visceral responses. The Thorndikian law of effect applies only to the training of skeletal motor responses. The specific controlling relationship for the establishment of conditioned emotional reactions is the temporal contiguity between CS onset and US onset. (US termination conditions are irrelevant to this process.) Mowrer called this process the problem-posing process. Previously neutral environmental events come to have the conditioned power to evoke visceral responses. These visceral responses create emotional and motivational tensions which then must be resolved by problem-solving behavior. The problem-solving is done by skeletal motor responses alone, as reinforced by drive-reduction (in Mowrer's terms, reduction of visceral tension-states). Therefore, conditioned reflexes are powerful mediators of instrumental responses. Mowrer argued that, in signalized avoidance experiments, the CS and US are paired on early trials, and this established CS anxiety, a type of conditioned fear. The anxiety has the properties earlier assigned to it by Miller (1941); that is, it is both a response and an acquired drive. As a response, it is a pattern of conditioned visceral reactions. The drive properties come from response-produced feedback stimulation arising from visceral reactions. Therefore, if CRs can produce drive, they can strongly influence instrumental responses. The more intense the conditioned anxiety, the more vigorous are avoidance responses, and the shorter are their latencies in the presence of fear-producing CSs. The more drive-arousing the CS, the more reinforcing would be a
response that terminated the CS. Avoidance responses are reinforced by anxiety-reduction. Thus did Mowrer provide both a motivational and a reinforcement principle for avoidance learning. Although Mowrer believed that the mediational principles would apply to appetitive CRs and reward learning, he did not develop this idea, perhaps because at that time the relevant observations were missing.

Because Mowrer's mediational hypotheses were so important in the development of and testing of two-process theory, we shall emphasize the experiments relevant to them. Slight modifications and expansions were made by other investigators, but the major ideas remained, and they served as the basis for a large number of experiments appearing in the 1950s, experiments which presented grave problems for all of the single-process theories (see Solomon & Brush, 1956).

Then some notable desertions from single-process learning theory occurred. Tolman (1949) argued that there might be as many as six kinds of learning, each with its own reinforcement principle. Spence (1956) acknowledged the possibility that there might be two reinforcement processes, one for instrumental learning and one for classical conditioning. However, Spence turned things around. He tentatively suggested that if he were to adopt a two-process theory, he would argue that classical conditioning is a habit acquired by reinforcement of an appetitional or aversive sort, whereas instrumental learning is acquired by contiguity principles without a specific reinforcing event. Spence's important idea from our particular point of view was the postulation of a mediational relationship between the Pavlovian, conditioned \( r_g \) and instrumental responding. This mediational process is the appetitive counterpart of Mowrer's description of aversively motivated behavior.

The manifestations of two-process learning theory have recently become difficult to follow. On the one hand, we have Spence's view of two-process theory, arguing that Pavlovian conditioning is reinforced by the law of effect. On the other hand, heavily influenced by Schlosberg (1937), Solomon and Wynne (1954) extended Mowrer's (1947) postulates to cover the conditioning of skeletal-motor reflexes by Pavlovian processes, rather than confining Pavlovian conditioning to visceral responses. In other respects, Solomon and Wynne (1954) and Solomon and Brush (1956) have held faithfully to the Schlosberg-Mowrer concepts, and their experiments have been guided by these concepts. Yet, in contrast, Mowrer himself has steadily abandoned his original two-process conception of learning. In the most recent statement of his position, Mowrer (1960) has proposed a learning theory which employs only one underlying learning process with two major types of reinforcing event. Although Mowrer continues to call this a "two-factor" theory, it clearly does not involve two learning processes in the same sense as do previous theories. This latest version of Mowrer's theory has not yet been widely used to generate new types of experimentation. In contrast, the number of experiments instigated by the Schlosberg-Mowrer type of two-process theory has increased steadily. It is this latter type of two-process theory that we shall discuss in detail.

**THE SCOPE OF THIS PAPER**

In this paper we analyze the two major questions posed by various two-process learning theories: (a) Are there two acquisition processes, a conditioning process and a learning proc-
ess, each with its own set of distinct laws? (b) Does the conditioning process serve a mediating function in the control of instrumentally learned responses?

Our main emphasis will be upon the second, mediational, question. In examining the mediation role of conditioning processes in the control of instrumentally learned responses, we will discuss two major research strategies: (a) The first is the concomitant measurement of Pavlovian CRs and instrumental responses during the course of acquisition and extinction of instrumental behavior. The question of interest here is to what degree the two classes of behavior are correlated. (b) The interaction of independently established Pavlovian CSs with instrumental behavior and the effectiveness of such CSs in controlling that behavior. In assessing both of these research strategies we concentrate upon the role of Pavlovian conditioning processes in evoking instrumental behavior. The establishment of reinforcers of behavior by Pavlovian processes is beyond the scope of this paper.

Although the mediational question is our main concern, it seems appropriate to deal first with the logically prior question of whether there are really two kinds of learning. It is obviously not possible to deal with this vastly complex question in all of its ramifications; however, in the next section we do attempt to lay out a logical framework within which the question can be answered.

**ARE THERE TWO ACQUISITION PROCESSES?**

A variety of two-process theories have been mentioned in the previous section. In attempting to specify the domain of the two processes, each theory has made a number of logical and empirical assertions. This section attempts a classification of the distinctions drawn by two-process theories and attempts to specify the kinds of evidence that may be taken as supporting the proposition that there are two acquisition processes. We will not attempt an exhaustive review of the relevant literature; rather we wish to make explicit the logical structure of the evidence that would be relevant to the two-process proposition.

All two-process theories emphasize the basic operational difference between the Thorndikian and Pavlovian experiment. In the former, E's presentation of the reinforcer is dependent upon the organism's behavior, but in the latter it is independent of that behavior. In Pavlovian conditioning the reinforcement is made contingent upon the occurrence of a stimulus; in instrumental training it is made contingent upon the occurrence of an arbitrarily selected response.

In general, this operational distinction has not been thought sufficient to justify by itself the assertion of two different learning processes. Theorists have felt that only if the difference between response-contingent (instrumental) and stimulus-contingent (Pavlovian) reinforcement has important implications for the way in which behavior is modified would we want to identify these two operations with different underlying processes. Therefore, the assertion of two separate learning processes has rested upon an assumed interaction between reinforcement contingency and other variables in producing behavior change. In particular, two-process theories have pointed to three sets of such variables (a) response class, (b) reinforcement class, and (c) characteristics of the products of learning. The claim is that the class of responses affected, the effective reinforcers, and the results of learning, all depend upon whether
response- or stimulus-contingencies are employed.

Response Distinctions

Theorists have tried to separate those responses subject to modification by stimulus- and response-contingencies in a variety of different ways. Some of the proposed response distinctions have been: (a) ANS (visceral or glandular) responses as contrasted with somatic (skeletal) responses (Mowrer, 1947); (b) operant (emitted) responses as contrasted with respondent (elicited) responses (Skinner, 1938); (c) voluntary responses versus involuntary responses (Schlosberg, 1937); (d) so-called "light-weight" responses as contrasted with "heavy-weight" responses (Miller & Konorski, 1928; Osgood, 1953); (e) diffuse, emotional responses as against precise, adaptive responses (Schlosberg, 1937); and (f) responses high in reflexiveness as contrasted with those low in reflexiveness (Turner & Solomon, 1962).

We do not wish to review in detail the evidence for and against the ability of each of these distinctions to discriminate between responses subject to modification by the two reinforcement contingencies. Instead, we will take as an example the autonomic-skeletal distinction to illustrate the logic and problems of testing the propositions of two-process theory. The autonomic-skeletal distinction has the advantage of being the easiest distinction to make with precision.

The assertion central to some versions of two-process theory is that skeletal responses are subject to instrumental reinforcement contingencies but not to Pavlovian reinforcement contingencies, while autonomic responses are only subject to Pavlovian contingencies. It is worth pointing out that the autonomic-skeletal distinction is typical of all response-class distinctions in relating response classes and reinforcement contingencies in a one-to-one manner. This particular form of interaction between response class and reinforcement contingency is, however, not a logical requirement of the two-process approach. The separation of response classes would be no less important if, for example, several classes of responses were subject to modification by one reinforcement contingency while only one class contained responses affected also by the other contingency.

Thus the question of theoretical interest is whether any autonomic responses are subject to instrumental training procedures and whether any skeletal responses are subject to modification by Pavlovian conditioning procedures. If both of these possibilities occur, we cannot rely on the interaction of reinforcement contingency with the autonomic-skeletal distinction to justify the theoretical separation of the effects of stimulus- and response-contingent reinforcement.

