ARE SCHEDULES OF REINFORCEMENT NECESSARY?
A REVIEW OF W. N. SCHOENFELD AND B. K. COLE'S
STIMULUS SCHEDULES: THE t - τ SYSTEMS¹

JOHN R. PLATT

MCMASTER UNIVERSITY

The publisher's notes on the back cover of this book read, in part: "Incorporating work done over the past 20 years by Professor Schoenfeld and his students, this book presents the first systematic framework for the study of reinforcement schedules and all other schedules of stimulus presentation to a responding organism." Although this statement understandably smacks a bit of ballyhoo, and the appropriateness of such adjectives as "first" and "all" is best left to the arbitration of time, the book does indeed represent an effort to provide a rational and systematic framework for the study of reinforcement schedules and other paradigms of stimulus presentation. This systematic framework is provided by the t and τ systems, which have been in the literature for some time. The t system first appeared (Schoenfeld, Cumming, and Hearst, 1956) a year before *Schedules of Reinforcement* (Ferster and Skinner, 1957), and the τ system (Schoenfeld and Cumming, 1960) was published four years later. The expressed justification for the current exposition of these systems is that: "Because the literature on the t - τ systems had grown to significant size, and because the thinking that the systems had started was still expanding, we came to the belief that a summarized account of the progress to date could be useful to other students and researchers" (p. vii).

The book is an extended research monograph built around abstracts of studies generated by the t - τ systems over the past two decades, mainly in Professor Schoenfeld's own laboratory. Over 120 pages of this 160-page

book are devoted to such abstracts. After a brief introductory chapter, subsequent chapters begin with a terse section of introductory text followed by relevant abstracts. Each abstract is divided into five sections. A first section states the original goals of the experiment, and a second indicates the subjects (pigeons, rats, or monkeys), responses, and independent and dependent variables employed. A third section lists empirical generalizations induced from the results, and a fourth summarizes the significance originally attributed to the results. A final section entitled "Present comments" provides the authors' comments . . . "on how that work appears to us today given our privilege of hindsight" (p. ix). These comments also provide the only real semblance of continuity relating the abstracts to each other and to the text. Many of the abstracts also include graphic presentations of experimental results, which are of considerable aid to the reader, although the general lack of reference to these figures in the abstracts often produces difficulty in identifying a relevant figure at the optimal point in one's reading.

The general organization of the book around research abstracts seems to be both a strength and a weakness of the presentation. On the positive side, the abstracts give the reader a good feel for the kinds of research that have been generated by the t - τ systems, and allow brief presentation of previously unpublished results. Nineteen of the 43 abstracts represent dissertation research, and although seven of these have been published in shortened form, the remaining 12 appear for the first time. Disadvantages of the heavy reliance on research abstracts in this book seem to be twofold. Firstly, the abstracts themselves are rather elliptical, reading more like laboratory notes than developed text. Descriptions of what was done and what was observed are

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often couched in variations of terminology from the t - τ systems, which have not been explicitly discussed, and details are often vague. Also, the lack of any sort of Index or detailed Table of Contents makes it very difficult to retrieve individual abstracts. Secondly, the "Present comments" sections seem unable to carry the entire burden of continuity and development, given the sparsity of additional text. It seems probable that the interested researcher will find frequent need to refer to original sources, while students may find themselves unwilling to expend the labor needed to follow the development through the abstracts. Implementation of the research-abstract concept could undoubtedly have been improved by additional textual material throughout the book. However, it appears to this reviewer that the more traditional format for this type of extended research monograph (*e.g.*, Ferster and Skinner, 1957; Logan, 1960; Notterman and Mintz, 1965) remains preferable for readability.

