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Pavlovian Conditioning and Its Proper Control Procedures

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The operations performed to establish Pavlovian conditioned reflexes require that the presentation of an unconditioned stimulus be contingent upon the occurrence of a conditioned stimulus. Students of conditioning have regarded this contingency between CS and US as vital to the definition of conditioning and have rejected changes in the organism not dependent upon this contingency (such as sensitization or pseudoconditioning) as not being "true" conditioning (i.e., associative). Therefore, in order to identify the effects due uniquely to the contingency between CS and US, a variety of control procedures have been developed. Each of these procedures attempts to retain some features of the Pavlovian conditioning situation while eliminating the CS – US contingency.

This paper argues that, in fact, none of the conventional control procedures for nonassociative effects is adequate, either taken alone or in combination; it further argues that a new type of "random stimulus" control procedure does enable one to identify the role of the CS – US contingency in Pavlovian conditioning.

Traditional Control Procedures

The conventional control procedures for Pavlovian conditioning are quite familiar, so they will be described only briefly. In all of these descriptions, we assume that the conditioning or control treatment is administered, and then all groups are tested with a single (unreinforced) CS presentation. It is only the results of the test trial that are of st. (Similar descriptions could be given when anticipatory CRs rather than test trial CRs are used as the index of conditioning.)

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The various control treatments which are administered prior to the test trial in place of Pavlovian conditioning are listed below together with examples of their use.

1. *CS-alone Control.* In this procedure a control subject (*S*) receives the same number of CS presentations as does an experimental *S*; however, no US is administered. This control is designed to evaluate the effects of familiarity with the CS and any changes in the organism due solely to that familiarity (Rodnick, 1937; Thompson & McConnell, 1955).
2. *Novel CS Control.* In this procedure, no CS is given prior to the test trial. The test trial gives an estimate of the unconditioned effects of the CS (Rodnick, 1937; Wickens & Wickens, 1940).
3. *US-alone Control.* Repeated presentations of the US alone are made in order to control for sensitization by, or habituation to, the US (Notterman, Schoenfeld, & Bersh, 1952; ickens & Wickens, 1940).
4. *Explicitly Unpaired Control* (sometimes called the random control). In this procedure, *S* receives unpaired presentations of CS and US. This can be done in a variety of ways, but the most typical is presentation of both CS and US in the same session in random order but never close together in time (Bitterman, 1964; Harris, 1943).
5. *Backward Conditioning.* The CS and US are paired, but the US is always presented prior to the CS (Kalish, 1954; Spence & Runquist, 1958).
6. *Discriminative Conditioning.* One stimulus (CS+) is paired with the US and the other (CS–) is not. In this way CS— receives a treatment similar to that of CS+ except that the contingency with the US is an "explicitly unpaired" one. Differences between the reactions to CS+ and CS— are taken to indicate Pavlovian conditioning (Solomon & Turner, 1962).

The very variety of control procedures which have been developed attests to he inadequacy of any one. But it may be worthwhile to point briefly to the pitfalls of each procedure because some of these have not been widely recognized. We take as the logical criterion for an adequate control procedure that it retain as many features as possible of the experimental procedure while excluding the CS – US contingency. In general, each of the control procedures, although attempting to eliminate the CS – US contingency, can be shown to do considerably more. The result is that a variety of other differences, both associative and nonassociative, between experimental and control procedures is confounded with the absence of the CS – US contingency. Some of the confoundings are pointed out below.

1. *CS-alone Control.* Quite obviously, an 6" treated in this way does not have the same number of US experiences as the experimental *S* does; therefore, any differences between *S*s can be attributed to this difference in experience with the US. But worse, repeated CS presentations in the absence of all USs may not lead to the same rate of CS habituation as does repeated CS presentation in a chamber in which the US also occurs.
2. *Novel CS Control.* It is useful to know the unconditioned properties of the CS, but it is not clear what relevance this has for identifying "true" Pavlovian conditioning. The experimental *S* has experienced the CS a large number of times prior to the test trial and it is no longer novel to him. Why compare

him to an *S* for whom the CS is novel? Comparison with a novel CS group allows one to assess the total change in reaction to the CS produced by the conditioning procedure but does not permit isolation of those changes due uniquely to the occurrence of Pavlovian conditioning.

