BEHAVIOR REGULATION AND LEARNED PERFORMANCE: SOME MISAPPREHENSIONS AND DISAGREEMENTS

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The behavior-regulation approach to learned performance has been the subject of misapprehension and disagreement concerning: (1) the nature and importance of behavior regulation, (2) the definition and role of behavioral set-points, (3) the relation of optimal schedule performance to behavioral set-points, and (4) the question of whether deviations from total responding or from response patterns are the primary determinant of molar responding under schedule constraint. After clarifying the nature and role of behavior regulation and set-points, this paper shows that the data used to question optimal schedule performance (Allison, 1981a) actually strongly support the general behavior-regulation approach. These data also indicate a role for response-pattern set-points in determining schedule behavior, but contradict the hypothesis that deviations from response-pattern characteristics are the primary determinant of molar schedule effects.

Key words: behavior regulation, behavioral set-points, optimization, molar equilibrium, response deprivation, response-pattern set-points, fixed-ratio schedules, concurrent schedules

This paper began as a modest attempt to resolve a few disagreements concerning the nature and role of set-points in the behavior-regulation approach to learned performance. Reviews of the original paper revealed a considerable lack of appreciation of the disagreements and, more importantly, wide-spread and diverse misgivings about the concepts of set-point and behavior regulation. Because behavior regulation in some form underlies a large number of recent models of learned performance (e.g., Allison, 1976; Hanson & Timberlake, 1983; Lea, 1983; Rachlin & Burkhard, 1978; Staddon, 1979; Timberlake & Allison, 1974), and because this approach deals well with a considerable range of data (e.g., Hanson & Timberlake, 1983; Staddon, 1979; Timberlake, 1977, 1980) that are often omitted in more traditional theories, it seemed important to address the misapprehensions and disagreements that might impede its con-

tinued development. Thus, the present paper was written to clarify the basic concepts of behavior regulation and to suggest resolutions to several current disagreements in this area.

The behavior-regulation approach realizes the concepts of response deprivation (Timberlake & Allison, 1974) and molar equilibrium theory (Timberlake, 1980) in the language of control theory (McFarland, 1971) and behavioral instigation (Atkinson & Birch, 1970). The approach clarifies and makes more precise the basic disequilibrium analysis of learned performance stemming from early work by Premack (1965, 1971). The fundamental assumption is that asymptotic learned performance is produced by a subject's regulatory response to a disequilibrium condition (challenge) imposed by the contingency schedule (Allison, 1976, 1981b; Allison & Boulter, 1982; Allison, Miller, & Wozny, 1979; Ettinger & Staddon, 1983; Hanson & Timberlake, 1983; Hursh, 1978; Lea, 1983; Mazur, 1975; Rachlin & Burkhard, 1978; Staddon, 1979; Timberlake, 1980; Timberlake & Allison, 1974; Timberlake & Wozny, 1979). Most investigators presume that responding under the constraint of a schedule is regulated with

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respect to a pre-schedule equilibrium condition, which can be measured in a free baseline. This baseline indexes the instigation (the combined response-inducing qualities of the environment and the internal state of the subject) for each important activity during a period in which all activities are unconstrained and simultaneously available. In the context of control theory, these baseline levels of responding can be viewed as set-points (Hanson & Timberlake, 1983; Staddon, 1980; Timberlake, 1980), and within an economic framework as an ideal or "bliss" point (Rachlin, Battalio, Kagel, & Green, 1981).

A typical contingency schedule imposes a challenge by constraining relative access to the baseline level of one of the responses, which is usually referred to as the contingent response or "reinforcer." The resultant disequilibrium produces a change in the instrumental response that counteracts the direction of the challenge and, within limits, is directly related to the severity of the constraint. The severity of the constraint can be gauged by the reduction in one response (e.g., drinking) that would result if the other response (e.g., wheel running) were to remain at its baseline level. Thus, a schedule that requires relatively too much wheel running for access to relatively too little water should produce an increase in wheel running leading to drinking (Timberlake & Allison, 1974). Further, the increase in wheel running should be directly related to the severity of the initial decrease in drinking imposed by the schedule.

Figure 1 illustrates some important elements of the behavior-regulation approach. The free-baseline set-points of instrumental and contingent responding are represented as a single point in a behavior space in which the y axis shows instrumental responding (e.g., wheel running) and the x axis shows contingent responding (e.g., drinking). A contingency schedule produces a disequilibrium condition by preventing the subject from simultaneously regaining its set-points of wheel running and drinking. For example, under a reciprocal ratio

Fig. 1. A two-dimensional behavior space showing amount of instrumental responding (e.g., wheel running) on the y axis and amount of contingent responding (e.g., drinking) on the x axis. The point (O_c, O_i) designates the baseline set-points of total instrumental and contingent responding; the diagonal line indicates the locus of responding specified by a ratio schedule. D_c represents the deficit in contingent responding if the subject were to perform the instrumental response at its baseline level under the terms of the ratio schedule; E_i represents the excess in instrumental responding if the subject were to perform the contingent response at its baseline level under the terms of the ratio schedule.

schedule (represented in Figure 1 by a straight line beginning at the origin), if the subject were to perform wheel running at its baseline level, it would fall considerably short of its baseline amount of drinking. On the other hand, if the subject were to drink at its baseline level, it would be forced to exceed its baseline amount of wheel running. The typical resolution of such a disequilibrium condition is a compromise in which the subject increases wheel running above its baseline, though not enough to return drinking to its baseline (Timberlake, 1980).

The important contributions of the behavior-regulation approach include a priori designation of the conditions of reinforcement, punishment, or no effect, and the prediction of qualitative and quantitative effects of manipulating schedule values. However, despite its potential importance and power, the behavior-regulation approach has had a mixed reception. Its contributions frequently have been obscured by misapprehensions on the part of advocates and detractors alike. The intent of this paper is to clarify four important areas of misunderstanding and disagreement: (1) the nature

and importance of behavior regulation, (2) the role and measurement of behavioral set-points, (3) the role of behavioral set-points in theories of optimal regulation, and (4) the relative importance of response-pattern set-points in determining schedule performance. The initial sections clarify the concepts of behavior regulation and behavioral set-points. The final two sections address some specific disagreements within the behavior-regulation approach.