THE t - τ SYSTEMS

The first three chapters of this book provide a background for and explication of the t - τ systems, along with abstracts of basic research generated by them. These systems are introduced in the context of Skinner's (1938; Ferster and Skinner, 1957) classification of reinforcement schedules, which involves a basic dichotomy between interval and ratio types. Interval schedules, of course, identify a response for reinforcement on the basis of its temporal position from some arbitrary time zero, while ratio schedules use ordinal number of the response from some arbitrary starting point for the count. The t system was an attempt to define a parameter space capable of at least approximating the common schedules of reinforcement, without introducing such a dichotomy between ratio and interval classifications. In so doing, the t system was based on time, rather than on response-count variables. This decision was made partly because time could be defined independently of an organism's behavior, and partly because it was hoped that effects of temporally defined reinforcement schedules might be more easily integrated with results of the Pavlovian paradigm, which was already defined in terms of temporal relationships between stimuli.

The initial version of the t system that emerged from the considerations just mentioned was almost deceptively simple. It specified a repeating time cycle of duration T which consisted of two fixed time segments, t^D and t^A , with the restriction that the probability of reinforcement for a response occurring during t^D be greater than that probability during t^A . Early work with the t system used several parameter restrictions that even further simplified the system. The most significant of these restrictions were that no reinforcers were presented during t^A , and only the first response in each t^D was reinforced. With these restrictions, the t system could generate a number of traditional reinforcement schedules. For instance, extinction (EXT) results whenever t^D is made very short, while continuous reinforcement (CRF) can be produced by making T shorter than reinforcement duration and having t^D occupy essentially all of T . By simply extending the duration of T , CRF becomes fixed interval (FI) by the clock.

In addition to those traditional schedules directly generated by the t system, at least one new schedule resulted and several other traditional schedules were approximated. The new schedule, called random ratio (RR), results when T is made shorter than the minimal interresponse time (IRT). Under these circumstances every response has an equal probability of reinforcement given by t^D/T if a random phase relationship exists between responses and the T cycle. The RR schedule is, thus, a very special case of variable-ratio (VR) schedules. Finally, certain fixed-ratio (FR) and VR schedules can be approached when t^D/T is made relatively small and T is made relatively large. The FR schedules are approximated by t^D/T values large enough for every t^D to be intercepted by a response, while VR is approximated by smaller values of t^D/T . In both cases, the approximation to ratio-like schedules depends on the subject developing a relatively high, constant rate of responding after postreinforcement pauses.

Research abstracts presented in conjunction with the t system are mainly concerned with relating response rate under food reinforcement to the parameter space defined by T and t^D/T . Data are presented for both pigeon key pecking and rat lever pressing, although pigeon data predominate. Much of this parametric data is nicely summarized by the three-

dimensional Figure 2-9-a, page 41. In general, response rate decreases with increases in T , while increases in t^D/T first increase and then decrease response rate. In addition, the value of t^D/T that produces maximal response rate tends to decrease with increases in T . The main import of these results, according to the authors, is the functional continuity of behavior over the parameter space of the t system. Thus, for example, ratio-like and interval-like behaviors have been generated by a single set of parameters with no indication of a need to dichotomize the two types of schedules or the behaviors controlled by them.

In spite of successes attributed to the t system by the authors, dissatisfaction with certain of its aspects led them to develop the τ system. In the first place, some difficulties were encountered in defining variable-interval (VI) schedules of reinforcement within the t system. One way to handle this was to vary T from cycle to cycle. According to the authors, this approach did not appear to "promise optimal contact with VI schedules as those had been traditionally conceived" (p. 13). Another approach was to hold T constant, set t^D/T at 1.0, and define a new parameter p as the probability of reinforcement for the first response in each t^D . If at least one response occurs per t^D , the now familiar random-interval (RI) schedule of reinforcement results (Farmer, 1963). Such a schedule produces a geometric distribution of intervals between reinforcements with mean T/p . The problem with this approach was that it made even more critical to the authors the logical difficulty that, "To specify 'first' in any response-contingent reinforcement schedule is to count 'one', and in principle any other response identified by ordinal position might be chosen for reinforcement in t^D with equal justification" (p. 14). Thus, a parameter space that was intended to be purely temporal "became flawed in this way with a confounded 'ratio' variable" (p. 14).

