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Drug Effects and Concurrent Performances*

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AMONG the etymological relatives of the term *response* is the Greek *spondē*, a drink-offering or libation. It is therefore perhaps fitting that students of behavior have often turned to drug effects as a major area of research. Typically the concern is with the analysis of drug effects and their interactions. In the present symposium, for example, Griffiths, Wurster, and Brady (p. 357) began with the reinforcing effect of heroin, and then proceeded to examine how naloxone and methadone attenuated this effect. Their application of the available behavioral technology allowed them to assess the reinforcing effect of heroin independently of other behavioral drug effects (*e.g.*, direct effect of heroin on rate of responding). The research skillfully used behavioral methods to address issues that were primarily pharmacological.

Drugs are, of course, of interest in their own right. Drugs are a class of stimuli that differ from other stimuli, such as those in the familiar sensory modalities, in their routes of administration, their time courses, and their mechanisms of action. Nevertheless their effects can be classified in much the same way (*e.g.*, reinforcing, eliciting, discriminative) as those of other classes of stimuli. Thus, it may be profitable to examine drug effects not only for their own sake, but also for their potential relevance to the analysis of behavior. Some of the contributions to the present symposium provide instructive examples, and the main purpose of the present discussion is therefore to consider some of the ways in which drug studies can contribute to our understanding of behavior.

Comparison of Food and Drugs as Reinforcers

The term *reinforcement* refers neither to a theory of nor an explanation for behavior. It is, instead, a name for a particular relation between behavior and environmental events. When responses have stimulus consequences and the responses increase because they have these consequences, it is appropriate to apply the term *reinforcement*. Once an instance of reinforcement has been noted, the empirical task is to distinguish this relation from other sources of responding (*e.g.*, as when a study shows that responding occurs because drug administration is its consequence rather than because of eliciting effects of the drug). But with respect to quantifying reinforcers and their effects, to demonstrating the properties of reinforcement schedules, and to examining the relations between reinforcing functions and other functions of stimuli, much of what we know comes from a fairly limited range of reinforcers (especially food). The recognition that reinforcing effects are included among the stimulus properties of drugs, therefore, provides opportunities for studying the generality of reinforcement effects, and substantial progress has been made in the direct comparison of food and drugs as reinforcers [*e.g.*, (7)].

One important feature of drugs as reinforcers is that other effects of their admin-

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istration accompany their reinforcing effects, and these other effects may be extended in time. For example, if a monkey has self-administered a sufficiently large dose of narcotic analgesic by pressing a lever, substantial time may elapse before the monkey returns to the lever, whereas with food reinforcers the monkey would probably return to the lever in just a few seconds. (In this respect, drug reinforcers seem to have more in common with sexual reinforcers than with food reinforcers, but this may be simply because laboratory procedures typically use small amounts of food as reinforcers rather than large portions that would quickly produce satiation.) This difference between experiments with drug reinforcers and those with food reinforcers sometimes complicates the design of equivalent procedures for each. The informative analysis by Iglauer and Llewellyn of concurrent schedules of cocaine infusion provides an illustration (p. 367).

Their basic procedure involved two concurrent variable-interval schedules arranged respectively for two levers. Reinforced presses on each lever produced a 35-sec infusion of cocaine followed by 5 min during which the levers were inoperative (time-out). At the end of the time-out, the monkey could initiate a new cycle of concurrent variable-interval variable-interval responding. The major experimental manipulation was the dose of cocaine arranged for each lever. In similar concurrent variable-interval variable-interval schedules with food reinforcers, subjects often approximately match the proportion of responses maintained by each concurrent schedule to the proportion of reinforcement (*e.g.*, relative reinforcement frequency or magnitude) arranged by that schedule. For example, if response A produced 60 food pellets per hour whereas response B produced only 30 pellets per hour, response A would be expected to occur about twice as often as response B (this relation, called *matching*, is discussed further below). Iglauer and Llewellyn found, however, that instead of distributing responses proportionately to the two levers, monkeys tended to respond exclusively on the lever that produced the higher dose of cocaine.