3. *US-alone Control.* This procedure has faults similar to those of the novel CS procedure. An *S* with this procedure receives a novel CS at the time of test, while the experimental *S* receives a CS which it has experienced many times.
4. *Explicitly Unpaired Control.* In many ways this procedure comes closest to being an appropriate control, and it has become increasingly popular in recent years. However, it contains flaws which cannot be overlooked. Although it escapes the criticisms of Procedures 1, 2, and 3, it, too, does not simply remove the contingency between CS and US; rather, it introduces instead a new contingency, such that the US cannot follow the CS for some minimum time interval. Instead of the CS being a signal for the US, it can become a signal for the absence of the US. Although this is an interesting procedure in itself, it does not allow a comparison between two groups, one with a CS – US contingency and one without it. We are, instead, in the position of having two different CS – US contingencies which may yield different results. How can we know which group showed Pavlovian conditioning?
5. Backward conditioning. The relevance of this procedure rests upon the assumption that in Pavlovian conditioning not only the CS – US contingency but also their temporal order of presentation is important. It is not clear whether this should be taken as part of the definition of Pavlovian conditioning or as an empirical result. Nevertheless, some investigators have suggested comparison with a backward conditioning group to evaluate the traditional experimental group. For the purposes of analysis, let us assume that the CS and US do not overlap in this procedure. We then have a sequence of events: US – CS . . . US – CS . . . US – CS . . . in conditioning. This procedure produces the same difficulty as does the explicitly unpaired procedure : The occurrence of the CS predicts a period *free from the US.* Again, presentation of the US is contingent upon CS occurrence but the contingency is a negative one. Of course, if the CS begins during the US in this procedure, CS occurrence predicts the termination of the US, which, in turn, introduces another contingency and further complications. It is worth noting that Konorski (1948) considered the backward conditioning paradigm as the prime example of an inhibitory conditioning procedure.
6. Discriminative conditioning. By now it should be clear that this control procedure falls prey to the same criticisms as do Procedures 5 and 6. CS— is explicitly unpaired with the US. In fact, the discriminative conditioning procedure can be viewed as the simultaneous administration to the same *S* of the experimental procedure and Control Procedure 4.

We can conclude that each of the proposed control procedures either confounds some important nonassociative change with the disruption of the CS – US contingency or changes the contingency from a positive to a negative one. Furthermore, there is no obvious way in which combined control procedures can

be used to eliminate confoundings. Therefore, we are in the unfortunate position of being unable to evaluate "true" Pavlovian conditioning by the use of any or all of the conventional control procedures

An Adequate Alternative

There is, however, a control procedure which solves the problems raised above. We shall call this procedure the "truly random" control procedure. In this procedure, both the CS and the US are presented to *S* but there is no contingency whatsoever between them. That is, the two events are programmed entirely randomly and independently in such a way that some "pairings" of CS and US may occur by chance alone. All CS and US occurrences for the control group are the same as for the experimental group except that the regular temporal contingency between CS and US is eliminated. The occurrence of the CS provides no information about subsequent occurrences of the US. This procedure is similar in conception to the explicitly unpaired procedure, (4), except that it eliminates the contingency of that procedure which allows the CS to signal nonoccurrence of the US.[1]

There are a variety of ways of arranging a truly random control condition. Two major alternatives are: (*a*) Present the CS as in the experimental group but randomly distribute USs throughout the session; (*b*) conversely, present USs as in the experimental group but randomly distribute CSs. Note that, in order for there to be no contingency, the distributions must be such that CS occurrences do not predict the occurrence of USs at any time in the remainder of the session. If the CS predicts the occurrence of a US 30 minutes later in the session, an appropriate random control condition has not been achieved.