At least three skeletal responses have been successfully brought under the control of Pavlovian procedures. Schlosberg (1928) found patellar reflex conditioning in humans; a number of investigators have demonstrated conditioned paw flexion in dogs (e.g., Konorski & Szwejsowska, 1956); and human eyelid conditioning has become a standard procedure for the investigation of acquisition processes. However, in trying to interpret these results we meet a problem typical of attempts to bring under Pavlovian control responses in any class supposedly not subject to Pavlovian conditioning. We must be able to assure ourselves that unwanted response-contingencies are not producing the results. There is a common way in which such contingencies often enter; occurrence
of the CR may influence the effect of the US, thus converting presumed Pavlovian to actual instrumental contingencies. For example, the inevitable occurrence of the shock US to a dog’s paw may be less aversive when the paw is in a flexed position. Schlosberg (1937) was the first to discuss this kind of possibility in detail. The typical way of dealing with this problem is to try to arrange a situation in which such an argument seems, at a common-sense level, implausible. However, an alternative procedure would be to give S the choice (following conditioning) between (a) presenting himself with the CS (and thus the CR) followed by the US or (b) presenting himself with the US alone (or followed by the CS). Presumably, if the role of the CR in altering the effect of the US is important, a clear preference would be demonstrated. A similar design has been suggested for this purpose by Wagner (1966) who used it to detect instrumental reinforcement in cortical conditioning experiments. Without this kind of evidence we must reserve judgment on supposed demonstrations of the Pavlovian conditioning of skeletal responses.

There is also evidence suggesting that autonomic responses can come under response-contingent control. Although Mowrer (1938) and Skinner (1938) reported failure to train autonomic responses instrumentally, more recent investigators have reported success. Fowler and Kimmel (1962), Kimmel and Kimmel (1963) and Crider, Shapiro, and Tursky (1966) have all reported successful instrumental training of the galvanic skin response (GSR). Lisina (reported by Razran, 1961) trained vasodilation as an escape response, and Shearn (1962) obtained suggestive evidence that heart rate changes can be used as avoidance responses. Although Sheffield (1965) found the salivary response insensitive to instrumental contingencies, using food as the reinforcer, Miller and Carmona (1967) were able to reinforce salivary responses in thirsty dogs when water was used as the reinforcer.

The interpretative problem that arises in this sort of experiment concerns the need to rule out mediating operants. We must be sure that some unnoticed skeletal response is not being learned and is not directly producing the observed autonomic changes. The most effective argument against this possibility would be the successful replication of these experiments while S is immobilized by curare agents. This type of experiment has recently been reported. Trowill (1967) and Miller and DiCara (1967) produced heart-rate changes in curarized rats using positive brain stimulation as the instrumental reinforcer. Birk, Crider, Shapiro, and Tursky (1966) partially curarized a human S and were able to produce GSR changes using instrumental avoidance contingencies. And yet there is the disturbing possibility that even the use of curare agents may not permit us to rule out operant mediators. Curare only precludes peripheral skeletal mediators and allows central responses to occur. Thus, even while paralyzed, a human can think of emotional events which will reflexly produce peripheral respondent events. It is not at all clear whether such “thoughts,” or brain events which are clearly subject to response-contingent reinforcement, should be considered to be “skeletal” or not. Possibly the distinction is better made between types of brain events than between types of peripheral nervous system association.

These brief comments give an idea of the logic and problems involved in testing the assertion that the autonomic-skeletal distinction is identical with the distinction between responses
subject to modification by stimulus-
and response-contingencies.

The kinds of experiments and prob-
lems generated by other response-class
distinctions are similar. The most fre-
quently mentioned of these other dis-
tinctions is the operant-respondent dis-
tinction. According to Skinner (1938,
pp. 20, 21) "behavior that is correlated
with specific eliciting stimuli may be
called respondent behavior . . ." (elic-
ted behavior) and an operant is identi-
fied by the fact that "no correlated
stimulus can be detected upon occasions
when it is observed to occur" (emitted
behavior). A two-process position then
asserts that respondents are subject
only to stimulus-contingencies and
operants can only be taught by re-
response-contingent reinforcement. One
can then attempt to test these notions,
as in the case of the autonomic-skeletal
distinction.

The operant-respondent distinction
raises special problems of its own.
Although, for many common responses,
there is no practical difficulty in identi-
fying which are operants and which are
respondents, there are, unfortunately,
cases where this is extremely difficult.
Many responses seem at times to be
operants and at other times to be re-
spondents. This observation suggested
to Turner and Solomon (1962) that
we examine a continuous dimension,
which they called "reflexiveness," on
which operants and respondents are
located. This modification of two-
process theory claims that the rela-
tive effectiveness of response- and stim-
ulus-contingent reinforcement would
vary along this response dimension,
each contingency being maximally ef-
fective at one end; it has yet to receive
any extensive empirical analysis.

The two remaining, commonly made,
response-class distinctions are very dif-
ficult to make empirically. Schlosberg
suggested that responses subject to
stimulus-contingencies were "prepara-
tory-diffuse" responses while those af-
fected by response-contingencies were
"precise-adaptive" responses. The
other response-class distinction is that
between voluntary and involuntary be-
havior. Reliable ways of distinguish-
ing between these latter types of be-
havior are few. One suspects that
attempts to classify responses into
voluntary and involuntary are not en-
tirely independent of reinforcement-
contingency distinctions. Thus, the
most reasonable objective criterion of
whether or not a response is voluntary
may be just whether or not it is subject
to modification by response-contingent
reinforcement contingencies. If a re-
sponse-contingent reinforcement pro-
cedure will not modify a response, it is
involuntary.

Although these different categoriza-
tions of response are far from identical,
they all seem to be attempting to em-
body the idea that behavior subject to
modification through instrumental con-
tingencies is somehow "freer," more
varied, and "adaptive," while the re-
sponses which are conditionable by
Pavlovian procedures are more "rigid,"
more "specialized," and more auto-
matic or "reflexive." In general, many
results support this correlation be-
tween response-class and reinforcement
contingency. However, considerably
more analytic experiments are needed
before a precise statement about the
nature of the response-class distinction
involved can be made.

Reinforcement Class

Instead of asking whether the class
of responses subject to modification
varies with type of reinforcement con-
tingency, one can ask whether the
events which serve as reinforcers differ
when response- and stimulus-contin-
gent delivery of reinforcement are used.
Clearly, reinforcers for Pavlovian con-
conditioning experiments are closely related to reinforcers for instrumental training. For example, food serves both as a US for the conditioning of salivation through stimulus-contingent reinforcement and as a reward for the training of bar-pressing through response-contingent reinforcement. But are there reinforcers which will function only in conjunction with one or the other contingency?

Two-process theories have generated several theoretical attempts to specify differences between reinforcement classes. Both Schlosberg (1937) and Mowrer (1947) have argued that the reinforcement event for instrumental training must have some affective character but, in contrast, the simple contingency of CS and US is sufficient for Pavlovian conditioning. In the instrumental case, the reinforcer must be pleasant or unpleasant, whereas for Pavlovian conditioning it is sufficient that the reinforcer regularly elicit the unconditioned response (UR). But such a characterization is probably not precise enough to be helpful. Even our intuitive notions of affect seem strained by such instrumental reinforcers as light onset (Kiernan, 1964) or the opportunity to run in a running wheel (Hundt & Premack, 1963). It is equally easy, in the case of almost all Pavlovian reinforcers, to become convinced that they produce a modicum of affect.

An alternative specification of the difference between instrumental and Pavlovian reinforcers has been suggested by Mowrer (1947): Instrumental reinforcers are drive-reducers, whereas Pavlovian reinforcers do not necessarily reduce drives and, indeed, may even increase drive level. A typical example of the latter is Pavlovian fear conditioning, for which there is now excellent evidence (Mowrer & Aiken, 1954; Mowrer & Solomon, 1954; Overmier, 1966) that the effective US is shock onset, a drive-increasing stimulus. Unfortunately, there is no guarantee that all instrumental reinforcers are drive-reducing; indeed, many examples of reinforcers (brain stimulation, light onset, novelty, etc.) strain this notion. Furthermore, such drive-inducers as shock onset are often instrumental reinforcers—albeit negative ones (punishers). Thus the notion of drive-reduction does not seem helpful in separating Pavlovian and instrumental reinforcers.

Perhaps a more fruitful, if more limited, approach is simply to examine empirically the degree to which the two classes of reinforcers overlap. "Reinforcer" is used here in both the positive and negative sense, that is, punishers are instrumental reinforcers, and Pavlovian CRs involving reduction in behavioral output are treated in the same way as those involving increment. Thus, in order to demonstrate that a given stimulus reinforces when used with one contingency, and does not do so when used with the other contingency, it is not sufficient to show that it has incremental effects in one case and decremental effects in the other. We here require that a stimulus have no effects when used with one contingency or the other. Of course, it is necessary to employ appropriate control procedures in making this assessment. A particular stimulus may have nonassociative effects upon a response which are not dependent upon the particular contingency with which it is used. Thus, to show that a given stimulus is an effective reinforcer in stimulus-contingent presentation, it is necessary to demonstrate, through appropriate control procedures, that the changes which it produces depend upon the contingency arranged. The problem of control procedures for Pavlovian conditioning has been discussed
in detail by Rescorla (1967b). Similarly, to demonstrate that a stimulus is a reinforcer when used in a response-contingent fashion requires suitable control procedures.