Periods of time-out after reinforcement are not typically included in concurrent variable-interval variable-interval schedules of food reinforcement. With no time-out imposed after reinforcement, if one variable-interval 1-min schedule delivered 12 food pellets as the reinforcer for a rat's presses on one lever and a concurrent variable-interval 1-min schedule delivered 3 food pellets as the reinforcer for its presses on the second lever, the rat could obtain 12 pellets per minute if it responded exclusively on the first lever or 3 pellets per minute if it responded exclusively on the second lever; the rat could obtain 15 pellets per minute, however, if it distributed its responses to both levers. But consider the same schedule if a 5-min time-out were imposed after each delivery of pellets. Exclusive responding on the first lever would produce 12 pellets every 6 min (1-min variable-interval plus 5-min time-out), or an average of 2 pellets per minute. Exclusive responding on the other lever would produce 3 pellets every 6 min, or 0.5 pellet per minute. Responding distributed to both levers, however, would produce 15 pellets for every 1 min of concurrent variable-interval responding but would also add two 5-min time-outs. Thus, such responding would produce 15 pellets every 11 min, or 1.36 pellets per min. In this case, exclusive responding on the first lever produces pellets more frequently than responding distributed to both levers. In accordance with an informal behavior principle (what you reinforce is what you get) and its corollary (you get the most of what you reinforce the most), it would not be surprising if the latter schedule generated exclusive responding on the first lever rather than responding distributed to both levers.

At this point, however, it is clear that the findings by Iglauer and Llewellyn are not inconsistent with those from concurrent schedules of food reinforcement. The 5-min time-out was used in their procedure so that the narcotic effects of the drug would

not mask its effects as a reinforcer. But once the time-out is taken into account the reinforcing effects of varied doses of cocaine seem comparable to those of varied amounts of food. In fact, an examination of the literature on concurrent schedules of food reinforcement, prompted by the findings by Iglauer and Llewellyn, shows that some existing data can be interpreted in this way. Fantino (5), for example, studied pigeons' key pecks maintained by concurrent chained schedules of food reinforcement [see also (11)]. Two equal concurrent variable-interval schedules operated in initial links. One of these produced a variable-interval 30-sec terminal link; the other produced a variable-interval 90-sec terminal link. Performance was examined with initial-link variable-interval schedule values of 600-sec, 120-sec, and 40-sec. Although performance with the two longer variable-interval values deviated from matching to some extent, concurrent responding was distributed to both initial-link keys. With the shortest variable-interval value, however, responding was almost exclusively restricted to the initial-link key that produced the variable-interval 30-sec terminal link. In table 1, the estimated time between successive food deliveries when responding is distributed between the concurrent initial-link keys is compared with that when responding is restricted to only one of these keys. With variable-interval 40-sec schedules in concurrent initial links, but not with the longer variable-interval values, the time between reinforcements is shortest if responding is restricted to the initial-link key that produces the variable-interval 30-sec terminal link. This example shows that cocaine reinforcers and food reinforcers have similar effects when they are studied with comparable procedures, and illustrates how performances maintained by drug reinforcers may contribute to the analysis of performances maintained by other classes or reinforcers.

Absolute and Relative Measures of Reinforcer Potency

But the significance of the data of Iglauer and Llewellyn is not restricted to the demonstration that organisms will ordinarily respond in ways that maximize the frequency of reinforcement in time. Implicit in their analysis is a concern with determining which aspects of behavior can serve appropriately as measures of the effects of reinforcers. Rate of responding is convenient, but to the extent that rates and patterns of responding are themselves differentiable by schedules of reinforcement, the interpretation of response rate becomes ambiguous [*cf.* Nevin's treatment of response strength as resistance to change rather than rate of responding (12)]. One way of approaching this problem is to deal not with absolute rate of responding but rather with relative rate of responding, *i.e.*, the rate of one response as a proportion of the sum of the rates of that and other

TABLE 1

Estimates of sec/reinforcer in concurrent chained schedules on the assumption of responding distributed to both initial-link keys or restricted to only one initial-link key

VI, variable-interval. See text for details. [From Fantino, J. Exp. Anal. Behav., **12**: 723–730, 1969 (5).]

Key	Concurrent VI Initial Links	Separate VI Terminal Links	Concurrent Responding	Key-1 Responding Only	Key-2 Responding Only
				sec/reinforcer	
1	600-sec	30-sec	360	630	690
2	600-sec	90-sec			
1	120-sec	30-sec	120	150	210
2	120-sec	90-sec			
1	40-sec	30-sec	80	70	130
2	40-sec	90-sec			

responses. In a range of procedures (single-response schedules, concurrent schedules, multiple schedules), the relative rate of a given response approximately matches that response's relative rate of obtained reinforcement (8). On the basis of its generality, this relation has been spoken of as a law of behavior: the matching law. Relative response and reinforcement measures have even been invoked in accounting for phenomena that can only be defined in terms of changes in absolute response rates; in such cases, the phenomena under consideration do not even appear in the relative measures [*e.g.*, in the transition from multiple variable-interval variable-interval to multiple variable-interval extinction schedules, behavioral contrast is defined as an increase in the rate of responding maintained in the unchanged variable-interval component when the other component is changed from variable-interval to extinction, but relative response rate in that component is 1.0 whether the response rate in the first component increases or remains constant, as long as responding decreases to zero in the extinction component; *cf.* (16)].