Despite the apparent adequacy of these alternatives, they actually add other confoundings. In the usual Pavlovian conditioning procedure, several time intervals other than the CS – US interval are kept relatively constant. Thus time intervals between successive CSs and successive USs are of some (relatively large) minimum value. Each of the two truly random controls would violate one of these relations and thus introduce changes other than removal of the CS – US contingency. Fortunately, this can be avoided if we depart from the traditional conditioning procedures and use a wide variety of intertrial intervals for the experimental *S*s. Then it is possible to arrange truly random presentations of CS and US for the control *S*s while preserving the inter-US and inter-CS intervals of the experimental condition. For instance, one could program CS – US pairings for the experimental group with a random-interval programmer. Then a truly random control would be arranged by using two independent random-interval programmers with the same parameters as that of the experimental group—one to deliver CSs and one to deliver USs.

We do not wish to understate the importance of a variety of nonassociative factors which do occur in Pavlovian conditioning. It is respect for their effects that leads to the advocacy of the truly random control for contingency-produced effects. One great advantage of the truly random control is that it holds constant between the experimental and control procedures all of the factors extraneous to the CS – US contingency without demanding that we be able to specify in advance what factors

might be operating. In contrast, the customary control procedures have often been developed only to deal with one supposed nonassociative factor.

It is also important to realize that the actual results obtained with the truly random control procedure are irrelevant to the present argument. It may be that in some conditioning situations, *S*s treated with the truly random control procedure will show strong changes in behavior when the CS is presented. This simply means that important changes not dependent upon a CS – US contingency occur in this situation; effects due to that contingency still must be evaluated as deviations from the effects produced by the truly random procedure.

Traditionally, the prime concern of American investigators has been the excitatory processes, and the inadequate conventional control procedures have reflected this concern. As noted above, many of these control procedures are biased toward the inhibitory side because of the explicit nonpairings of the CS and US. But the inhibitory effects of conditioning deserve attention in their own right. Clearly, we need an appropriate base condition against which to compare both the inhibitory and excitatory kinds of conditioning relations. The truly random sequence of CSs and USs provides an unbiased control procedure for both positive and negative contingencies between CS and US. In fact, if we are going to retain the conceptual terms "conditioned excitatory" and "conditioned inhibitory" stimuli, the truly random control procedure will provide a base line against which to define these effects.

In addition to serving as a control condition for Pavlovian conditioning, the truly random presentation of CS and US provides an unbiased extinction procedure. To the degree that our concern in extinction of Pavlovian CRs is with how the animal loses its associative connection, simply removing the US from the situation is an inappropriate extinction procedure. Simple removal of the US eliminates not only the CS – US contingency but also whatever nonassociative effects the US might have. However, using the truly random presentation of CS and US as an extinction procedure permits examination of the loss of contingency-dependent learning independently of these other effects. Furthermore, the truly random procedure serves as an unbiased procedure for extinction of both excitation and inhibition. If inhibition can be acquired it seems reasonable that it can be extinguished. The truly random presentation of CS and US is the most natural extinction procedure for inhibitory as well as excitatory effects.

Objections to the "Truly Random" Procedure: Two Theoretical Views of Conditioning

It seems certain that our arguments will not be entirely convincing. All conventional control procedures have a common feature: They never allow forward pairings of the control CS and US. The reluctance which one might feel toward accepting a truly random control procedure stems in part from the close temporal pairings of CS and US which *will occur by chance* in that condition. One may thus argue that the truly random control procedure itself allows Pavlovian conditioning because of those few chance trials which pair CS and US; if so,

it can hardly be considered a "pure" control condition. According to such an argument, the same processes may be operative in both the experimental and control procedures, but to a lesser degree in the latter.