THE NATURE AND IMPORTANCE OF BEHAVIOR REGULATION

The Nature of Behavior Regulation

A frequent question about the nature of behavior regulation concerns its relationship to physiological drive states and homeostasis (Cannon, 1932). Behavior regulation is not tied directly to physiological mechanisms. Instead, it is related to the instigating (response-producing) qualities in the animal and the environment. In traditional language instigation refers to the combined response-producing effects of stimulus incentives in the environment and the physiological state of the organism. Instigation is not contained in the animal or in the environment; it is a product of their interaction and can be thought of as a force underlying behavior (Atkinson & Birch, 1970). For example, in the case of drinking, the instigating qualities of the situation include the intra-cellular and extra-cellular fluid deficits, other internal cues that control drinking, and external cues such as the odor, physical location, taste, and temperature of the water. Though physiological mechanisms are involved, it is not necessary that they be understood or that their action be strictly homeostatic (Bolles, 1980). The single basic requirement is that the total instigation in the situation be reliable during the interval of interest.

The fundamental assumption of behavior regulation is that, in the absence of changes in instigation, a forced deviation in the expression of behavior results in a disparity between expression and instigation that

motivates a return to previous levels of responding. Under a schedule that links two responses, the tendency to return to the previous level of one response must be expressed by changes in the other response. For example, if a ratio schedule allows less than the baseline amount of drinking for the baseline amount of wheel running, then part of the instigation for drinking is expressed by increasing wheel running above its baseline level, thereby providing further access to drinking.

Thus, what is regulated in the present approach is any disparity between the expression of a type of behavior and its instigation. Under a schedule linking two responses, the means of regulation most frequently involves changes in expression of the linked response (Hanson & Timberlake, 1983). Allison (1976) has referred to regulation as the "conserving" of an unspecified dimension underlying responding (instigation). An alternative phrasing is that the animal substitutes or exchanges increases in one response for the amount of constraint on the other response (Allison & Boulter, 1982; Rachlin et al., 1981; Timberlake, 1971, 1979). Still another phrasing is that the animal balances (or minimizes) the deviations of the responses from their respective baseline set-points (Hanson & Timberlake, 1983; Staddon, 1979; Timberlake, 1971). Basically all these views are related characterizations of the way disparities between expression and baseline instigation are regulated by expression under schedule constraint.

It is worth emphasizing that schedule performance is related to all important deviations in the situation, not just the relative deficit in the contingent response. Figure 1 makes clear that as the subject increases instrumental responding (e.g., wheel running) and thereby gains access to the contingent response (e.g., drinking), it simultaneously decreases the deviation from the set-point of drinking and increases the deviation from the set-point of wheel running. Asymptotic performance will be determined by relating the size and value of the deficit in drinking to the size and value of the excess in wheel run-

ning. This balancing of weighted deviations can be used to predict nonmonotone relations between schedule parameters and total instrumental responding (see Staddon, 1979, or Hanson & Timberlake, 1983, for more extensive development of this point).

In this light, the original term "response deprivation" (Timberlake & Allison, 1974), though calling attention to the behavioral level of regulation, had two unfortunate connotations. First, it focused attention on the response that was relatively in a condition of deficit with respect to its set-point without directing similar attention to the response that was relatively in a condition of excess (Timberlake, 1980). Both deviations are obviously important in producing learned performance. Second, the term could be misinterpreted as referring to an actual reduction in responding (as in Premack, 1965), rather than to an a priori condition of relative constraint (disequilibrium) imposed by the schedule on expression of the instigation underlying the contingent response. To treat the actual reduction of responding as a causal variable changes the behavior-regulation approach from an a priori to a post hoc theory with attendant loss of power (Timberlake, 1980).

In sum, the behavior-regulation approach does not require homeostatic physiological mechanisms, but merely reliable instigation under schedule constraint and the tendency to reduce disparities between levels of instigation and their expression in behavior. Instigation is the product of a particular animal in a particular environment at a particular time, and its expression in learned performance is the product of a schedule that links the disparity between the levels of instigation and expression for one response with the expression of the other response (Hanson & Timberlake, 1983). At present the level of instigation in a situation must be reliably known before behavior-regulation theories can be applied. This is not a large problem in laboratory studies because it is possible to run long baseline assessments and ensure consistency of instigation over sessions, but it may be a drawback in ap-

plied settings, especially those with variable instigation. Some common-sense procedures and guesses about instigation would be helpful here. Perhaps in the long run a theory of instigation combined with a single behavioral assessment or knowledge of physiological processes will allow predictions across circumstances with variable instigation.

The Importance of Behavior Regulation

Traditionally, learned performance has been attributed to the combined effects of local associative (reinforcement) variables and more general motivation or drive variables. With few exceptions, operant research has focused on the local "reinforcement" effects produced by different schedules, while holding overall motivation constant by using highly deprived organisms and small, infrequent rewards. Within this framework the behavior-regulation approach is often viewed as a theory of general drive or motivation that can be used to set the overall potency of a given reinforcing agent, but which is unrelated to the particulars of schedule effects. Reinforcement theories must be used to determine the reinforcement effects of schedules on the instrumental response.

In fact, behavior regulation is not a theory of the overall potency of "reinforcers," but is a theory of how the schedule interacts with instigation levels to produce learned performance. What is confusing to many is that the language and the conceptual development of behavior regulation are in terms of motivation or function, not of the shaping of behavior or of discriminative control. Further, the presumed level of regulation is most often at the session level, not at the local level of individual "reinforcers" contingent on individual responses (however, see Allison & Timberlake, 1975; Timberlake & Hopp, 1979; see also the matching law, which despite its avowed allegiance to reinforcement shares the same strategy of focusing on the "balancing" of different responses over larger intervals of time [Herrnstein, 1970; Herrnstein & Vaughan, 1980]).

In essence, the behavior-regulation approach accounts for the effects of schedule variables on responding on the basis of their regulatory effects viewed across the entire session, not on the basis of their presumed local response-strengthening effects. However, I disagree with Rachlin and Burkhard's (1978) argument that the ability to predict and fit responding without direct appeal to reinforcement mechanisms implies that learning is unimportant. All this means is that given circumstances that allow expression of constrained instigation through an instrumental response, the regulation of unexpressed instigation accounts for much of the change in behavior. I expect future work to deal more carefully with the contribution of associative effects to schedule responding (Timberlake, 1979) and with regulation occurring at both shorter and longer intervals than the session.