The τ system that resulted from these considerations bears many similarities to the t system. The τ system involves a time cycle τ , which is strictly analogous to T . This cycle is partitioned into two fixed time segments, τ^D and τ^A , which parallel t^D and t^A in the t system. The difference between the two systems comes in the manner of identifying responses for reinforcement. In the τ system, τ^D and τ^A are further broken down into alternating time cycles

t^D and t^A with the restriction that t^D is longer in τ^D than in τ^A . Furthermore, any response in any t^D is reinforced. When t^D and t^A alternate rapidly with respect to the minimal IRT, every response has a probability of reinforcement $p = t^D/(t^D + t^A)$. Since t^D is longer in τ^D than in τ^A , p is higher in the former case. Within this system, RR schedules result when $\tau^D/\tau = 1.0$; and RI schedules are approached when τ is long, τ^D/τ is small, and p in τ^A is zero. With respect to traditional reinforcement schedules, only CRF and EXT are strictly definable within the τ system. All other traditional schedules are merely approached as limiting cases.

As in the case of the t system, research abstracts are presented that attempt to map behavioral effects throughout the parameter space of the τ system. However, in the latter case, this mapping is somewhat less exhaustive. Although the authors do not make direct reference to the fact, this less exhaustive mapping with respect to the τ system is probably due to its considerably more complex parameter space. The restricted t system had only two free parameters: T and t^D/T . The minimal τ system has at least four free parameters: τ , τ^D/τ , p in τ^D , and p in τ^A . For this reason no attempt will be made here to summarize behavior through the parameter space of the τ system.

EXTENSIONS OF THE t - τ SYSTEMS

The remaining two major chapters deal with more recent extensions of the t - τ systems. These are concerned with stimuli other than response-contingent reinforcers, and with aversive control. The topic of scheduling stimuli in addition to response-contingent reinforcers is divided into two subtopics, depending on whether or not these additional stimuli are identical to the reinforcing stimuli of the behavioral baseline. If they are, contact is made with such topics as amount, delay, and number of reinforcements. If they are not, one is dealing with such matters as discriminative stimulus control, conditioned reinforcement, and classical conditioning. In both cases, the general strategy is to define each of two or more schedules of stimulus presentation in terms of the t - τ systems, and then to specify a temporal phase angle between the schedules. Critical to this endeavor is of course the freeing of stim-

ulus presentation from response dependence, which is easily accomplished in these temporally defined schedule systems.

The research abstracts presented in conjunction with schedules involving stimuli other than response-contingent reinforcers do not appear to represent any unified theme or to produce particularly startling conclusions. The studies are probably best taken as simply exemplifying the variety of topics that can be addressed within the t - τ systems. As such, the abstracts range from investigations of the effects of brief "intruded" stimuli on FI performance to comparisons of contingent and noncontingent reinforcement.

Extensions of the t - τ systems to aversive control are discussed mainly in terms of the t system. Scheduling aversive stimuli presents no immediate need to extend the t system, which was already designed to schedule stimulus presentations in general. However, in order to generate approximations to traditional schedules of aversive control, a somewhat different tack is formalized at this point. At the heart of this approach is the familiar notion that the behavior stream can be divided into two mutually exclusive and exhaustive classes based on the occurrence (R) or nonoccurrence ($\bar{R}$) of a particular response. In practice, this involves classifying discrete intervals of time on the basis of whether or not they contain at least one instance of the particular response. This notion of a response class and its converse is then used to define two concurrent t schedules. One schedule is based on a time cycle T_R , which specifies the requirement for delivery of a "positive" or a "negative" reinforcing stimulus dependent on response occurrence. The other schedule is based on a cycle $T_{\bar{R}}$, which controls the reinforcement dependency for periods devoid of responses. The cycles T_R and $T_{\bar{R}}$ may be assigned durations either together or independently. In either case, two independent conditional probabilities, $p(S^R/R)$ and $p(S^R/\bar{R})$, are then used, respectively, to specify the probability of a reinforcing stimulus presentation in a T_R cycle containing at least one response and the probability of a similar event in a $T_{\bar{R}}$ cycle in which no prespecified response has occurred.