This objection runs deep and is worthy of extensive examination. It rests upon an assumption, often not made explicit, that the temporal *pairing* of CS and US is the sufficient condition for "true" Pavlovian conditioning. It views Pavlovian conditioning as a one-sided affair in which conditioning is either absent or excitatory; the number of CS – US pairings determines the degree to which conditioning is excitatory. It is this view which dominates American notions of conditioning and which has been influential in preventing inhibitory processes from playing a major role in our thinking. A good example of this position is the Guthrian claim that the reinforcing event in Pavlovian conditioning is simple contiguity between CS and US. From this point of view, a reasonable control procedure for Pavlovian conditioning is one in which *S* "is not taught that the US follows the CS." This has been interpreted to include the possibly quite different learning that "the CS is not followed by the US." With this type of bias, it might be reasonable to conclude that the "explicitly unpaired" and the discriminative conditioning procedure are appropriate controls for Pavlovian conditioning.

An alternative theoretical view of Pavlovian conditioning, and one which has not often been distinguished from that in the previous paragraph, is that the temporal contingency between CS and US is the relevant condition. The notion of contingency differs from that of pairings in that the former includes not only what is paired with the CS but also what is not paired with the CS. Thus the truly random procedure contains no contingency between the CS and US, even though it does contain some chance CS – US pairings. From this point of view the appropriate control condition for Pavlovian conditioning is one in which the animal is taught that "the CS is irrelevant to the US." Deviations from this base condition can be either positive (CS is followed by US) or negative (CS is followed by absence of US). This view of conditioning has the advantage of separating out, from the simple absence of conditioning,

a conceptualized inhibitory process which has a status equal to that of excitatory processes. Intuitively it seems clear that learning that the US does not follow the CS is different from failing to learn that the US follows the CS or learning that the CS is irrelevant to the US. In this sense, at least, the contingency view of conditioning, and the truly random control procedure which it generates, is more in the spirit of Pavlovian theory.[2]

The idea of contingency used here needs explication. By it we mean the degree of dependency which presentation of the US has upon prior presentation of the CS. This is clearly a function of the relative proportion of US events which occur during or at some specified time following the CS. Thus, in the truly random condition no dependency exists, but in the standard Pavlovian conditioning situation the dependence is complete. The control condition is brought closer to the experimental condition as we increase the proportion of USs occurring in the presence of the CS. When, at the other extreme, all USs occur in the absence of the CS, the inhibitory end of the continuum is reached. These proportions can be stated in terms of the probability of a US occurring given the presence of a CS (or given that the CS

occurred at some designated prior time), and the probability of a US occurring given the absence of the CS (cf. Prokasy, 1965). The dimension of contingency is then a function of these two probabilities; if Pavlovian conditioning is dependent upon the contingency between CS and US, it, too, will be a function of these two probabilities. However, no attempt is made here to specify a particular function which relates these two probabilities to a continuum of contingencies."[3]

If two conditioning procedures have the same probability of reinforcement in the absence of the CS, but have different probabilities in the presence of the CS, they differ in what is usually called the degree of partial reinforcement. Whether or not this affects the degree of contingency depends upon the function of these two probabilities that we choose to describe degree of contingency. We suggest that the contingency dimension, rather than the number of CS – US pairings, is the theoretically fruitful dimension in Pavlovian conditioning.

As soon as one admits a symmetry of inhibition and excitation in the Pavlovian conditioning situation, the CS – US pairing view of conditioning begins to lose appeal. Pavlovian conditioning consists of a sequence of CSs and USs arranged in a particular temporal pattern. Suppose, now, that one is primarily interested not in excitatory processes but in inhibitory processes, or in how an animal learns that the CS signals a period free from the US. From the point of view that the pairing of CS and US is the important Pavlovian event, the truly random control procedure is inadequate for a reason that is exactly the opposite to what it was for excitatory conditioning; now it contains a number of nonpairings of CS and US. Therefore, from such a view we are forced to conclude that the symmetrical control procedure for the study of inhibitory processes is to consistently pair CS and US. This, it seems, is less than sensible.