An example may help clarify the distinction between the typical interpretation of behavior regulation as a theory of the motivational determinants of the overall potency or value of a "reinforcer," and the more appropriate view of behavior regulation as a theory of learned performance. A theory of value creates a "reinforcer" by depriving the animal of access outside the experimental session (and, without acknowledging it, imposing a schedule within the experimental session that constrains the contingent response relative to its baseline). Thus we might take water away from an animal in its home cage to ensure its potency as a reinforcer for wheel running, or take the wheel away from the animal to ensure its potency as a reinforcer for drinking (cf. Premack, 1962). In contrast, the behavior-regulation approach holds that depriving the animal of access to a commodity outside the experimental situation is neither a necessary nor a sufficient condition to create a "reinforcer."

The circumstances of reinforcement are created by imposing a relative deprivation of the expression of a response within the experimental session. Thus, to create drinking as a "reinforcer" for running, the schedule

must produce an initial constraint on drinking during the session relative to its baseline levels. In theory it is irrelevant whether water has been available to the subject outside the experimental session. Conversely, to create running as a "reinforcer" for drinking, the schedule need only be altered to produce an initial constraint on wheel running (Timberlake & Wozny, 1979).

To be sure, there are pragmatic limits on all this. If the animal will not drink at all during the experimental session, a disequilibrium cannot be created. Thus, depriving the animal of water outside the experimental session will facilitate procedures depriving the animal within the experimental session by increasing the amount of drinking available to manipulate. But this does not alter the basic theoretical issue. At the most fundamental level, "reinforcers" (actually circumstances in which reinforcement occurs) are created by combinations of schedules and instigation levels, not by noncontingent deprivation manipulations imposed outside the experimental situation. In practical terms, the world does not divide easily into categories of reinforcers and nonreinforcers (Premack, 1965, 1971), nor into neat categories of drive operations and reinforcement operations. Instead, learned performance is the outcome of the regulation of the disparity between instigation and expression, where this disparity depends conjointly on drive and reinforcement operations and on the stability of instigation.

To summarize: Whatever kind of theory it may appear to be, behavior regulation accounts for learned performance, including any associative effects that occur as a product of the schedule. It is not a theory of general reinforcer potency because whether an organism is deprived of a commodity outside the experimental situation is not theoretically important or interesting. To create the circumstances for reinforcement across a session, one must create a within-session disequilibrium in the relative expression of the responses linked by a schedule. Behavior regulation is clearly not well developed at the level of conceptualizing the

local effects of access to constrained responses ("reinforcers") and integrating these effects into a complete account of learned performance, but it is nonetheless a theory of learned performance at the level of total responding in a session. And there are considerable advantages to this approach, including predicting the circumstances for reinforcement and both direct and inverse relations between reward density and instrumental performance (Allison, 1981b; Hanson & Timberlake, 1983; Staddon, 1979; Timberlake, 1977, 1980), predictions not made by most traditional models.

BEHAVIORAL SET-POINTS

The concept of behavioral set-points has proven to be the most controversial aspect of the behavior-regulation approach, perhaps because set-points are seen as implying an invariant internal state. It should be clear by now that a behavioral set-point is basically an index of the instigation for an activity present in a particular situation. For that situation only, it can be viewed as a "bliss point" representing the preferred level of expression of an activity when unconstrained by a schedule. When the expression of a set-point is constrained by a schedule, the disparity between expression and instigation becomes a driving force for learned performance, given mechanisms that allow the coupling of the instigation for one response to the expression of another (Hanson & Timberlake, 1983). For example, when drinking is constrained as in Figure 1, its deviation from set-point level drives instrumental wheel running. A most critical question for the behavior-regulation approach is how a behavioral set-point is identified and measured. There are two current answers to this question: (1) assessment of responding in a free baseline, and (2) calculation from schedule performance on the basis of a model. I will consider them in turn.

The Assessment of Behavioral Set-Points

Any measurement procedure for defining behavioral set-points must satisfy several

criteria. Inasmuch as a behavioral set-point is simply the expression of instigation underlying a particular activity, the more accurately behavior reflects the underlying instigation, the more accurately it should serve as a set-point. Thus, a behavioral set-point should be measured under unconstrained conditions so that its current level of instigation is clearly expressed. Further, because a set-point will change with changes in instigation, the conditions during both assessment and constraint must be as constant as possible. Session length, physical environment, time of day, available responses, and the subject's physiological and experiential state must remain fixed except for the precise schedule manipulations of interest. If response determinants other than the imposition of the schedule are allowed to vary between baseline and contingency, it is necessary to reassess the baselines. This is the price paid for the advantage of using the baseline to estimate the set-points.

The free-baseline procedure (previously termed the paired or multiple baseline) appears to fulfill these criteria in a reasonable fashion. The baseline is measured with all relevant responses freely available under the reliable instigating conditions that will be present when the schedule is imposed. Considerable data show that free-baseline measures are reliable and recoverable (Peden, Rohe, & Keller, 1983; Timberlake, 1980). However, some data suggest that these measures may change over time and as the result of a contingency (Timberlake, 1980; see also Tierney, Smith, & Gannon, 1983). It could be argued that the free baseline itself contains a certain degree of constraint and thus tends to underestimate the amount of instigation present. In fact, there are data compatible with this assertion. Timberlake (1980) reviewed results that showed increases in both instrumental and contingent responding under relatively easy schedules, a result that would be expected if the free baseline tended to underestimate the instigation present. Nonetheless, with appropriate precautions concerning the separation of response alternatives (e.g., Allison et

al., 1979) the free baseline appears to be a reliable and reasonable empirical assessment of basic instigation.

Several investigators have suggested other baselines. However, typically the rationale is not as compelling. Some have argued that a single baseline involving only one of the responses is a more accurate assessment of the instigation for a particular response. However, to the extent that two responses may share instigation, the single baseline overestimates the total instigation present by measuring the common instigation twice, once as it is expressed in each type of behavior. Rachlin et al. (1981) suggested a baseline that measures instrumental responding with the contingent response constrained but in the absence of an instrumental requirement. This baseline does not allow independent assessment of the instigation for contingent responding. It is most appropriate for assessing contingent versus noncontingent effects of the schedule (Timberlake, 1979).

A more common approach is to measure baselines under a schedule imposing a low degree of constraint—for example, FR 1. Such baselines may accurately reflect the instigation for an inelastic contingent response such as feeding, given a flexible instrumental response such as bar pressing. In such cases the experimenter infers the independent instigation of bar pressing to be near zero, and presumes that bar pressing is essentially transparent to the expression of instigation for feeding. However, with other response combinations, failure to use the free baseline may make a considerable difference in assessing the amount of instigation present. Instrumental responses such as wheel running have significant levels of independent instigation and are not transparent in expressing the instigation for contingent responses. Thus, schedule assessment of instigation is of more limited use.