It seems likely, as has been implied by the various theoretical attempts to separate the two kinds of reinforcers, that the class of Pavlovian reinforcers is larger than that of instrumental reinforcers, and in fact includes as a subclass the set of events which serve as instrumental reinforcers. With this in mind, we may ask whether there is any stimulus event which will reinforce behavior when made contingent upon prior stimulus presentation but not when made contingent upon a response. Unfortunately, this question, though basic to the two-process approach, seems to have received relatively little direct experimental attention; but there are a few hints available. One of the earliest USs to be used in Pavlovian conditioning was a tap on the patellar tendon; there is considerable evidence that this is an adequate stimulus to establish a Pavlovian conditioned knee-jerk (e.g., Schlosberg, 1928). Yet, if the US is administered properly, Ss report being "neutral" toward it. It would be of considerable interest to see whether this patellar tap could be used to reinforce instrumental behavior in a situation comparable to that in which it conditions the knee-jerk. A second, promising source of "pure" Pavlovian reinforcers is the class of interoceptive USs described by Bykov (1957). Many of the internal USs used to produce Pavlovian conditioning would most likely go completely unnoticed in an instrumental training situation. However, we do not yet know whether or not such internal USs can serve as instrumental reinforcers. This would certainly be an important type of investigation to pursue.

Another example comes closer to fulfilling our experimental requirements. Doty and Giurgea (1961) have recently provided considerable evidence that direct stimulation of the motor cortex will serve as a US for limb-flexion conditioning. Yet, when the same US is made contingent upon ongoing operant behavior, in many cases it produces no change in that behavior. Although one would like similar demonstrations with a large number of operants, the Doty and Giurgea findings indicate that this type of brain stimulation is indeed a Pavlovian reinforcer with no instrumental rewarding or punishing properties. Likewise, Malmo (1965) has reported a few cases of septal stimulation which serve as USs for heart-rate conditioning in rats but which will not maintain operant barpressing.

However, recent evidence presented by Wagner (1966) indicates the presence of instrumental reinforcement in such experiments. Paw flexion was conditioned in dogs, using a motor center brain stimulation as US. When the CS was presented, the dogs appeared to be positioning themselves in such a way as to modify the effect of the US. When the dogs were later given a choice between signaled and unsignaled presentations of the US, they chose the signaled US. This indicates that this type of experiment may not be a pure case of Pavlovian conditioning.

Finally, experiments directed toward examination of sensory preconditioning (which fits the Pavlovian, stimulus contingency paradigm) provide some support for the separation of Pavlovian and instrumental reinforcers. Unfortunately, such experiments have failed to include direct evidence that the neutral "US" used for the sensory preconditioning is not also an instrumental reinforcer. Furthermore, the dem-
onstration that sensory preconditioning has actually occurred is often less than convincing.

We can only conclude that the evidence on the overlap of Pavlovian and instrumental reinforcers is scanty. Despite the fact that most Pavlovian reinforcers seem also to be instrumental rewards or punishments, the evidence does imply that the overlap is not complete. To the degree that Pavlovian and Thorndikian reinforcers are different, a two-process theory receives strong support. Clearly, this is one of the most exciting areas of research suggested by a two-process theory of learning, and considerable work remains to be done.

**Characteristics of the Learned Behavior**

It is often thought that the product of the learning process differs across stimulus- and response-reinforcement contingencies. Several attempts have been made to specify how the result of learning is different in the Pavlovian and Thorndikian experiments.

**S-S versus S-R connections.** The first distinction is theoretical. Both Schlosberg (1937) and Maier and Schneirla (1942) believed that Pavlovian conditioning procedures established S-S connections; at the same time they suggested that instrumental learning consists of acquired S-R bonds. Other authors have made similar claims in describing conditioning as stimulus-substitution and instrumental learning as response-substitution (Hilgard & Marquis, 1940). Both of these distinctions arise as direct consequences of the contingencies of reinforcement which E arranges; however, they imply that a difference beyond that of experimental manipulation is involved.

Two types of experiment have been thought to bear on these theoretical distinctions. First, a number of investigators have shown that Pavlovian conditioning is possible even when peripheral responding has been prevented. Salivary conditioning is possible when salivation is blocked by atropine (Crisler, 1930; Finch, 1938) and Pavlovian fear conditioning occurs while S is paralyzed by curare (Solomon & Turner, 1962). To the degree that the S-R bond is conceived to require peripheral skeletal responding for its establishment, the S-S alternative is favored for Pavlovian conditioning.

The second line of evidence stems from the use of direct motor-cortex stimulation as a US for Pavlovian conditioning. Loucks' (1935) failure to obtain conditioning using such a US was taken as evidence that Pavlovian conditioning involves S-S connections. However, Brogden and Gantt (1937) obtained conditioning with direct stimulation of the cerebellum as the US. And Doty and Giurgea (1961) were able to obtain Pavlovian conditioning with electrical stimulation of the motor-cortex as the US. If the S-S and S-R notions are given physiological interpretation as sensory- and motor-cortex connections, this result suggests that Pavlovian conditioning may not be S-S in nature. We can conclude that the present evidence does not support a sharp distinction between Pavlovian conditioning and instrumental training in terms of hypothetical S-S and S-R connections.

**Similarity of CR and UR.** Greater similarity of the CR to the UR is often mentioned as setting Pavlovian conditioning apart from instrumental learning. However, the CR is by no means identical with the UR, even for Pavlovian conditioning; indeed, many have suggested that the CR is preparatory for the US or that it is a fractional part of the UR. But there is a gross similarity of the CR and UR in Pavlovian conditioning, at least to the extent that they usually involve the same response system. This is in general not true in instrumental training situations, where, for example, the response may be bar-pressing, which bears no fixed relation to the UR, ingestion of a food pellet.

It is possible that the more valuable distinction here rests in the relation of the CR to the US. Skinner has pointed out that in Pavlovian conditioning, once the US is selected, E is no longer free to select the CR at will (except in the trivial sense that he chooses to ignore parts of the behavior pattern). In instrumental training, selection of the US does not uniquely determine the CR which is acquired; E is free to select arbitrarily the response he will reinforce. Thus, it may be that the apparent CR-UR relationship results from the added constraint which selection of the US places upon Pavlovian conditioning but not upon instrumental training. The US may uniquely determine both the UR and the Pavlovian CR, even though the learned and unlearned responses are quite different.
Sensitivity to parametric variations. Finally, the Pavlovian CR may differ from the instrumentally trained response in its sensitivity to a variety of parametric variations. In general, as Kimble (1961) points out, there is a striking resemblance in the reaction of the two kinds of learning to such variables as amount of reinforcement, delay of reinforcement, etc. However, Kimble suggests one possible difference. Instrumentally trained responses consistently show greater resistance to extinction following partial reinforcement; this may not be the case for Pavlovian CRs. The evidence on this point is far from clear-cut. However, a sharp difference in the sensitivity of Pavlovian conditioned responses and instrumental behavior to such a parametric variation would give strong support to the distinctions of two-process theories. The investigation of such parameters seems to us to be a fruitful area for future research.

Conclusion

We have argued that the basic operational distinction between response- and stimulus-contingent reinforcement may interact with various other variables in such a way as to justify the claim that two independent processes are acting. In general, the results relevant to such interactions are still inadequate. Our attempt therefore has been not so much to marshal all the evidence in support of such interactions as to point out the kinds of evidence which would be relevant. The questions we have raised here have often not received explicit experimental attention, although to our minds these are basic questions in the study of behavior modification.

Experimental Approaches Generated by Two-Process Theory

In addition to asserting the existence of two independent acquisition processes, two-process theories have postulated interrelationships between the two processes in the control of behavior. They usually assert that Pavlovian CRs serve as mediators of instrumental behavior, functioning as either instigators or reinforcers. Such assumptions have given rise to two research strategies: (a) concurrent measurement of the development and maintenance of conditioned reflexes and instrumental responses within instrumental learning situations; and (b) testing the interaction between separately conducted Pavlovian conditioning contingencies and instrumental contingencies in the control of instrumental behavior.

It should be mentioned at the outset that the claim that instrumental behavior is mediated by Pavlovian CRs is by no means a unitary theoretical idea. As is pointed out below, different theorists have emphasized different aspects of the mediational process. But their ideas also differ on the precise role that CRs play in mediating instrumental behavior. Some propose that the observed CR itself, or sensory feedback from it, is an event which elicits and/or reinforces a particular instrumental act. In this case, the research strategy is to seek out and vary those particular CRs which one suspects are mediating the instrumental behavior. As we will conclude below, this approach does not seem to have been a fruitful one, because the attempts to find specific mediating CRs have been generally without success. A more viable claim is that operant behavior is mediated by a complex of CRs, both autonomic and skeletal; no one of these may be necessary for operant behavior, but each contributes to that behavior. This position suggests an extension of the concurrent measurement research strategy to the study of more complex CRs.