It may also be argued that the truly random control procedure does more than simply remove the contingency of Pavlovian conditioning. It might, for instance, introduce a new process of its own such as increasing the likelihood that *S* will ignore or habituate to the CS since it bears no relation to the US. This is, of course, possible; but it means that the arrangement of a contingency affects the rate at which *S* comes to "ignore" a CS. Thus this ignoring of a CS is governed by its associative relation to the US and is a proper part of the development of a CR. From the point of view of this paper, then, the truly random control procedure still provides the appropriate control.

Another objection to the truly random control procedure rests again upon the notion that the pairing of CS and US is the significant event for Pavlovian conditioning. One can claim "what is random for the experimenter may not be random for *S*." Such an objection argues that if we use the truly random control, we should arrange it so that the relation between the CS and US is phenomenally random. One suspects that, at least in part, this objection is based upon the notion of pairing of CS and US. The statement implies that even though CS and US are not related, *S* will behave as if the CS predicts the US. Those who make this claim are rarely concerned that *S* will behave as if the CS predicts no US!

It is, of course, possible that some process which normally produces Pavlovian conditioning when the US is made contingent upon the CS is operative even when the CS and US are presented in random fashion. Such a process might fail to operate

only when there is a slight inhibitory, or only when there is a slight excitatory, contingency between CS and US. In its most general form, this argument says that the limits of our operational procedures do not necessarily define the limits of psychological processes in the organism. It is difficult to disagree. On the other hand, this is not an objection which applies uniquely to the truly random control procedure. For instance, it applies also to the traditional controls for Pavlovian conditioning: What is explicitly unpaired for *E* may not be explicitly unpaired for *S*. A solution to this problem requires an ability, which we do not yet have, to identify psychological processes; until we do, there is little choice but to associate psychological processes in Pavlovian conditioning with experimental operations.

A major advantage of the contingency view of Pavlovian conditioning is that it provides a continuum of CS – US contingencies along which a zero point can be located. In the long run, the location of this zero with respect to process is not crucial; if we discover that the assumed correspondence between experimental contingency and psychological process is in error, it may be that results can be brought into line by relocating the point of "zero contingency."

Two Experimental Predictions

The truly random control has led to the consideration of two theoretical views of Pavlovian conditioning, the pairing view and the contingency view. The difference between these two theoretical conceptions of Pavlovian conditioning is partly semantic. From our present knowledge it is arbitrary whether we wish to have a point of "zero" conditioning with deviations on both sides or a zero point from which deviations can occur only in one direction. On the other hand, the difference is also partly empirical, and in this framework the question is whether the number of CS – US pairings, or the relative probabilities of US in the presence and absence of the CS, is the determinant of Pavlovian conditioning. A comprehensive empirical answer to this question requires an extensive program of research, but two specific predictions can be extracted for illustrative purposes.

The area of most blatant disagreement between the two conceptions of conditioning is the notion of inhibition, (*a*) The pairing viewpoint fails to distinguish between *S*s failing to learn and *S*s learning that the CS and US are explicitly unpaired. Experimentally, in accord with the pairing view, a CS which has been repeatedly presented alone should not differ from one which has been explicitly unpaired with the US. (This simple statement of the prediction neglects the operation of such factors as sensitization which would produce more CRs in the explicitly unpaired condition.) (*b*) From the viewpoint that CS – US contingencies are the important determinants of Pavlovian conditioning, repeated CS presentations may result in failure to condition; but, explicitly unpairing CS and US should lead to the development of inhibitory phenomena. Thus, under some circumstances, the contingency viewpoint predicts a difference between the outcomes of these two treatments and the pairing view does not. But it is important to note that the contingency approach only predicts this difference when the CS is tested in the presence of some other excitatory stimulus. Inhibitory effects can be measured only

when there is some level of excitation to be reduced. Again, at the risk of being pedantic, it is important not to confuse the question of the presence or absence of inhibition with the question of the ability to measure inhibitory effects.