There is one notable limitation on free-baseline measures as predictors of responding under schedule constraint. Although the baseline provides evidence of the fundamental levels of response instigation, it does not

indicate how this instigation will be translated into expression under a schedule (although Hanson & Timberlake, 1983, proposed a relationship between expression characteristics in baseline and contingency). For example, some responses (or more properly, some response combinations, such as bar pressing and eating) show great resilience to challenge; other response combinations (such as wheel running and saccharin licking in satiated rats) show only momentary or asymmetric defense of baseline levels. Such expression characteristics have been previously noted under concepts such as elasticity (Allison et al., 1979; Burkhard, 1982; Hursh, 1980; Lea, 1978; Rachlin, Green, Kagel, & Battalio, 1976; Rachlin et al., 1981), consummatory force (Atkinson & Birch, 1970), resilience (Houston & McFarland, 1980), and resistance to change (Nevin, Mandell, & Atak, 1983). These modifying characteristics are best determined under conditions of constraint, but systematic rules for the assessment of some have not yet been agreed on. What is needed at this point is more research into the nature of expression characteristics and models that explicitly take them into account.

The second general technique of assessing set-points is to use a model sufficiently complex to infer baselines from fits to schedule performance. This technique has been used or suggested by Allison (1981b), Allison and Boulter (1982), Hanson and Timberlake (1983), Rachlin and Burkhard (1978), Rachlin et al. (1981), and Staddon (1979). The technique requires a model that references responding to some basic preferred response distribution, and allows the conceptual separation of such a "bliss point" from expression characteristics and schedule effects. There are several drawbacks to this approach. First, in some cases the reality status of these set-points is the subject of confusion (Motherall, 1981; Rachlin et al., 1981; however, see Houston & McFarland, 1980). It is not clear whether they refer literally to internal states of the organism, potentially to external expressions in behavior, or simply to imaginary entities.

A second problem is that when models include the set-points as free parameters, the number of parameters fit from the data increases, usually to four or five. This means that models cannot reasonably be tested without a large number of data points, 25 to 40 depending on different rules of thumb. Very few, if any, data sets are based on this number of manipulations. A reasonable future strategy would be to compare the results of free-baseline measures of instrumental and contingent responding with measures computed from different models. Depending on the outcome, this might allow the relative assessment of the strengths of different models as well as an indication of the general accuracy of the free-baseline measure (Timberlake, 1981).

Common Reservations about Behavioral Set-Points

Although the rationale for behavioral set-points and their assessment is reasonably clear, several reviewers have remained reluctant to accept their use. Their reservations take several forms: (1) It appears that the concept of a behavioral set-point requires a subject to keep track of its amount and pattern of behavior with unreasonable precision and timing. (2) Any phenomenon that can be explained by set-points and behavior regulation can be explained by reinforcement and punishment. (3) How does one know there really are set-points?

On the problem of unreasonable measurement sensitivity, it is apparent that behavior shows extreme reliability in duration and pattern in many situations. Animals kept under constant conditions perform reliably day after day in behavior patterns ranging from exploration and grooming (Timberlake, 1969) through feeding (Le Magnen, 1981; Richter, 1927) to direction and timing of running in a wheel (Kavanau, 1969; Kavanau & Rischer, 1968). The typical reliability of baselines obtained by investigators within the present approach, and the reliable mathematical relations between baseline and contingency performance (e.g., Allison, 1976; Hanson & Timberlake, 1983; Stad-

don, 1979) show that reliable timing of responding occurs.

It is interesting that arbitrary tests of the ability to time intervals reveal systematic limitations (e.g., Gibbon, 1977), but this result is not necessarily related to the organization and timing of naturally occurring activities. A mechanism that distributes meals or bursts across a session may not be available under experimental demands for timing arbitrary intervals in arbitrary circumstances. Because it appears unquestionable that precise and accurate timing of behavior occurs, our concern should be with its description and cause, not with a priori rejection of its existence. An important direction for research might well be the investigation of the control of the timing and duration of natural behavior under free and constrained conditions coupled with a more careful look at its precision of expression.

The second contention, that results predicted by behavior regulation and set-points can be explained by reinforcement and punishment, is basically an argument for the familiar rather than the unfamiliar, comforting ourselves with knowledge we do not really have. Reinforcement and punishment are too often merely labels for particular combinations of procedures and results. Presumed reinforcers and punishers are not adequately assessed as independent causal agents. Whatever the shortcomings of the behavior-regulation approach, it has exerted considerable effort to assess alleged causal variables in the reinforcement situation independent of their presumed effects (Timberlake & Allison, 1974).

One reviewer suggested that behavior-regulation phenomena could be explained by relating the presumed effects of "reinforcers" and "punishers" to the disequilibrium condition produced by the schedule. Reinforcement is then a function of the same variables as behavior regulation, and therefore can replace it as an explanation for learned performance. This sort of free use of the concept of reinforcement strikes me as akin to a claim that the physical theory of combustion is simply a more complete characterization

of the action of phlogiston. The existence of phlogiston and reinforcers can always be invoked from their presumed effects, but in these contexts they are basically superfluous concepts that are not adequately predictive.

Further, to identify reinforcement with the determinants of behavior regulation requires abandoning many previous assumptions and practices of reinforcement theory. For example, responding should typically be a bitonic rather than a monotonic or unspecified function of variables such as amount of reward and ratio size. The distinction between the contingent and noncontingent effects of schedules is no longer critical in predicting performance. The presentation of a known reinforcer in close temporal and spatial juxtaposition to a response need not produce reinforcement, and may actually produce punishment. In general, behavior-regulation and reinforcement theories have been based on rather different concepts and phenomena. As a result they are not completely interchangeable. We should be working toward an empirical and theoretical integration, not toward "explaining" the phenomena with a term that is not clearly defined before the fact, and that does not seem to apply in its usual way.

The final question of how one knows there are set-points seems to be nearest the heart of the matter. In general, one knows there are set-points in the same way one knows there is any theoretical concept (e.g., reinforcement). One defines a measurement procedure for the concept, predicts a relation between it and other variables, and determines whether the relations hold. The key characteristic of a behavioral set-point is that it expresses specific instigation. Thus, if the instigating circumstances remain reliable, so should the response characteristic. Secondly, if the expression of the instigation in responding is challenged, it should be given up gradually and monotonically with increased challenge, not suddenly or nonmonotonically. Third, the response characteristic should be recoverable, and may show a rebound in expression following release of constraint. If a response characteristic has these

properties, we expect it to support instrumental behavior that reduces schedule constraint imposed on it. If it does not have these properties, we do not expect learned performance.