The simplest cases for the scheduling scheme just outlined involve T_R and $T_{\bar{R}}$ being equal and coterminous. Under these circumstances, an avoidance-like arrangement results when

$p(S^R/R) < p(S^R/\bar{R})$ since the frequency of an aversive stimulus can then be decreased by increases in the frequency of the prespecified response. In the terminology of Sidman avoidance, $T/p(S^R/\bar{R})$ gives the mean shock-shock interval, and T gives the maximum response-shock interval. Other aversive schedules can be similarly approximated. For example, a punishment-like situation would result when $p(S^R/R) > p(S^R/\bar{R})$, and an escape-like situation can be constructed by allowing the prespecified response to terminate the aversive stimulation for a sufficient time. In addition to such response-contingent schedules, Pavlovian paradigms can also be generated by freeing stimulus presentations from response dependence and scheduling additional stimuli.

The research abstracts presented in conjunction with aversive control are a somewhat more systematic package than those dealing with extension of the t - τ systems to stimuli other than response-contingent reinforcers. However, the research is still probably best viewed as merely indicative of possible avenues of investigation, rather than as exhaustive or definitive. Topics dealt with include some parameter mapping of the t -system aversive schedules, comparisons of "escape" and "avoidance" paradigms with noncontingent shock, drug effects on behavior generated by t -system aversive schedules, and physiological byproducts of exposure to such schedules.

REFLECTIONS ON THE t - τ SYSTEMS AND THE SCHEDULE ENTERPRISE

Thus far, the format and contents of the book have been reviewed mainly at a descriptive level with evaluative comments limited to relatively isolated matters. At this point it seems reasonable to state the reviewer's overall impressions as to the significance and locus of impact of this work.

It is perhaps clear by now that the t - τ systems are theories of stimulus schedules, rather than theories of behavior, or even of schedule-controlled behavior. In other contexts (*e.g.*, Schoenfeld and Farmer, 1970), Schoenfeld has made explicit the theoretical, or even metatheoretical conceptions of the behavior stream that he sees as underlying the t - τ systems. Nevertheless, the systems specify how schedules are to be generated and classified without necessarily offering any predictions about or expla-

nations of resulting behavior, although such accounts might be organized around the parameters of the systems. In addition, such systems suggest directions for research. Unfortunately, there are very few attempts at schedule systems against which to evaluate the present ones. The major alternative in existence is the Ferster and Skinner (1957) scheme. The present systems appear to offer some advantage in parsimony over that scheme in that they are defined by continuous parameter spaces with orthogonal dimensions, rather than by what would best be described simply as a set of categories. However, this parsimony is not achieved without loss, because many traditional schedules are only approximated within the t - τ systems. This problem is particularly noticeable when the accuracy of such an approximation depends on the behavior generated so as to not be specifiable *a priori*. This might not be a major objection, because the t - τ systems may in some sense specify a more significant or fundamental set of parameters around which to organize an analysis of how reinforcement schedules affect behavior. Indeed, the authors seem to be suggesting this in their description of the t - τ systems as "an effort to order reinforcement schedules in a rational manner based on the natural parameters of those schedules" (p. 1).

This last point forces one to face the issue of how a theory of reinforcement schedules is to be evaluated. The reviewer can find little in the book that attempts to validate any claim that the parameters of the t - τ system are the natural or true parameters of reinforcement schedules. As a matter of fact, the authors' closing words in the book seem to represent a much more modest claim as to the status of the systems:

"It is sometimes asked whether the t - τ systems are 'correct'. This is not, however, a cogent question. The systems developed out of experimental procedures, they traffic in real variables, and they produce genuine behavioral effects. None of this can be 'wrong' so long as it stays empirical. But the systems may not materially aid behavioral scientists in their work. If that turns out to be the case, we shall have to look to later efforts by others at systematizing reinforcement or stimulus schedules" (p. 160).