The conditions for testing the empirical fruitfulness of the contingency view were met in an experiment by Rescorla and LoLordo (1965). In that experiment, two groups of dogs were trained on a Sidman avoidance task. Both groups were then confined and given Pavlovian conditioning treatments. While confined, one group received repeated tone presentations without any shock USs, while the other group received tones and shocks explicitly unpaired in the manner of Procedure 4 above. Later presentation of these tonal stimuli during the Sidman avoidance performance led to a substantial reduction in avoidance rate during the CS in the explicitly unpaired group and little change in rate during the CS for the group that received only tones. Because previous experiments supported the assumption that avoidance rate is in part a function of the level of fear, these results were interpreted to indicate that explicitly unpairing the CS and US led to the development of Pavlovian inhibitory processes capable of reducing fear. Merely presenting the tones did not lead to this result. The outcome of this experiment is consistent with the theoretical view that CS – US contingency, rather than simply CS – US pairing, determines the outcome of Pavlovian conditioning procedures.

The two contrasting views of Pavlovian conditioning also make differential predictions for the outcomes of excitatory conditioning procedures. Suppose that we condition one group of SB with a type of truly random conditioning procedure in which USs are delivered on a variable interval schedule and CSs are randomly distributed throughout the session. A second (experimental) group receives the identical treatment except that the preprogrammed USs are allowed to reach *S* only if they come in a 30-second period following a CS onset. Thus, for this group a switch permits the delivery of the independently programmed USs only for a period just after each CS. USs which are programmed for the truly random *S*s during other periods of the session never occur for the experimental group. The *S*s in this experimental group receive at least as many CS – US pairings as do *S*s in the truly random group, but USs can occur only following CSs. If the number of CS – US pairings is important, then this procedure should produce results similar to those of the truly random control. However, if the CS – US contingencies are important, then a considerably greater number of CRs should occur in the experimental group.

This conditioning procedure was used in a paradigm like that of the Rescorla and LoLordo experiment (Rescorla, 1966). All dogs were trained on a Sidman avoidance schedule. Then, separately, half of the animals received the truly random control treatment while the other half received the modified treatment of the experimental group described above. Shock was the US and tones served as CSs. After these conditioning treatments, the tones were presented during performance of the avoidance response. The CS of the truly random group had little effect upon performance, while the CS of the experimental group showed marked fear-producing properties, increasing the avoidance response rate. Again, this result supports the view that the important dimension in Pavlovian conditioning is the CS – US contingency rather than CS – US pairing.

These are but two examples of the kinds of experiments which the contingency view of Pavlovian conditioning generates. The fact that the results of these experiments support the fruitfulness of the contingency view suggests a program of research varying the relative probabilities which form the basis of the CS – US contingencies. In this way we can explore the relations between CS – US contingencies and Pavlovian conditioning.

In summary, we have argued that the conventional control procedures for Pavlovian conditioning are inadequate in a variety of ways. An alternative procedure, in which the CS and US bear no relation to each other, was proposed. It was argued that the failure previously to use this procedure stems from a particular, and probably inadequate, conception of Pavlovian conditioning. Taking seriously the truly random control procedure, we proposed an alternative theoretical view of Pavlovian conditioning in which the CS – US contingency is important rather than the CS – US pairing. The empirical usefulness of this alternative view has been illustrated.

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Notes

1. A similar control procedure has been suggested by Jensen (1961) and by Prokasy (1965).
2. It is worth pointing out that the argument advanced in this paper has direct analogues for instrumental training. Whatever faults it might have, the yoked-control procedure was introduced precisely to determine what effects are uniquely due to instrumental reinforcement contingencies. Similarly, the distinction between pairing and contingency views has recently been examined for operant conditioning by Premack (1965).
3. "These probabilities can be calculated whatever the number of CS and US events. If, for instance, there is only one CS-US pairing, there is a high degree of contingency since the probability of a US following a CS is one and the probability of a US in the absence of the CS is zero. However, it may turn out empirically that with only a few CS and US events the relative importance of single pairings is greater.