By way of illustration, if total drinking in constant circumstances were reliable, if it resisted reduction by challenge through adjustments of rate or pattern, and if it rapidly recovered following release of constraint, we would be confident that it reflected specific underlying instigation and would support instrumental behavior reducing a schedule constraint imposed on it. On the other hand, if total drinking in constant circumstances were not reliable, if it were maximally reduced by any challenge, and if it were not recoverable following release of constraint, we would conclude that it did not reflect specific underlying instigation and would not expect it to support instrumental behavior. It should be clear that simple alterations in the environment, such as providing access to an additional water source, may change drinking directed to the original water source from a strongly to a weakly defended response characteristic.

Another interesting issue not typically addressed is the number of potential set-points. It is quite possible that we have only scratched the surface of this approach by dealing largely with total instrumental and contingent responding. Individual background responses may reflect set-points, as well as measures of more molecular response characteristics such as burst length, topography, or local rate of drinking, or more molar characteristics such as daily intake. Further, it may be that reliable levels of instigation are uniquely related to time periods such that instigation is best viewed in the context of particular intervals or structures of responding, such as half-hour periods, meals, or bouts. I will address some of these issues again in the final section of this paper. The next section considers further questions concerning the importance of set-points in determining instrumental performance, and their relevance to optimality models of learned performance.

In general, the set-point concept has provided a useful and powerful tool in model building and predicting behavior. Free-baseline responding serves reliably and reasonably in identifying the circumstances of reinforcement and in facilitating modeling of absolute schedule performance. Several common misgivings about the use of behavioral set-points are not well founded. There is nothing magical or mysterious about them. They are simply a priori estimates of the instigation for a response that can be used to provide in advance a reasonable estimate of response instigation under a schedule. If we could measure this instigation directly via some physiological index, the assessment and use of behavioral set-points would be unnecessary. Since we cannot, their assessment becomes critical. Whatever its flaws, the behavior-regulation approach invites, if not demands, empirical analysis of the reinforcement situation, not in terms of an arbitrary classification or manipulation of schedules, but in terms of the effects of schedules in expressing and altering instigation for responding. Basically the use of behavioral set-points provides the possibility of grounding learned performance in behavior in a more specific way than has previously been the case.

BEHAVIORAL SET-POINTS IN OPTIMAL REGULATION

The accuracy of set-points is particularly important in evaluating a subset of behavior-regulation models based on the assumption of optimal behavior (e.g., Rachlin & Burkhard, 1978; Rachlin et al., 1981; Staddon, 1979, 1980). These *optimal* regulation models predict that responding under schedule constraint should *minimize* deviations from behavioral set-points (the bliss point). As Allison (1981a) pointed out, it is difficult to test the minimization prediction directly (instead of in terms of whether the function can be adjusted to fit the data), because it is difficult to establish an a priori basis for scaling the deviations of different responses. (It should be noted that this problem of a priori

scaling of constants is shared by nearly all behavioral models.) Appropriate indirect tests might include comparing the bliss point derived from fitting schedule data with the actual levels of responding obtained in free baseline, and examining the consistency of constants across schedule manipulations.

Allison (1981a) proposed a more direct test of the minimization prediction by arguing that subjects should approach as close to presumed behavioral set-points as was physically possible. On the basis of a reanalysis of previously published data, he showed that animals working on simple and concurrent ratio schedules typically did not achieve their maximum possible proximity to presumed set-points. As a result Allison concluded that the baseline must not actually represent set-points (ideal points) of behavior and, therefore, that any theory using baseline measures as ideal or set-points must be in error. As we shall see, this conclusion is based on several misapprehensions concerning behavior regulation and set-points, but the data are of considerable interest to further development of the behavior-regulation approach.

Simple Ratio Schedules

The initial data cited in Allison's (1981a) critique were obtained in studies of rats bar pressing on simple ratio schedules that controlled access to water (Marwine & Collier, 1979) or food (Collier, Hirsch, & Hamlin, 1972). These researchers measured free baseline intake of water (or food) and then made access contingent upon bar pressing, over a long ascending series of fixed-ratio schedules, followed by a short descending or random series of schedules. A critical aspect of the procedure was that each subject was allowed to set its own amount of reward intake per access. Each time the reward became available, it remained available until the animal failed to take any within a fixed time (5 min for water, 10 min for food), and then was withdrawn. This indeterminate access allowed the rat to increase its intake per access and thus decrease the effective schedule ratio of bar pressing to amount

of reward, below the initial ratio imposed by the experimenter. In fact, the data show that the rats systematically increased their intake per access to reward as a function of the ratio requirement, the greatest intake occurring at or very near the largest requirement.

Allison (1981a) argued that optimal regulation theory required each animal to achieve its maximum intake per access at all schedule values, thereby minimizing the distance between the schedule ratio and the baseline ratio of bar pressing to amount of reward. Allison made his point with a series of plots for each animal which showed that the actual ratio of intake per access to bar pressing was smaller than it would have been had the animal always taken its maximum intake of water per access. A minor problem with this test is that using the entire schedule line as the standard, rather than an appropriate point of minimal distance, means that data would have been interpreted as supporting optimal regulation theory if the subject had completed the ratio requirement only once and then taken its maximum length of intake for that single access. In no sense would this result have minimized deviations from baseline set-points. Since no animal did this, the point is not critical.

Figures 2 and 3 replot the data in question as total bar pressing, intake per access, total intake (drinking or eating), and frequency of access, all as a function of ratio requirement. To reduce them to the same relative scale, all measures are shown as log percentage of baseline level. In terms of these plots, Allison's argument is that the line for intake per access should have gone to maximum at the first ratio and remained there rather than showing systematic increases with increasing schedule challenge. However, there are several problems with Allison's assumptions and analysis.

First, failure to minimize set-point deviations is not a general criticism of the use of set-points in the behavior-regulation approach, but only evidence against optimal regulation. In a simple form, the behavior-regulation approach requires only that

changes in responding under schedule constraint counteract and be directly related to the severity of that constraint (Hanson & Timberlake, 1983; Timberlake, 1980). As can be seen, the data support the general behavior-regulation approach by showing a direct functional relation between degree of challenge (fixed-ratio size) and set-point deviation.