One difficulty with interpreting concurrent performances in terms of relative reinforcement rates is that the performance by the organism may not produce all of the reinforcers that have been scheduled. In the extreme, when responding is maintained exclusively by only one of two concurrent schedules (such as that maintained by the higher dose of cocaine in the Iglauer and Llewellyn experiment discussed above), the relative rate of responding will necessarily be insensitive to changes in the reinforcers scheduled for either response; the relative rate of such responding is always 1.0. For example, when 2-fold and 10-fold differences in concurrent drug doses both produce responding maintained exclusively by the higher dose, little can be concluded about the quantitative relation between dose and reinforcing effect, except perhaps that the relation is monotonic.

To circumvent this problem, Iglauer and Llewellyn turned to a procedure that minimizes the deviations of obtained reinforcers from scheduled reinforcers in concurrent performances. In this procedure (19), the concurrent schedules do not operate independently; instead, both schedules stop operating each time a reinforcer has become available until a response has produced that reinforcer. With this procedure, responding cannot be maintained exclusively by one of the two concurrent schedules; if both responses are not maintained, both responses will necessarily extinguish. With this procedure, Iglauer and Llewellyn found that responding was maintained concurrently by both the high-dose and low-dose cocaine schedules. Their subsequent analysis, however, elegantly demonstrated that the functions relating relative rate of responding to relative dose of cocaine were determined in large part by the schedule requirements; low-dose responding was maintained at a rate sufficient to keep both the high-dose and the low-dose schedules operating. The problem of using these data for assessing relative reinforcing effects, however, is clear. With this procedure, both responses would have to be maintained even if one of them produced only saline (the analogous case with food reinforcers, where a full food hopper and an empty food hopper are the respective reinforcers for a pigeon's pecks on two keys, has not been studied, perhaps because the outcome seems so obvious).

The Fallibility of the Matching Law

The significance of these findings is not limited to assessment of the reinforcing effects of the drugs. In their attention to absolute response and reinforcement measures, Iglauer and Llewellyn not only provide a more detailed quantitative analysis than is available for many comparable examples of studies with food reinforcement, but also raise questions about the conditions under which relative response and reinforcement measures are appropriate to a behavioral analysis. Relative-rate measures can sometimes obscure phenom-

ena that are evident in absolute-rate measures. The point can perhaps best be illustrated by comparing absolute and relative measures in specific cases. Absolute and relative response and reinforcement rates from two experiments on concurrent performances in pigeons are presented in figure 1: Catania (2) examined concurrent schedules in which both responses were maintained by food; Hollard and Davison (10) examined concurrent schedules in which one response was maintained by food and the other was maintained by electrical stimulation of the brain. For convenience, the data from each experiment have been averaged across three pigeons; the points made here, however, hold equally well for the data from individual pigeons.

In both experiments, concurrent variable-interval schedules were used in which the maximum rate of reinforcement for one response was varied (key A) while the maximum rate of reinforcement for the other response was held constant (key B). Also used in both experiments was a 2-sec changeover delay, to prevent one response from being followed closely by a reinforcer produced by the other response. Catania, however, used independent concurrent variable-interval variable-interval schedules in a Findley changeover-key procedure (6), whereas Hollard and Davison (10) used non-independent variable-interval variable-interval schedules (19) in a two-key procedure. In the changeover-key procedure, the concurrent schedules are each correlated with a different stimulus on one key, and the pigeon can change from one stimulus to the other by pecking a second key, the changeover key. The procedure is ordinarily regarded as functionally equivalent to two-key concurrent schedules, in which the pigeon switches from one schedule to the other simply by moving from one key to the other, because the two schedules operate concurrently and are available at all times *via* pecks on the changeover key. In figure 1, the key A and key B designations correspond to the two concurrent schedules, whether correlated with different stimuli on a single key or correlated with two keys in different locations.