Still another position is that the observed Pavlovian CRs are not themselves mediators of instrumental behavior but rather are merely an index of a central nervous system state which does mediate that behavior. This posi-
tion leads to a research strategy reviewed in the final section of this paper.

It is often difficult to tell which of these positions an author intends when he describes the mediation of instrumental behavior by Pavlovian CRs, so it is well to keep these distinctions in mind.

Concurrent Measurement of Pavlovian Conditioning and Instrumental Learning

Any instrumental training situation has within it the conditions favoring the development of Pavlovian conditioned responses. In the discriminated operant paradigm there is a regular sequence of $S_4$ and the reinforcement; in nondiscriminated operant behavior, feedback from various responses leading to reward is also regularly followed by reward. To the degree that the stimulus event maintaining the operant behavior is also a Pavlovian reinforcer, we would expect the development of Pavlovian CRs in addition to the acquisition of instrumental behavior. Given that food is both a Pavlovian and an instrumental reinforcer, we would expect that its use in an instrumental training situation would also lead to the development of Pavlovian CRs such as salivation, cardiac changes, licking, swallowing, etc.

However, two-process theories make the still stronger assertion that these Pavlovian CRs are somehow crucial to the maintenance of instrumental behavior. Two different mediational roles have been assigned to Pavlovian CRs. Some authors have emphasized their motivational role. This conception seems to have originated, at least for averively motivated behavior, with Miller (1948), who postulated that emotional reactions become associated with previously neutral stimuli by the action of drive reduction. The emotional reactions give rise to immediate sensory feedback, having both cue and drive properties. Thus the "acquired drive state" is a complex of emotional reactions and then correlated perceptual events. Such mediators have been given either or both of two properties, motivational or reinforcing. The two-process theories of Spence (1956) and Mowrer (1947) have likewise emphasized the motivating function of conditioned reflexes, arguing that such CRs as salivation or cardiac change may reflect the level of motivation or incentive in instrumental training situations. Conditioned responses are assigned the role of instigators (or indexes of instigators) of instrumental behavior. These theories, therefore, predict a close correspondence between the occurrence or nonoccurrence of Pavlovian CRs and the magnitude or probability of specific instrumental responses.

On the other hand, Konorski (1948), Soltysik (1963), and Mowrer (1960) have emphasized the rewarding functions of mediating respondents. Thus the reduction of heart-rate or the increase in salivary flow may be thought to reflect a state which is instrumentally rewarding. For these theories the important changes in conditioned reflexes reflect instrumental reinforcement and thus occur following instrumental behavior. Again, a close relation between conditioned reflexes and learned instrumental behavior is predicted.

The instigating and rewarding functions of conditioned reflexes in maintaining instrumental behavior are by no means incompatible. For instance, conditioned cardiac acceleration may reflect the motivation for an avoidance response while cardiac deceleration following the response may reflect a reward. This is roughly the picture of avoidance behavior which Mowrer (1947) drew. For appetitive behavior, it is not clear whether salivation should be treated as reflecting a motivating or a rewarding state; in the former case, we might expect salivation to precede the operant (Spence, 1956), while in the latter it should follow the operant (Konorski, 1948).

The dual role which two-process theories assign to conditioning processes leads naturally to an examination of the sequence of CRs and instrumental responses in instrumental training situations. One research strategy for studying these temporal sequences is to allow the normal instrumental sequence to be established while taking simultaneous measures of various CRs and operants.

The degree to which the various theories are bound by these predictions depends upon the precise role which the theory assigns to mediating CRs. In the preceding few paragraphs we have purposely been vague on this role, using such phrases as "the CR reflects a motivational state." It is clear that a theory which claims that a particular CR or complex of CRs is itself mediating the instrumental behavior predicts a closer correspondence between the CR and instrumental behavior than does a theory which assigns to the CR the role of indexing a
central mediator. Thus the experiments to be described below are particularly relevant to the view that the CR itself (or its associated feedback) is mediating the instrumental behavior.

Appetitive Behavior

It is probably no accident that the first experiment using the concurrent measurement technique was performed by Konorski and Miller (1930), who were the first to propose a two-process theory. They trained a dog to lift his paw when a signal sounded, in order to obtain food. They found a close relation between the occurrence of the paw movement and the magnitude of conditioned salivation. But for them the important finding was that the operant consistently preceded increased salivary flow. Working in Konorski's laboratory some years later, Wolf (1963) found similar results using a fixed ratio (FR) schedule of reinforcement. These findings have been substantiated by similar results of Williams (1965) for FR, and of Shapiro (1961) and Kintsch and Witte (1962) for fixed interval (FI) performance and extinction. In addition, Kintsch and Witte found that the characteristic FI scallop developed prior to a similar temporal discrimination in the salivary response.

These studies suggest that, at least under some circumstances, conditioned salivation does not provide the essential motivating state which instigates operant behavior. Rather, they support the notion that operant behavior precedes (and possibly serves as a CS for) conditioned salivation. The observed temporal sequence of events is that predicted by Konorski’s (1948) notion that salivation indexes a state of excitation which serves to reinforce instrumental behavior.

But results inconsistent with this conclusion have also been obtained by Shapiro (1962), who trained dogs to obtain food by pressing a panel on a differential reinforcement of low rates (DRL) schedule. On this schedule, bursts of salivation regularly preceded the operant, even though the occurrence of the operant itself generally led to a further increment in salivation. Evidently the temporal sequence of CRs and instrumental behavior is not fixed, but depends upon the relations which the E arranges between instrumental response and reinforcement. A dramatic demonstration of this dependence is provided by Ellison and Konorski (1964). They trained dogs to panel-press on an FR, the completion of which initiated an 8-second waiting period at the end of which food was delivered. Using this technique, panel-pressing and salivation were kept almost completely separate temporally, the first occurring only during the FR requirement and the second only following its completion.

It thus appears that although salivation and operant behavior may bear a gross relation to each other in typical instrumental training situations, the details of this relation are not constant. Salivation consistently represents neither Spence’s r_e nor Konorski’s alimentary excitation; salivation must neither precede nor consistently follow operant behavior in order for that behavior to be maintained.

Similar conclusions are in order for other “mediating” CRs. Both Soltyssik (1960) and Wenzel (1961) have found a gross temporal correspondence between cardiac acceleration and performance on a motor response reinforced by food. Further, Soltyssik found that cardiac acceleration occurred prior to the motor behavior, suggesting that it may be involved in instigating that behavior. But Wenzel found, upon administration of reserpine to her cats, that the heart-rate response was markedly reduced with no effect on operant behavior.
upon operant behavior. We need further research, detailing the relation between food-motivated behavior and conditioned cardiac changes; but at the present time the evidence does not suggest that cardiac changes are necessary mediators for operant behavior.

Another possible CR, licking, has been studied by Miller and DeBold (1965). Using a discriminated bar-press operant reinforced by intraoral liquid, and simultaneously measuring intraoral licking, these investigators found that although licking was more probable just prior to a bar-press than at other times, it was maximal just following an unreinforced bar-press. To the degree that the licking response is under the control of Pavlovian contingencies, this parallels the case of salivation; neither the notion that the operant leads to the respondent, nor the notion that the respondent must occur prior to the operant, can alone encompass the data. This empirical conclusion proves to be an interesting problem for those two-process theories that postulate the mediation of instrumental responses by action of peripheral Pavlovian CRs (and their associated feedback).

Aversive Behavior

Two-process theories of avoidance learning have typically ascribed motivating and rewarding properties to autonomic responses and their afferent feedback. In a standard, discriminative avoidance training situation, the pairing of a CS with electric shock leads to the development of a conditioned "fear" reaction. Increase in sensory feedback from that "fear" reaction is postulated to instigate the instrumental avoidance response while reduction in the feedback rewards it. Various CR indexes of this fear-state have been suggested: heart-rate increase, blood-pressure increase, pupillary dilation, GSR, defecation, urination, suppression of appetitive behavior, etc. If two-process conceptions of avoidance behavior are adequate, and if the various indexes of emotionality reflect adequately the level of conditioned fear, a close correspondence between the occurrence of instrumental avoidance behavior and these indexes is clearly predicted.

Some of the relations which two-process theories require are the following: (a) Conditioned fear should increase in the early stages of avoidance training; (b) acquisition of the fear reaction should precede acquisition of a reliable avoidance response, and extinction of the avoidance response should occur concurrently with, or follow, extinction of the fear reaction; (c) during avoidance responding, fear should be greater preceding successful avoidance responses than on other trials; (d) fear should decrease following the avoidance response; and finally (e) physiological manipulation such as administration of drugs or sympathectomy which may directly affect the level of conditioned autonomic responses should likewise indirectly affect the avoidance behavior.

The two most often used indexes of the conditioned fear reaction used to test these predictions are heart-rate and suppression of appetitive behavior (conditioned emotional response, or CER, technique) by a CS. The evidence on cardiac conditioning is more extensive, and we will examine it first.