Second, because the animals took in less food or water at each successive ratio, the instigation for intake may have varied across ratios, thus questioning the reasonableness of a single measurement of the intake per access as an appropriate general index of the animal's capacity. Supporting this argument is the finding that the maximum intake per access always occurred at the ultimate or penultimate ratio requirement (Marwine & Collier, 1979; Collier et al., 1972; it might be noted that Allison's reworking of the data shows slightly more variability in the maximum point). It is important to emphasize that the animals were not fed or watered outside the experimental session and that the data were taken from the ratios administered in ascending order. The resultant cumulative decrease in intake across bar-press requirements probably increased the instigation for intake of reward and contributed to the large increase in intake per access at the highest ratios. Thus, the maximum intake at the final ratios probably was not appropriate as an estimate of the "working capacity" of the subject at lower ratio schedules, because the instigating conditions were different.

Third, the maximum physical capacity of the subject in performing a response is not the primary determinant of responding under schedule challenge using any behavior-regulation model. The key to performance is the regulation of responding with respect to deviations from all relevant set-points. In the case of optimal regulation theories, asymptotic performance is determined by simultaneously minimizing deviations from baseline set-points for instrumental, contingent, and "background" responding (e.g., Staddon, 1979). Although the concept of "background" responding is not well articulated,

in fairness to current theories Allison's critique should have considered the potential contribution of a set-point for background responding. Finally, these data also indicate that a complete theory of learned performance must consider the possibility of defended response patterns, set-points of

responding that refer to the local organization of behavior.

Concurrent Ratio Schedules

Allison (1981a) extended his critique of optimal regulation theory to concurrent choice by noting that animals do not ex-

Fig. 2. Log percent of baseline of total bar pressing, water intake, frequency of access, and intake per access versus the number of bar presses required for each access to water. Data are from Marwine and Collier (1979) and are shown separately for each rat. The baseline of bar pressing was assumed to be 1.

Fig. 3. Log percent of baseline of total bar pressing, food intake, frequency of access, and intake per access versus the number of bar presses required for each access to food. Data are from Collier, Hirsch, and Hamlin (1972) and are shown separately for each rat. The baseline for bar pressing was assumed to be 1.

clusively choose the most liberal of two ratio schedules as would occur if they were approaching baseline set-points as closely as possible (Herrnstein & Loveland, 1975; Lea & Roper, 1977; Shapiro & Allison, 1978). In presenting the data, Allison constructed two potential outcomes—all responding on the more liberal schedule or all responding on the more conservative schedule. He then plotted the obtained ratio of responding, which generally fell between the two extreme

outcomes, though most often closer to the liberal alternative.

Again this test does not bear on the general behavior-regulation approach, and it is imprecise because responding anywhere on the minimum schedule line would have been taken as supporting optimal regulation theory. Other important issues are the potential contribution of interference effects on memory, discriminability of reward rates, and the baseline frequency of switching be-

tween alternative sources of reward. The Shapiro and Allison (1978) study of bar pressing for food in rats prevented the unique relation of a particular bar with a schedule by reversing the relation from day to day. Allison (1981a) claimed that this procedure did not affect the results because he informally observed sampling of both schedules late as well as early in each session. Presumably, the rats would have learned which bar was correlated with the more liberal schedule within the first few minutes of the session. However, this supposition may be too strong. Daily switching of the schedules between two bars might well produce considerable proactive interference. Shapiro and Allison (1978), for example, reported that data for one animal showed a shift from a three-to-one to a five-to-one preference after twenty choices of each bar.

The other experimenters mentioned (Herrnstein & Loveland, 1975; Lea & Roper, 1977) followed the more typical procedure of correlating each schedule with a unique location and obtained results that in most cases reflected a preference for the more liberal schedule. Their findings are also supported by more recent work reported by Herrnstein and Vaughan (1980) and by Krebs, Kacelnik, and Taylor (1978). However, the pattern of data does raise a question of discriminability of rate of reward under the two schedules. The studies of both Lea and Roper (1977) and Herrnstein and Loveland (1975) revealed more nearly exclusive preferences for the liberal schedule when the schedules differed considerably. At very similar ratio requirements (FR 8 vs. FR 11; FR 6 vs. FR 8) or overlapping ratios (VR 25 vs. VR 35; VR 50 vs. VR 70) responding tended toward indifference between the two schedules.

The data are also compatible with the existence of a baseline tendency (set-point) to sample alternative sources of food, a tendency that is expressed most clearly under low instrumental requirements, and decreases systematically under increasing schedule challenge. The pigeons of Herrnstein and Loveland (1975) showed a moder-

ate initial tendency to sample both responses, a tendency that decreased in favor of exclusive preference for the more liberal schedule as a function of the strictness of the leaner schedule (Allison, 1981a, Figure 10). Thus, the greater the difference between the two schedules, the more likely the animals were to exclusively prefer the more liberal schedule. A similar trend is shown in the data of Lea and Roper (1977) between the bottom two figures and the top two (Allison, 1981a, Figure 8), and in the data of Shapiro and Allison (1978, Table 1).

A tendency to sample alternative and even depleted sources of food has been frequently cited as a sound evolutionary strategy for foraging in patchy environments (Krebs, 1978; McNamara & Houston, 1980; Smith & Sweatman, 1974). Depleted resources are often renewed and plentiful resources are depleted at unpredictable intervals. Thus, a tendency to sample alternative sources of a commodity would be expected because it could easily be an advantage in making maximum use of available resources. It may be important that the animals in Lea and Roper's (1977) study showed the most sampling, because their alternative sources of food were at spatially different locations. This might be more typical of sampling in natural circumstances than a situation such as Herrnstein and Loveland's (1975) in which alternative forms of the same response produced access to food at the same location.

Taking the simple and concurrent-ratio data together, the force of Allison's (1981a) critique of behavioral set-points and optimal regulation is weak. The criticism does not apply to regulatory theories in a general way, and its application to optimal regulation theory can be questioned. There are many bases for the results cited other than the failure of the animal to minimize its distance from baseline set-points. The measure of physical capacity on which the argument turns was obtained at what appeared to be the highest level of a variable deprivation regime, and the interpretation failed to consider the effects of set-points of background responding in meliorating the

predicted outcome. Further, failure always to choose the most liberal of the concurrently available ratio schedules was confounded with problems of memory interference and schedule discriminability. Finally, important regularities in both the simple and concurrent-ratio data suggest that behavior is regulated around more than simple molar set-points, including baseline patterns of contingent responding and the tendency to sample alternative reward sources.