Of the upper panels of figure 1 (Catania), the left panel shows the absolute response rate for each key plotted against the reinforcement rate for key A. As key A food reinforcement rate increased, key A responding increased; concurrently, the key B response rate, maintained by a constant

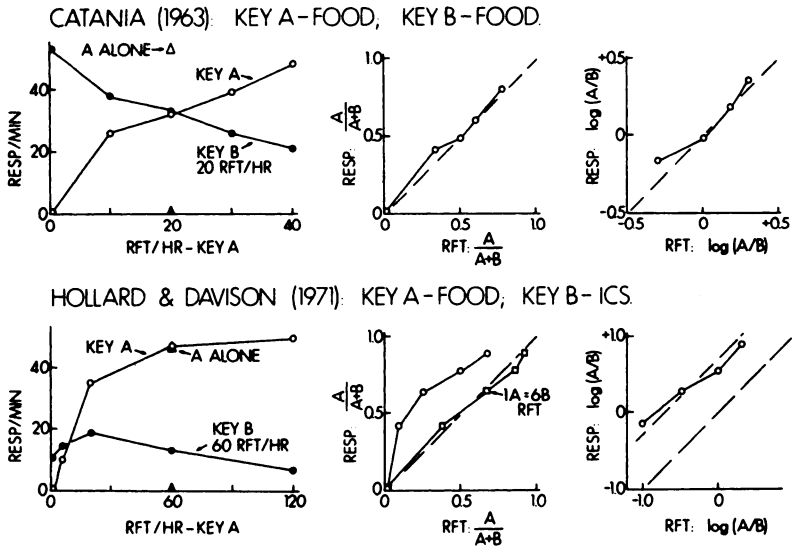

Fig. 1. Absolute and relative measures of the performance maintained by two concurrent procedures. ICS, intracranial electrical stimulation of the brain. (See text for details.)

food reinforcement rate, decreased. The interaction between food reinforcers in concurrent schedules is illustrated by the triangles, which show the response rate that would have been maintained by key A alone with extinction scheduled for key B: The response rate maintained by a given schedule increased with increased rates of variable-interval reinforcement, but was reduced by the reinforcers scheduled for another, concurrent response.

The middle panel shows the transformation of these data to relative response and reinforcement measures. Key A responses and reinforcers are expressed as a proportion of the total responses and reinforcers for keys A and B together. The diagonal line shows the locus of points at which relative response rate equals relative reinforcement rate; the data approximate the matching relation discussed above. The right panel shows another relative transformation, in which the logarithm of the ratio of key-A to key-B responses is plotted against the logarithm of the ratio of key-A to key-B reinforcers. The locus of matching points is again shown by the dashed diagonal line. This transformation (1) was introduced to deal with cases in which responding was systematically biased toward one of the two concurrent responses. Its significance will be considered below. For the present, it is sufficient to note that data obtained when one of the schedules provides no reinforcers cannot be incorporated into this plot.

Of the lower panels (Hollard and Davison), the left panel shows absolute response rates on key A and key B plotted against the rate of key A food reinforcement (note that Hollard and Davison examined a wider range of food-reinforcement rates than in the experiment by Catania). In this case, rate of key A responding increased with rate of key A reinforcement, but the rate of key B responding changed nonmonotonically. Key B responding increased with key A reinforcement rate up to about 20 rft/hr, but with further increases in key A reinforcement the rate of key B responding decreased. In addition, changing the key B schedule to extinction (triangles: A alone) suggested that key B brain-stimulation reinforcers had no effect on key A response rate. Thus, with food reinforcers scheduled for key A and brain-stimulation reinforcers scheduled for key B, the interactions were not comparable to those obtained when food reinforcers were scheduled for both concurrent responses.

The middle panel shows the transformation to relative response and reinforcement rates. Food reinforcers maintained substantially higher rates of responding than brain-stimulation reinforcers, and therefore the data (circles) are displaced considerably from matching. Examination of the absolute rates, however, shows that key A and key B response rates were about equal when the variable-interval food schedule arranged about 10 rft/hr. Thus, the effect of one food reinforcer seemed roughly equal to that of six brain-stimulation reinforcers. If relative reinforcement rate is calculated on the basis of this relation between food and brain-stimulation reinforcers (squares), the data come to approximate the matching relation.

The right panel shows the transformation of relative response and reinforcement rates to logarithms of the key A to key B ratios. Here, the difference in the effectiveness of key A and key B reinforcers is shown by the displacement of the data from the lower dashed diagonal, which represents matching. The advantage of this transformation is that a systematic difference in the effectiveness of the two reinforcers should produce a linear function that is parallel to the matching line. The present data approximate such a function, although the slope seems to be less than 1.0. (Differences in response properties as well as in reinforcer effectiveness can also be incorporated into this account. For example, a high-effort response might occur at one-third the rate of a low-effort response if the two responses were maintained by equal concurrent variable-interval schedules. This proportionality should

then hold with changes to other unequal pairs of concurrent schedules, and produce a function parallel to the matching line in the present transformation.)