1. Cardiac CRs — acquisition. Changes in cardiac responding during acquisition of an avoidance response provide some support for the two-process position. Both Gantt and Dykman (1957) using paw flexion and Black (1959) using a panel-press response found general increases in heart-rate during instrumental avoidance training in dogs. Furthermore, both reported
the development of conditioned heart-rate increases during the S<sub>d</sub> for the avoidance response. Typically, heart-rate conditioning occurred prior to acquisition of the avoidance reaction. But one of Black's more detailed findings contradicts at least one form of a two-process position; maximum heart-rate occurred following the avoidance response, and it was only some seconds later that the rate declined. This is in disagreement with the two-process requirement of rapid reduction in fear as a reinforcement for the avoidance response. It may be that the influence of the skeletal avoidance movement and respiratory changes upon heart-rate makes cardiac change suspect as an index of conditioned fear in such situations. The possibility of artifact from movement is especially great when instrumental responses are required or possible.

**Performance.** The evidence relating heart-rate to avoidance behavior during continued performance of the avoidance response is conflicting. Soltysik (1960), using a paw-placement response with dogs, obtained results which fit quite closely with two-process predictions. In well-trained animals, an increase in heart-rate preceded the avoidance response and a decrease followed it. Furthermore, heart-rate CRs and avoidance responses were brought under parallel, discriminative stimulus control. The conditioned heart-rate was maintained through continued, long-term avoidance. In contrast to Black's findings, Soltysik found that maximum heart-rate occurred prior to the avoidance response. The avoidance response was followed by sharp cardiac deceleration. Bersh, Notterman, and Schoenfeld (1956), in disagreement with Soltysik, found that with continued avoidance performance, human Ss showed no heart-rate acceleration to the S<sub>d</sub> for avoidance. That is, avoidance behavior was maintained in the absence of conditioned fear, as indexed by cardiac acceleration. Using cats, which show cardiac deceleration as a CR when shock is the US, Wenzel (1961) found a gross relation between magnitudes of deceleration and the latency of a bar-press avoidance response. However, the introduction of reserpine left unaffected the conditioned cardiac deceleration although it disrupted the avoidance behavior. McCleary's (1960) failure to demonstrate interocular transfer of avoidance responding in fish in spite of good interocular transfer of Pavlovian cardiac conditioning also questions the role of cardiac responses in the mediation of avoidance behavior.

**Extinction.** Several relations have been found between heart-rate and avoidance responding during extinction of the avoidance response. Gantt and Dykman (1957) found extinction of the instrumental response long before extinction of the cardiac CR. In contrast, Soltysik's dogs showed parallel extinction of the cardiac CR and the avoidance response, including trial-by-trial correspondence. To further complicate matters, Black (1959) found more rapid extinction of the cardiac CR than of the instrumental response, and no relation between the rates of extinction for the cardiac CR and the avoidance response in individual Ss. Furthermore, Black (1958) found that extinction trials under curare facilitated extinction of the avoidance response without affecting that of the heart-rate CR.

It is clear that the relation between cardiac changes and avoidance behavior is not well understood. The sharp disagreements in findings suggest that the relation, if any really exists, is easily disturbed by yet unidentified variables. Most likely we have been naïve in selecting a single aspect of
cardiovascular change as an index of conditioned "emotionality." The cardiovascular system is a highly complex one with many self-regulatory mechanisms. To expect simple heart-rate changes, which are only a small portion of this system, to mirror adequately a state such as "fear" is to oversimplify hopelessly the operation of the cardiovascular system. When we apply stress to an organism, we affect not only the heart rate but also a number of other aspects of the circulatory system, such as blood pressure, peripheral vessel resistance, stroke volume, etc. Many of these have intricate interrelations such that they can compensate for and change the action of each other within a fraction of a second. It is clear that we cannot look at only heart rate in isolation, but must examine the entire cardiovascular system if we hope to establish a fruitful peripheral index of a motivational state.

2. Conditioned suppression. If a stimulus associated with the onset of shock is sounded while a hungry rat is pressing a bar to obtain food, it produces a marked decrement in bar-pressing. This is usually interpreted to mean that the stimulus has produced a CER which is incompatible with bar-pressing. This CER is not specified precisely, but is usually thought to be due to a pattern of Pavlovian CRs, identical to the conditioned fear reaction postulated by two-process theories of avoidance learning. Thus, the degree of conditioned suppression, like changes in the heart rate, can be used to assess the amount of fear elicited by the $S^d$ from a signaled avoidance situation.

The suppression measure is not entirely unrelated to conditioned heart-rate changes. Stebbins and Smith (1964) found a positive relation between the occurrence of CER suppression and heart-rate acceleration in monkeys. But, more recently, deToledo and Black (1966) have found slower acquisition for cardiac CRs than for CER suppression in a simple Pavlovian conditioning situation.

Hoffman and Fleshler (1962) attempted concurrent measurement of avoidance behavior and conditioned suppression. While rats pedal-pushed for food, an avoidance $S^d$ was sounded, during which they had to press a nearby bar to avoid shock. Suppression of pedal-pushing during the avoidance $S^d$ was greater on successful avoidance trials, in agreement with two-process predictions. However, only with further training was conditioned suppression less following the avoidance response than it was during the $S^d$. Fear reduction, as indexed by conditioned suppression, did not seem to be the reinforcement for early avoidance responses.

Kamin, Brimer, and Black (1963) used a procedure similar to that of Hoffman and Fleshler. However, they separated the avoidance training and conditioned suppression situations. After training rats to various criteria of avoidance acquisition and extinction, Kamin et al. imposed the avoidance $S^d$ upon food-motivated bar-pressing. They found that as extinction of the avoidance response proceeded, conditioned suppression was reduced. However, during avoidance acquisition, conditioned suppression produced by the avoidance $S^d$ first increased and then decreased as avoidance training proceeded. If a conditioned fear reaction indexed by conditioned suppression was maintaining the avoidance behavior, this latter result is difficult to understand. It is not entirely consistent with that of Hoffman and Fleshler who found continued conditioned suppression with long-term avoidance behavior. It may be that the suppression found by Hoffman and Fleshler resulted from the incompatibility of the
avoidance response with the appetitive bar-press, rather than from some conditioned emotional state.

Like heart-rate changes, conditioned suppression does not reflect a mediating fear reaction in a manner completely consistent with two-process theories. However, there are two alternative interpretations of the CER experiments which might make the results compatible with a two-process description of avoidance learning. First, it may be that the role of the fear reaction in maintaining avoidance behavior is different from its role in the establishment and extinction of avoidance behavior. Thus the failure of a CS for a well-learned avoidance response to produce conditioned suppression may indicate that the CS is not producing fear in the avoidance situation and that the traditional two-process account of avoidance learning does not apply to maintained avoidance behavior. A second possibility is that the CER experiment is not an adequate index of the conditioned fear reaction. After all, there does not exist a closely reasoned account of the fact that the CER procedure produces suppression of the appetitively maintained operant. Why should we not instead find rate increases?

3. Physiological manipulations. Another method can be used to examine the interrelations between Pavlovian CRs and instrumental responses. If we suspect that a specific set of CRs is mediating instrumental behavior, we can simply eliminate those CRs and observe the effects upon the instrumental behavior. Solomon and his co-workers have pursued this line of research for various classes of CRs.

Using sympathectomized dogs, Wynne and Solomon (1955) have demonstrated that although removal of peripheral autonomic CRs impairs avoidance learning, it does not prevent it; nor does such removal facilitate extinction of avoidance. Sympathectomy after avoidance learning does not impair performance in dogs. Presumably, sympathectomy combined with vagal blocking as used by Wynne and Solomon eliminates cardiac and blood-pressure changes. Following the same strategy, Auld (1951) used tetraethylammonium (TEA) to block sympathetic autonomic nervous system (ANS) reactions, and found results perfectly paralleling those of Wynne and Solomon. There followed a long series of experiments, too numerous to describe here, in which barbiturates, autonomic blocking agents, stimulants, and tranquilizers were used to study the relationship between autonomic CRs and avoidance behavior. They did not importantly affect the conclusion that autonomic CRs are not necessary mediators of avoidance behavior.

Similarly, the transfer of Pavlovian fear conditioning from the curarized to the normal state, demonstrated by Solomon and Turner (1962) shows that peripheral skeletal CRs are not required for avoidance behavior. (These experiments are described in detail in the next section.) Both the sympathectomy and the curarization preparations eliminate broad classes of peripheral CRs as necessary mediators of avoidance behavior.

In summary, we have not yet identified any peripheral CRs which are necessary to mediate avoidance behavior. From this review of both aver- sively and appetitively motivated behavior, the simple idea that some peripherally observed CR is essential in the mediation of operant behavior seems implausible. In no case that we have studied does a peripheral CR seem to bear the required strong relation to the instrumental behavior. However, the two alternative views of the mediational process, (a) that a complex of autonomic and skeletal CRs is the
mediator, and (b) that the peripheral CRs are simply indexes of central events, still seem to be reasonable. Both views permit some slippage between instrumental behavior and CRs. That we are not measuring complex enough peripheral behavior is difficult to refute; on the other hand, it is a relatively unattractive position because it suggests little that is new by way of experimentation except the recording of a larger number of CR measures.