The reviewer is in essential agreement with this statement. It is difficult to see how a theory of reinforcement schedules would be evaluated other than by its success in systematizing experimental procedures and results, and its ability to guide research and theory in productive directions. Any such success would of course be relative to other alternatives available, and only one major alternative seems to have been developed and explored. In this respect it can only be noted that almost 20 years after presentation of the t system, its use seems largely limited to work issuing from its originator's laboratory. The vast majority of operant research and instructional materials continues to be cast in terms of variations on the Ferster and Skinner (1957) classification scheme. Perhaps this simply reflects a resistance to change in scientific vocabulary and concepts. Or, perhaps it reflects a lack of expectation of sufficient gain from such a change. Only additional historical perspective is likely to allow evaluation of such alternative interpretations.

The t - τ systems can also be considered in terms of their potential contribution to the goals of what might be referred to as the schedule enterprise. Opinion as to the purpose of the schedule enterprise has, of course, varied considerably. Jenkins (1970) identified at least three different views on this point. First, schedules might be thought of as producing a subject matter that is to be explained by analysis in terms of more elementary processes such as basic conditioning principles. This seems to be the view represented by Ferster and Skinner (1957). Jenkins criticizes this view mainly because of its apparent failure to rationalize the choice of schedules as a significant subject matter to be explained. In any case, the significance of the t - τ systems within the Ferster and Skinner conception of the schedule enterprise would seem rather limited. The systems do generate a set of schedules whose effects might be analyzed in terms of more elementary processes. Since the rationale for choosing schedule effects as a subject matter to be explained is not very clear in the first place, it could be argued that one schedule system is as plausible here as another. The real shortcoming of the t - τ systems under this conception of the schedule enterprise, however, is that they do not appear to suggest what more basic processes are to be used in analyzing their effects. The same

criticism could be directed against Ferster and Skinner's classification scheme, although not against their work as a whole.

One potential for explanatory concepts is suggested by the t - τ systems: namely, the actual parameters of the system, or more accurately, general laws concerning the behavioral effects of these parameters. Such an approach has been advocated by Reynolds and McLeod (1970) and is exemplified by Catania and Reynold's (1968) analysis of VI schedules. It also seems to this reviewer that acceptance of such a view is implicit in the present book. This view seems most compatible with what Jenkins has identified as the second conception of the schedule enterprise. According to this conception, schedules are a "new order of phenomena that are to be accepted as a replacement for the so-called elementary conditioning processes" (Jenkins, 1970, p. 106). That is, schedule phenomena themselves become primitive and are merely to be catalogued and perhaps used in the analysis of yet more complex situations. Indeed, the t - τ systems seem ideally suited for such an undertaking and may be sufficient for it. Jenkins has criticized such a role for reinforcement schedules on the grounds that it invites intellectual chaos in the sense that any new behavioral regularity or additional schedule parameter tends to suggest yet another process. This reviewer (Platt, 1973) has offered similar arguments emphasizing the pitfalls of theoretically equating paradigms and processes.

The final view Jenkins identifies as to the role of reinforcement schedules is that they are merely contrivances used to study conditioning principles. If this view is extended to include other behavioral processes, such as perceptual, motivational, and pharmacological ones, this reviewer joins Jenkins in his acceptance of it. If the view is taken seriously, reinforcement schedules would be seen as neither necessary nor sufficient for an understanding of the processes under investigation, but merely convenient tools of experimental analysis. Accord-

ingly, theories of reinforcement schedules such as the t - τ systems would be of minimal interest because the basis for systematizing experimental procedures and their behavioral effects would be the processes presumed to be under investigation, rather than the paradigms used to investigate them.

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