RESPONSE-PATTERN SET-POINTS AND MOLAR REGULATION

As indicated in the introduction, most regulatory theorists have assumed that the change in total instrumental responding under a schedule was determined by a molar disequilibrium condition involving the set-points of total instrumental and contingent responding (and perhaps background responding). However, a rather different view of the appropriate level of analysis has been advanced by Premack (1971) and by Dunham (1977). These authors argued that the change in total instrumental responding results from schedule constraints on local response patterns (response-pattern set-points). Specifically, Dunham (1977) claimed that the key to increased instrumental responding was a schedule that decreased the burst length of contingent responding and increased its interburst interval. Premack (1971) argued in a similar vein that the key to reinforcement was an increase in the momentary probability of the contingent response, presumably related to decreased burst length and/or increased interburst interval imposed by the schedule.

Their fundamental argument, that the overall change in instrumental responding is driven by deviations from response-pattern characteristics rather than by deviations from total responding, has not been tested adequately. There is some evidence that response patterns serve as set-points—that there is unique instigation for a particular pattern of responding. Schedules that constrain the patterns of contingent responding

produce increases in the local probability or rate of the contingent response under schedule constraint (Lucas, 1981; Terhune, 1978; Timberlake, 1979), although contradictory data have been provided by Mazur (1977) and by Bernstein and Dearborn (1978, reported in Timberlake, 1980). However, there has been no independent assessment of the effects of deviations from response-pattern set-points on molar instrumental responding.

The major problem in assessing the importance of response-pattern set-points is that constraints on response patterns and constraints on total contingent responding are usually completely confounded. A typical schedule imposes similar a priori restrictions on molar and response-pattern characteristics, so that both approaches make the same predictions of effects on instrumental responding. For example, a ratio schedule that constrains the subject's total access to eating typically reduces its burst length and increases its interburst interval relative to baseline. Thus, both views predict an increase in instrumental responding, and one cannot separate the potential contributions of the two sources.

An Important Test

The work of Marwine and Collier (1979) and Collier et al. (1972), discussed above, is unique in that the procedure of indeterminate access to the contingent response permitted evaluation of the relation between deviations from molar and response-pattern baselines, and made possible assessment of their relative importance in driving increases in total instrumental responding. The key property of the procedure is that it allowed an instrumental requirement to constrain total contingent responding without placing any constraint on the intake per access to the contingent response. As a result, these data provide a test of four possible relations among deviations from molar and response-pattern set-points in determining total instrumental responding. (1) If deviations from response-pattern set-points are the key element, two things would be expected: (a)

maintenance of the intake per access at baseline level (inasmuch as this is not constrained), and (b) slow decrease in frequency of access with increasing challenge accompanied by rapid increase in bar pressing to combat the constraint of the bar-press requirement for access. (2) If only deviations from total response set-points are critical, one would expect response-pattern characteristics to be given up instantly to the maximum extent possible, thus allowing maintenance of total instrumental and contingent responding (e.g., intake per access should immediately increase to its maximum, maintaining total intake without requiring a marked increase in bar pressing). (3) If levels of response characteristics have effects, but one or the other is the more critical, all characteristics should show systematic deviations from baseline with increasing schedule challenge, but either molar or response-pattern characteristics should be given up more rapidly. (4) If molar and response-pattern set-points are equally important, we would expect to find parallel rates of change with increasing schedule constraint.

The data in Figures 2 and 3 contradict three of these possibilities and provide strong evidence for both response-pattern and total response set-points. By way of reminder, these figures show the log percentage of baseline plotted as a function of ratio requirement for total bar presses, intake per access, total intake, and frequency of intake. Figure 2 represents rats' bar pressing that produced access to water (Marwine & Collier, 1979), and Figure 3 represents rats' bar pressing that produced access to food (Collier et al., 1972). None of the response characteristics was either preserved or given up immediately. Instead, deviations from the baseline of each measure were a monotonic increasing function of degree of constraint. However, the baseline characteristics did not appear to be equally resistant to change. Bar pressing, intake per access, and access frequency showed rapid initial changes for all animals, followed by fairly stable asymptotes for intake per access and

access frequency, and by a slowed rate of increase for bar pressing.

In contrast to these measures, total water or food intake showed a very slow rate of decrease across increasing schedule challenge. If we refer to the initial rate of change of a characteristic as its resistance to change, and the maximum change as its flexibility, then within the range of schedules used the data can be described: The response-pattern characteristics of intake per access and access frequency showed low resistance to change and relatively high flexibility; the molar characteristic of total bar pressing showed low resistance to change and still greater flexibility; total intake showed high resistance to change and relatively low flexibility.

Thus, these data both support the existence of response-pattern set-points and contradict the notion that deviations from them are the primary determinant of instrumental responding in molar contingencies. Despite the absence of constraint on intake per access, there were large increases in total bar pressing. It might be argued that the increase in bar pressing was the result of constraints on frequency of access, but this characteristic was given up to the maximum possible extent almost immediately—scarcely what would be anticipated for a critical causal variable. Further, there was an unforced increase in the burst length of the contingent response to well above its baseline, an outcome completely at odds with any theory that deviations from response patterns are the critical determinant of molar schedule performance. By the predictions of Dunham (1977), such an increase in the burst length of the contingent response should have produced punishment of bar pressing rather than reinforcement. Thus, instead of being the fundamental driving force in the system, deviations from response-pattern set-points appear to be driven by deviations from total intake, and to a lesser extent by deviations from total bar pressing. At least in the case of water reward, maximum bar pressing occurred only after near maximum changes in response patterns were obtained.

Practical Problems and Future Directions

The possibility of sharply increasing the number and importance of presumed set-points relevant to learned performance raises two important questions: First, how many set-points are there and can each one be independently justified? Second, what is the relation among the different set-points? Last, given its power and flexibility, how can the behavior-regulation approach be integrated with other ways of viewing the learned performance situation?

On the first question, the concept of set-points may have seemed harmless enough with only two or three, but with potentially large numbers of set-points facing us, where should we stop? In other words, how does one guard against invoking imaginary set-points whenever it seems necessary to explain some irregularity in the data? The answer is in two parts. First, there should be a theoretical or consistent empirical reason for exploring the possibility that a particular response characteristic serves as a set-point. Second, the purported set-point must pass the criteria discussed previously. Any set-point is identified by (1) reliability and recoverability under conditions of minimal constraint and constant instigation; (2) a direct and gradual monotonic relation between the amount of deviation and the degree of challenge; (3) the ability to support instrumental behavior leading to reduction in constraint. The interdependence and compensatory nature of changes in responding also may provide evidence for the existence of multiple set-points.