However, consider a third view, (c), that what concomitance we do observe between instrumental behavior and peripheral CRs is due to mediation by a common central state. Then the concurrent measurement of instrumental behavior and Pavlovian CRs is not the optimal experimental strategy. Indeed, it becomes an irrelevant strategy.

Accepting the third view, then to find that a particular CR does not control operant behavior is hardly a refutation of a general two-process approach; indeed, it would be surprising if we should be able to select from the complex instrumental situation the few controlling CRs. Rather, the essential postulate of two-process theory will then be that manipulation of Pavlovian conditioning procedures should have important effects upon instrumental behavior. Although we may not be able to identify the precise Pavlovian CRs which affect instrumental behavior, we can demonstrate that Pavlovian conditioning procedures exert strong influences over instrumental behavior in the absence of changes in instrumental contingencies. Such studies are reviewed in the next section.

Manipulation of Instrumental Behavior by Separately Conducted Pavlovian Conditioning Procedures

It is one matter to lift Pavlovian concepts out of Pavlovian theory and experiments, as Hull and Spence did, and use them to explain instrumental behavior. It is quite another matter to employ the procedures of Pavlovian conditioning in order to influence already established, or to-be-established, instrumental behavior. The latter strategy is generated by two-process theory, because it assumes that Pavlovian conditioning and instrumental learning are two distinct processes, each governed by its own appropriate sets of operations and laws, and it is typified by the experiment of Solomon and Turner (1962). They avoidance-trained dogs in a panel-pressing apparatus with a visual S\(^{d}\). The dogs were then completely paralyzed by d-tubocurarine, and were subjected to purely Pavlovian, discriminative conditioning procedures, with tone CSs and a shock US. When Ss were later tested in the panel-pressing apparatus, they retained their avoidance response to the visual S\(^{d}\). In addition, they showed reliable panel-pressing responses to the tone paired with shock (CS+) during Pavlovian conditioning, but these responses were weak or absent when the tone not paired with shock (CS-) was presented. Thus, the postulated two processes were seen to interact in a particular way, such that the instrumental panel-pressing was immediately elicited by the introduction of a Pavlovian CS+, even though S had never before pressed a panel in the presence of CS+. This experiment can be analyzed in terms of two propositions of two-process learning theory: (a) Pavlovian association processes precede the acquisition of emotional reactions to previously neutral stimuli; and (b) these emotional reactions have motivational properties that can influence instrumental responding. It follows that any empirical or theoretical law of Pavlovian conditioning has profound implications for the control of instrumental responding when the two
processes are interactively combined by E’s procedures.

What are some of these Pavlovian laws (see Pavlov, 1927), and how would they be expected to reveal their impact?

1. The Law of Excitation. A CS consistently paired with a US acquires excitatory properties. Previously neutral stimuli, originally unable to elicit salivary responses in the dog, come to do so after several temporal pairings with meat powder on the tongue (the US for salivation). Irradiation of excitation should occur, and so stimuli similar to the CS should elicit the CR.

2. The Law of Internal Inhibition. (a) Differential inhibition. If a CS+ is consistently paired with a US on one-half of the conditioning trials, and a CS− is consistently presented unpaired with the US on the other half of the conditioning trials, the last phases of the conditioning show “differentiation”; that is, S gives a reliable CR to each CS+ presentation but not to CS−. Differential inhibition is postulated to suppress actively the CR in the presence of CS−. Salivation is not merely failing to occur in response to CS−; it is being suppressed. That CS− actually has inhibitory powers can be demonstrated by presenting it along with an effective CS+. When we do this, a CR that normally would have a specific magnitude will occur in markedly reduced magnitude. (b) Conditioned inhibition. If a compound CS is used as CS−, and one segment of the compound CS is used as the CS+, we meet the conditions for producing a conditioned inhibitor. For example, on half of the conditioning trials we present CSi, paired with the US, and on the other half of the trials we present CS2, in sequence, unpaired with the US. Then, eventually, good CRs will emerge in the presence of CSi, and no CRs in the presence of the CS−-CS2 sequence. We can test the properties of CSi and CS2 by presenting each one in a test trial together with some effective CS+. CSi with CS+ will lead to an enhanced CR, but CS2 with CS+ will lead to a diminished CR. Therefore, CSi is a conditioned inhibitor. It has acquired the property of actively suppressing a CR that would have occurred in greater magnitude; it is no longer neutral. (c) Inhibition by temporal delay. We carry out the conditioning of the salivary reflex under a procedure that delays the onset of the US long after the CS+ has begun. For example, a tone comes on and remains on for 30 seconds before the meat powder is delivered to the dog’s tongue. When this conditioning technique is used, the excitatory CR at the end of many conditioning trials has a long latency, “crowding” the end of the CS-US interval. Pavlov supposed that the CR was actively inhibited during the early moments of presentation of CS+ and that this inhibition dissipated in time, allowing the excitatory influence of CS+ to appear. The CR is thus temporally paced by an inhibition process. A similar phenomenon occurs if a trace conditioning procedure is used with a long CS-US interval. (d) Extinctive inhibition. If a dog is given 50 conditioning trials with CS+ always paired with the US, and then the CS+ is presented unpaired with the US for several hundred trials, the CR, previously measurable after 50 trials, will disappear. This extinction procedure, according to Pavlov, does not merely reduce the excitatory power of CS+ but rather builds up its inhibitory power. Thus, if CS+ is presented along with another CS+ which normally elicits a CR, the CR should be diminished in magnitude. The extinguished CS+ is then labeled an extinctive inhibitor, with power to suppress CRs. (e) Induction. During the course of establishing a differential CR, when CS+ clearly produces a CR of greater magnitude than does CS−, a few CS− trials will often produce an enhanced CR on the next CS+ trial. This phenomenon is called positive induction. Conversely, a few CS+ trials are thought to produce a diminished CR on the next CS− trial. This is called negative induction.

3. The Law of External Inhibition. Novel or distracting stimuli, whether weak or unusually intense, can temporarily diminish the magnitude of a CR. Thus, when an effective CS+ is presented, the occurrence of a loud noise will diminish the CR magnitude. Conversely, novel, distracting, or unusually intense stimuli can destroy temporarily the inhibitory power of a CS−. Any inhibitory process is thought to be susceptible to disruption by an external inhibitor. This is called disinhibition. Repeated presentation of an external inhibitor diminishes its inhibitory and disinhibitory power.

We have reviewed in some detail a few of the major laws of Pavlovian conditioning. What does two-process theory do with such laws? First, it as-
assumes that these laws of Pavlovian conditioning of the salivary reflex are probably the laws of emotional conditioning or laws of acquired drive states. Second, it assumes that conditioned emotional states change S’s motivation level and thus can serve either as motivators or reinforcers of instrumental responses.

Table 1 provides a convenient summary of the variety of ways in which Pavlovian conditioned emotional states can interact with instrumental learning to produce changes in instrumental responding.

Note that Table 1 accomplishes three purposes. First, it allows us to classify and organize the existing knowledge about interactions between the two hypothetical processes. Second, it dramatizes the absence of certain kinds of knowledge, thus pointing to new experiments which need to be done. And third, it raises new and interesting theoretical questions concerning the outcomes of the experiments in the table.

The Solomon and Turner (1962) experiment, which we have already described, can be located in Table 1 in the following manner. In this experiment, the US for fear conditioning was aversive (shock) as was the reinforcer for avoidance behavior. In addition, the Pavlovian conditioning was discriminative, and the Ss were tested with independent presentations of CS+ and CS−. The instrumental training was discriminative, since Ss learned to respond by panel-pressing in the presence of S4. This allows us to insert the results of the Solomon and Turner experiment in Cells 15 and 16. We arbitrarily use a (†) sign in Cell 15 to indicate that the Pavlovian CS+ produced an enhancement of instrumental responding. CS−, on the other hand, had little or no effect, and so we have inserted a (?) in Cell 16.

The traditional CER experiment falls into Cell 3. The S is trained to perform some instrumental response reinforced by some appetitive stimulus. Pavlovian conditioning is carried out with an aversive US. The S is tested with presentations of CS+ while performing the instrumental response. The usual finding is that the response rate is suppressed by CS+, and so Cell 3 contains a (↓).

Now we can examine the laws of Pavlovian conditioning as they are reflected in the interactions contained in Table 1. In all cases, the dependent variable is some measure of instrumental responding. Yet the independent variables, the influence of which is being tested, are those contained in the Pavlovian conditioning experiment.

**TABLE 1**

**COMBINATIONS OF SEPARATELY CONDUCTED PAVLOVIAN PROCEDURES AND INSTRUMENTAL TRAINING PROCEDURES**

<table>
<thead>
<tr>
<th>Pavlovian conditioning</th>
<th>Instrumental training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appetitive</td>
</tr>
<tr>
<td>no S4</td>
<td>S4 − SΔ</td>
</tr>
<tr>
<td>Appetitive (alimentary)</td>
<td>CS+</td>
</tr>
<tr>
<td>CS−</td>
<td>2</td>
</tr>
<tr>
<td>Aversive (defensive)</td>
<td>CS+</td>
</tr>
<tr>
<td>CS−</td>
<td>4</td>
</tr>
</tbody>
</table>

Note.—† and ↓ refer to the effect of the conditioning-training combination on amount of instrumental response.
actively whatever emotional reflex pattern is usually elicited by CS+.

Thus, CS— should be able to inhibit “fear of shock.” 

Prior to discriminative fear conditioning, the dogs had been trained so that they reliably responded on a Sidman avoidance schedule at a rate of seven jumps per minute in a dog shuttlebox. While Ss were jumping, short presentations of CS+ and CS— were given in some random sequence.

Two-process theory leads to the following expectations. If CS+ is a Pavlovian excitor, then conditioned fear should be augmented by its presence, and the instrumental responding rate should increase above the normal rate. In contrast, if CS— is a Pavlovian differential inhibitor, then it should actively suppress conditioned fear and the instrumental responding rate should decrease below the normal rate.

Rescorla and LoLordo (1965) found that the presentation of the CS+ resulted in a doubling of the Sidman jumping rate, but the presentation of the CS— resulted in a large reduction in the Sidman jumping rate. It seems clear that CS— had acquired inhibitory properties. The Rescorla and LoLordo experiment can be inserted in Cells 11 and 12 in Table 1. They represent the intersection of aversive, discriminative Pavlovian conditioning preceded by un-signalized (Sidman) aversive training, with no S4.

Another example of differential Pavlovian conditioning combined with instrumental training is the experiment by Ray and Stein (1959) who trained hungry rats to bar-press for milk on a VI-2 schedule. Then, when the rats attained a steady response rate, an 1800 cps tone was presented for 5 minutes and it terminated with shock to the feet. A contrasting 200 cps tone was presented at other times, but it terminated without shock. Eventu-
ally, the 1800 cps tone acquired the capacity to suppress bar-pressing completely. In contrast, presentation of the 200 cps tone (CS—) often produced increases in the bar-pressing rate above the normal base-line rate, though this difference was not a large one (see Cells 3 and 4, Table 1).

Hoffman and Flesher (1964) have carried out a series of experiments similar to that of Ray and Stein. In general, their findings paralleled those of Ray and Stein with regard to the CER suppression effect of CS+ presentations. However, unlike Ray and Stein they did not find the enhancement of instrumental responding in the presence of CS—. Hammond (1966) repeated and extended the results of Ray and Stein. He further showed that enhancement of bar-pressing rate by presentation of CS— occurred only when the base-line responding rate was below normal.

These interesting findings raise the possibility that a Pavlovian differential inhibitor established by aversive conditioning can enhance instrumental responding established by an appetitive reinforcer. But what could the finding, that an inhibitor of fear enhances appetitively maintained behavior, mean? One possibility is that reflex interrelations exist between appetitively and aversively based incentive states. The occurrence of an elicitor or inhibitor of a fear state may reflexly depress or enhance positive incentive motivation. On the other hand, it may be that an inhibitor of fear has no effect upon an appetitive motivation state. Instead, there may be a general level of fear produced by the experimental situation; since such fear presumably reduces the response rate, an inhibitor of that fear would lead to a rate enhancement. The Hammond experiment strongly supports such an interpretation. These findings are of consider-
able importance to a theory of incentive motivation.

So far, we have concerned ourselves with aversive Pavlovian conditioning, and have traced the effects of CS+ and CS−, in their roles as differential excitors and inhibitors, on both aversive and appetitive instrumental responding. There is, in addition, a series of experiments in which appetitive, discriminative conditioning procedures are combined with appetitive instrumental training procedures. These experiments come out of the Skinnerian tradition. A prototype experiment is that of Estes (1948), and it was probably the first of its kind to be successful in showing that a CS+, previously paired with food presentations, could enhance, during extinction, the rate of an operant previously reinforced by food presentations. As is the case in all of the experiments subsequently using the Estes paradigm, CS+ presentations are in reality being paired not only with food presentations, but also with magazine approach responses. This is inevitable, because the conditioning procedure in these experiments is done through magazine training. In order to get the food, Ss must make instrumental responses. Even though this procedure is not “pure” Pavlovian conditioning, it resembles it to the extent that the approach response cannot produce the food US; only the CS+ can produce it. Neither can the approach response produce the CS+. (The procedure can be described in Skinnerian terminology as a “discriminated operand.”)

Morse and Skinner (1958) trained pigeons to approach a magazine for food in the presence of one color (CS+), but the food never was presented in the presence of a contrasting color (CS−). The behavior of S was irrelevant for the occurrence of magazine operation. Then, in the second stage of the experiment, Ss learned to peck at a white key for food. Finally, extinction was instituted, during which there were test periods in which CS+ and CS− were alternately presented. The pecking rate was higher in the presence of CS+ than it was when CS− was present. There was, however, no control for normal extinction in white light alone, so we cannot tell whether CS− was inhibitory, or the CS+ excitatory, or both. We know CS+ showed differential excitatory properties when compared to CS−, and this confirms Estes’ (1948) findings, but it leaves in doubt the proper sign to put in Cells 1 and 2 of Table 1. It is our guess that Cell 1 should contain a (↑) sign, and Cell 2 a (↓) sign, but in the absence of the proper controls we cannot be sure. A recent experiment by Bower and Kaufman (1963) confirms the finding by Morse and Skinner of a difference between the effects of CS+ and CS−.

Most of the earlier experiments showing the differential excitatory and inhibitory effects of CS+ and CS− on instrumental responding have used extinction responding as a base line. Recently, however, there have been several experiments exploring the effects of differential Pavlovian conditioning procedures on subsequent learning of discriminative instrumental responses. For example, Bower and Grusec (1964) used thirsty rats, conditioning them by having tone S, paired with water reinforcements and tone S2 occurring without water reinforcements. The rats had previously been trained to press a lever to get water, but this early training was not discriminative (no S4). Then, in a third stage of the experiment, the rats were given discriminative instrumental training. One group was trained with its CS+ from the conditioning phase now the S4 for the operant, and its
CS— as S\textsuperscript{A}, while in contrast, another group had its CS\textsuperscript{+} from the conditioning phase now the S\textsuperscript{A} for the operant and its CS— as S\textsuperscript{A}. Thus, in one group the CS/S\textsuperscript{A} relationship was consistent, but in the other group the CS/S\textsuperscript{A} relationship was inconsistent. Bower and Grusec found that the acquisition of the S\textsuperscript{A}— S\textsuperscript{A} discrimination was enhanced for the consistent group but was interfered with in the inconsistent group. There was, however, no way of ascertaining whether or not CS— had true differential inhibitory properties because there was no control group that learned the S\textsuperscript{A}— S\textsuperscript{A} discrimination without prior conditioning with CS\textsuperscript{+} and CS—. We can speculate, however, that learning was interfered with whenever CS— inhibited conditioned appetitive reactions in the presence of S\textsuperscript{A}, and learning was facilitated whenever CS\textsuperscript{+} facilitated excitatory appetitive reactions in the presence of S\textsuperscript{A}.

More recently, Trapold (1966) has shown that inconsistent differential conditioning can actually facilitate reversal learning of a discriminative instrumental response. Rats were first trained, in an operant discrimination, to press a lever for food in the presence of S\textsubscript{1} but to refrain from pressing in the presence of S\textsubscript{2}. Then the lever was removed, and S\textsubscript{2} was paired with food presentation while S\textsubscript{1} was paired with absence of food. Later, when the rats were presented again with the lever, they were required to reverse the original operant discrimination and press in the presence of S\textsubscript{2}. They learned this reversal more rapidly than a group that had not received pairings of S\textsubscript{2} with food presentation. Thus, Pavlovian contingencies were powerful enough to assist the instrumental discrimination reversal.

2. Conditioned inhibition. Rescorla and LoLordo (1965) trained dogs in our laboratory on a Sidman avoidance contingency in the shuttlebox, until the dogs performed the avoidance response at a stable rate. Then they subjected some of the dogs to a Pavlovian fear conditioning procedure in which CS\textsuperscript{+} was followed 2–8 seconds later by shock on one-half of the trials, but on the other half of the trials CS— was followed 2–8 seconds later by CS— and no shock. Other dogs, after learning the Sidman avoidance response, were subjected to a Pavlovian fear conditioning procedure in which CS\textsuperscript{+} was followed by shock on one-half of the trials, but on the other half of the trials CS— was inserted 5 seconds prior to CS\textsuperscript{+} and no shock followed. CS— in both procedures was shown to have inhibitory properties. Test presentations of CS— reduced the Sidman avoidance response rate significantly. Rescorla and LoLordo infer that conditioned fear was inhibited by their CS—. In contrast, fear was aroused by CS\textsuperscript{+}.