It is not the case, as one reviewer argued, that a set-point is inferred on the basis of any functional relation between dependent and independent variables. Set-points are inferred only when there is a direct relation between deviations from the baseline of a reliable and recoverable response characteristic and increasing challenge to its expression. Schedule constraint on the response characteristics should also increase responding that is instrumental in reducing the constraint. For example, that latency to eat in a novel environment is inversely related to

hours without food does not suggest that latency to eat is a set-point. However, latency to eat under a particular set of environmental and organismic circumstances could serve as a set-point supporting bar pressing instrumental in maintaining a low latency.

Caution must be exercised in identifying set-points when several response characteristics are related and there is no independent test of the regulatory effects of each one. In the data above (Marwine & Collier, 1979; Collier et al., 1972) molar and response-pattern measures were related in that total intake could be determined by the frequency of access multiplied by the average intake per access, and frequency of access could be determined by total bar presses divided by the ratio requirement. Do these relations mean that only two set-points are possible (in the sense that there are only two independent measures of total or average responding after the experimenter has determined the schedule)? The answer is no, because the mathematical relations among the measures do not necessarily predict the form of the deviation functions with increasing challenge. For example, if the animal were concerned only with deviations from total instrumental and contingent responding, then one would expect a maximum increase in intake per access at the first challenge; instead, intake per access changed systematically with degree of challenge up to some asymptotic degree of change. Similar arguments can be made by taking intake per access and instrumental responding, or intake per access and contingent responding, as two set-points and determining whether changes in the remaining response appear to reflect only tendencies to reduce deviations from the other two.

However, such a careful analysis casts doubt on the independent effects of the fourth measure, frequency of access. If we assume that the other three measures represent set-points, then the form of the relation between changes in frequency of access and degree of challenge can be seen as determined by compromises among the deviations from the other three set-points. It is clear

that with multiple related response measures, reliability and recoverability cannot be considered the sole criteria of a behavioral set-point. A test of the ability of each response characteristic alone to control regulatory behavior is necessary. In the case of frequency of access, it cannot be manipulated while holding constant the deviations from total responding and burst length, but perhaps a choice situation could be developed in which deviations from frequency of access and burst length were pitted against each other.

The second issue, that of modeling the relation among different set-points, has only been broached. Previous work has treated all presumed set-points the same, with little specific concern with their unique characteristics and relations (Staddon, 1979; Timberlake & Allison, 1974). The data described here clearly suggest the existence of a hierarchical relation between the set-points of total intake and the set-points related to response patterns. Deviations from response-pattern characteristics did not appear to drive total bar pressing, but deviations from total bar pressing and intake did appear important in determining response patterns. However, it is not yet clear how deviations from response-pattern set-points are related to changes in response patterns, whether these relations involve different time periods of integration as would be expected under a hierarchical control system (Powers, 1978), and to what extent relations depend upon the presence of the schedule. Further development of the behavior-regulation approach might well explore questions of hierarchy, periods of integration of set-points, and the role of learning in modifying existing control systems. Finally, as suggested earlier, a complete model of behavior regulation could eliminate the necessity of requiring a baseline assessment of instigation over the same time course and under the same conditions as the subsequent schedule constraint.

The last problem, that of integrating the behavior-regulation view with more typical control theory and reinforcement notions,

may well be critical in further development of a general theory of learned performance. As noted previously, part of the difficulty in accepting the concept of behavioral set-points is the historical ties between set-points and presumably inflexible physiological mechanisms. In fact, in both physiology and behavior, the term *set-point* could be replaced by the term *defended characteristic*, which plays down the notion that there is a single critical point. There is suggestion that set-points may function more as bi-directional thresholds than as individual points. Compensatory reactions to deviations from baseline responding may occur only for deviations greater than a threshold value. This threshold may vary as a function of the direction of the deviation from baselines, as well as with the expression characteristics and baselines of the response combinations involved. For the time I prefer the term *set-point* because it includes all these uses and creates specific connections with the powerful concepts and models of control theory (Hanson & Timberlake, 1983; Powers, 1978).

The integration of behavior regulation and the traditional reinforcement view is most hindered by habitual patterns of thinking about reinforcement. It appears quite difficult to consider learned performance in terms of reinforcement theory and behavior regulation at the same time (cf. Rachlin & Burkhard, 1978; Rachlin et al., 1981). Concepts are filtered and translated in awkward ways in moving from one approach to the other. This is obvious in the comments of reviewers, in textbook treatments, and in interactions with colleagues and students. In my experience it was necessary to let go many preconceptions about the action of reinforcers to get to the behavior-regulation approach, even given the reasonably clear direction pointed by Premack (1965, 1971). In the past investigators have appeared to embrace one or the other viewpoint. Since both approaches have defensible aspects, I am hopeful, but not entirely sanguine, that we can move toward a more integrated view (see Timberlake, 1983).

CONCLUSIONS

The behavior-regulation approach to learned performance provides a unique and potentially powerful mechanism, the regulation of disparities between instigation and expression of behavior, for the identification of the circumstances of reinforcement and the prediction of asymptotic performance under schedules. The present paper clarifies several of its assumptions and procedures. First, behavior regulation does not imply a particular physiological model of response determinants, only reliable levels of response instigation and the mechanism to translate disparities between instigation and expression into instrumental behavior. Second, behavioral set-points are not arbitrarily chosen, but are identified by their invariance and recoverability under conditions of reliable instigation and minimum constraint, and by the functional relation between degree of challenge and amount of deviation from them. The free baseline, although it does not account for all determinants of responding, appears to provide a reasonable index of basic instigation.

Third, that animals may fail to exert maximum physical effort to minimize deviations from presumed set-points of instrumental and contingent responding (Allison, 1981a) was shown to be irrelevant to the general behavior-regulation approach, and to be of questionable relevance to optimal behavior regulation. Fourth, the question of whether instrumental responding is driven by deviations from response-pattern or total-responding set-points was resolved in two ways. First, there was reasonable evidence that response patterns could serve as set-points. Second, in the data considered, deviations from response-pattern characteristics not important in driving instrumental responding; rather, deviations from total intake were important in driving deviations from response-pattern characteristics. It is suggested that future work focus on the study of different levels of behavioral set-points and their relations, as well as promote

the development of a more complete view of learned performance.

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