3. Inhibition by temporal delay. Rescorla (1967a) trained dogs in our laboratory in a Sidman avoidance response in the dog shuttlebox. When the dogs had acquired a stable jumping rate, they were subjected to a Pavlovian fear conditioning procedure in which only a long-delay CS\textsuperscript{+} was used. A 30-second tone was followed by shock on all conditioning trials. Then later, when the dogs were performing their avoidance response in the shuttlebox, the 30-second tone was presented from time to time. Rescorla found that the onset of the tone produced a decrease in jumping rate, and the rate thereafter increased until, at about 20-second duration, the jumping rate went above normal, increasing steadily to the end of the interval. Cessation of the tone produced a decrease in jumping rate to a below-base-line level, followed by slow recovery to the base-line rate. Here is a case
where onset of a “danger signal” resulted in a temporary decrease of avoidance responding. This is what one would expect from Pavlovian experiments on long duration CSs. CS onset is never closely paired with shock, and so it serves as a CS—, an inhibitor of conditioned reflexes. In the Rescorla experiment, we can infer that CS+ onset inhibited fear.

Recently, Trapold, Carlson, and Myers (1965) have shown how Pavlovian inhibition by temporal delay can operate in an appetitive situation. They conditioned rats with either fixed or variable temporal delay intervals between food US presentations, in the absence of any CS (temporal conditioning). Then they gave the rats FI training with food reward in a barpress situation. They found that when the temporal interval between US presentations previously used in Pavlovian conditioning was the same as that used in the subsequent FI training, the development of a sharp FI “scallopl was facilitated. Evidently the delivery of a US can serve as a stimulus which temporarily inhibits an appetitive state that mediates bar-pressing for food. The temporal pacing of instrumental behavior, as in FI contingencies, can be “sharpened” by Pavlovian conditioning treatments of the proper sort. This is evidence quite compatible with that of Pavlovian experiments.

4. Induction. Not much is known about the operation of the Pavlovian induction phenomenon as it influences instrumental responding. Rescorla (1967a) and Rescorla and LoLordo (1965) found that termination of an aversive CS+ during instrumental avoidance responding reduced the response rate for a few seconds. This, however, is not the only way of showing induction. One might explore the increase in jumping rate produced by a CS+ presentation that followed a CS— presentation, as compared with one that followed another CS+ presentation, in order to measure positive induction. This has not been done. Neither has negative induction been studied in such a way. In order to do this, one would compare responding to CS— when it has recently been preceded by a CS+ presentation, as compared with being preceded by a CS— presentation.

5. External inhibition and disinhibition. The effects of extraneous stimuli upon CSs imposed on ongoing instrumental behavior have been little studied. It would be of interest to see whether a novel stimulus could disrupt the effect which a CS+ has upon instrumental behavior (external inhibition). Likewise, we would like to know whether we can remove the inhibitory effect which a CS— has upon instrumental behavior by presentation of a novel stimulus (disinhibition). Preliminary experimentation with dogs (Rescorla, 1967a) suggests that disinhibition of inhibition of temporal delay can be produced with fear conditioning; however, no evidence was found for external inhibition.

We have covered many of the experiments showing how Pavlovian procedures, interacting with Thorndikian (or Skinnerian) procedures, can influence instrumental responding. In doing so, it became clear that many of the cells in Table 1 are empty. Some of the empty cells are as interesting as the filled ones. For example, take Cell 9. This cell would require the testing of the effect of an appetitive CS+ on unsignaled avoidance responding. What would happen? Would the “irrelevancy” of the fear that mediates avoidance to the appetitive CRs elicited by CS+ mean that avoidance rate would be unaffected by CS+? Or is
there a matrix of interrelationships among emotional-motivational states that requires that appetitive CRs interfere with or inhibit all aversive states to some extent? Perhaps, instead, the Spence (1956) view of "generalized D" would be correct, and any excitatory CS+ would enhance any response mediated by any excitatory state in the presence of $S^a$. CER experimentation (see Cell 3) would argue against this expectation, but perhaps it is too early to be certain. Certainly, much work is needed in this area of ignorance.

Another interesting cell is No. 10. Suppose a dog has acquired a stable Sidman avoidance response in the shuttlebox. He is then given test presentations with a CS— previously established in an appetitive Pavlovian conditioning procedure. What might be expected to happen? Would CS— be "irrelevant" for fear level, and therefore leave jumping rate unaffected? Or would CS—, being a signal for the nonoccurrence of an appetitive US, be "disturbing" in some way, thus "adding to" fear level and increasing the avoidance response rate? Is there a dimension of "pessimism" established in the emotional life of laboratory animals, such that a signal that says "food won't come," although it may superficially seem irrelevant for fear motivated avoidance responding, nevertheless is a "bad" event, just as shock is also a "bad" event? Amsel (1965) and Brown and Wagner (1964) have recently shown the generality of a "perseverance" attribute for laboratory Ss given special types of partial reinforcement experiences. Perhaps "pessimism" can be similarly established by appropriate Pavlovian and Thorndikian treatments, such that all CS—'s for appetitive differential conditioning, and all CS+'s for aversive differential conditioning, can enhance all instrumental responses reinforced by the avoidance of aversive USs of any type. It certainly would be valuable to know how these interactions work. The techniques for getting this information have already been worked out.4

There are other cells in Table 1 that command attention, but the reader can now generate his own experiments to fill them. We should note, however, that Table 1 does not exhaust the possibilities for analysis of interactions between Pavlovian and Thorndikian processes. The Pavlovian conditioning procedures can either precede, or be preceded by, the instrumental training procedures (thus focusing attention on order effects in the interaction of the two processes). Or the Pavlovian conditioning procedures can be carried out either within the situation used for instrumental training or in another situation as distinctively different as possible from the instrumental training situation. This variation focuses attention upon situational stimuli as a factor in the interaction of the two processes. Intrat個ual Pavlovian conditioning can, in turn, either be carried out "on the base line," that is,

4 After the completion of this manuscript LoLordo (1966) showed that the summation of fear of two different aversive events is reflected in instrumental responding. He trained dogs to avoid shock by pressing a panel, with an unsignalized (Sidman) procedure. He then exposed the dogs to a Pavlovian conditioning experience during which the CS+ was paired with a loud blast from a horn and CS— was explicitly unpaired with the horn blast. Later, in a test session, 5-second presentations of CS+ and CS— were imposed on Sidman responding. The CS+ elicited an increase in the pressing rate, but the CS— did not produce an inhibitory effect on the pressing rate. Such a result indicates that the generalization of fear excitation as a mediator is probably quite great (from noise to shock), but perhaps the generalization of fear inhibition is not very great.
while the instrumental behavior to be influenced is occurring; or, in contrast, it can be carried out "off the base line," that is, when instrumental responding is impossible.

Up to this point we have talked only of variations in the Pavlovian conditioning parameters. Another strategy is to vary the instrumental training parameters while holding the Pavlovian conditioning constant. For example, would Pavlovian conditioned stimuli based on a shock US have the same effect on an S during asymptotic, reinforced, operant performance as it would have during the first moments of extinction of that operant? Such a question has implications for any theory that argues for the importance of emotion in the control of instrumental responding, since presumably different emotions are present in training and extinction. It seems clear that systematic variations of both the Pavlovian and instrumental operations in Table 1 would be valuable in extending our understanding of the emotional control of instrumental behavior.

The many possible variations in procedure will complicate Table 1 and expand it to almost unmanageable proportions. Nevertheless, such variations must be kept in mind, because we already know that they are important. For example, the effects of the order of Pavlovian conditions and instrumental training are subtle and interesting. Overmier and Leaf (1965), working in our laboratory, found that the discriminative control of avoidance responding by a Pavlovian CS+ and CS— was poorer when the conditioning preceded avoidance training than when the reverse order was used. However, there is nothing in two-process theory that predicts an order effect. This result indicates that two-process theory is rapidly generating new data requiring further refinement and extension of such theory while not requiring the abandonment of the approach.

We can conclude that, following one strategy suggested by two-process theory, Pavlovian conditioning procedures can readily be used to control instrumental responding. Furthermore, it might very well turn out that instrumental responding is as sensitive, or perhaps even more sensitive, a measure of the effects of Pavlovian conditioning procedures than are the traditionally measured conditioned visceral or motor reflexes themselves. If this should turn out to be true, it would constitute a major heuristic, albeit somewhat ironic, contribution of two-process learning theory.

Finally, we point to the success achieved in controlling instrumental responding by means of a wide variety of Pavlovian procedures, contrasted with the failure to establish definitive relationships between CRs (as mediators) and concurrent instrumental responses. Such success gives support to the version of two-process theory postulating that the concomitance we do observe between CRs and instrumental responding is mediated by a common central state, and the changes in that state are subject to the laws of Pavlovian conditioning.

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