The similarity of the graphs at the right in figure 1 might superficially be taken as an argument in favor of these relative data transformations, but on examination they instead support an argument against such transformations. The upper and lower right panels appear similar, but they do so because they are sufficiently far removed from the original absolute-rate data that important differences between the two experimental outcomes are obscured. Hollard and Davison in fact concluded, from the transformation on the right, that the properties of concurrent performances with different reinforcers scheduled for the two responses are comparable to those with the same reinforcers scheduled for both responses. But the absolute response rates tell a different story. When the reinforcers are the same, increases in the reinforcement of one response decrease the rate of the other responses: This is not necessarily the case when the reinforcers are different. [Differences in the conclusions to be drawn from absolute rates and relative rates are not restricted to the effects of different concurrent reinforcers; *e.g.*, *cf.* (20) on the effects of magnitudes of food reinforcers.]

The matching law has been a focus of controversy [*e.g.*, (8, 17)]. The present account has not attempted to enter into the empirical and theoretical issues of that controversy. Instead, it has tried to emphasize the practical point that the exploration of relative data transformations that more or less closely approximate matching has often obscured other and perhaps more important properties of behavior.

Prospects and Problems

Few studies of concurrent performance have examined concurrent responses maintained by different reinforcers. Some research has begun, at different laboratories, on concurrent schedules of food and water reinforcement. In the meantime, psychopharmacological research has already begun the examination of different drugs as reinforcers in concurrent performances, as in Johanson's contribution to the present symposium (p.343). It is important to recognize that such experiments with drugs may do as much to extend the boundaries of our understanding of behavior as experiments with other, more familiar reinforcers. Certainly it is appropriate to agree with the point that, if we ask whether drug A is a more potent reinforcer than drug B, the only proper answer is, "It depends." Any number of variables, including scheduling, experimental history, deprivation, and so on, may influence the relative potency of reinforcers. But it may also be important to know whether the reinforcing effects of drug A interact with the reinforcing effects of drug B, just as it may be important to know how water deprivation may alter the reinforcing effect of food. The value of a basic understanding of concurrent performances, then, will come when we have examined concurrent interactions with various combinations of reinforcers and can relate them to other behavioral phenomena.

Hopefully, the case has been made that psychopharmacological studies have at least as much to offer to the analysis of behavior as the analysis of behavior has to offer to psychopharmacology. A brief and admittedly speculative account of some other potentially useful areas of interaction between drug studies and behavior studies may therefore be appropriate. These areas include discriminative-stimulus properties of drug reinforcers, the use of drugs to distinguish functional from topographical response classes, and the potential relevance of the punishing as well as the reinforcing effects of drugs to behavioral analyses of self-control.

Discriminative-stimulus properties of reinforcers. Because the effects of drugs often have a slow onset after a drug has been administered, experiments on drug reinforcers often include an exteroceptive stimulus that immediately follows the rein-

forced response. Sometimes such a stimulus is explicitly arranged, and sometimes it is simply an incidental accompaniment of the experimental setting, such as the auditory and mechanical stimuli produced by the operation of an infusion pump (*cf.* Johanson, p.343 with Griffiths *et al.*, p.357). Another factor that may influence the effect of a reinforcer is the extent to which it sets the occasion for responding. For example, brain stimulation itself may be less effective as a reinforcer than a stimulus in the presence of which a response can produce brain stimulation [*e.g.*, (13); comparable differences in human performance may depend on whether the subject must attend to the reinforcer once it is delivered: *cf.* (21) with (9)]. In other words, the effects of the reinforcer depend on whether the organism must make a magazine response. These effects of different reinforcer properties have often been noted, but they still await a systematic experimental analysis. Because the details of the administration of drug reinforcers often differ from one experiment to another, a study of the role of exteroceptive stimuli correlated with drug reinforcers and of the responding occasioned by the presentation of drug reinforcers may provide an important impetus to such an analysis.

Functional versus topographical effects of drugs. When drugs have effects that are specific to one type of performance but not another, it is tempting to conclude that the differential drug effect provides a basis for classifying the behavioral processes that maintain the two types of performance. But such an analysis must determine whether the drug acts on the functional classes of behavior that are established by a given procedure or simply on topographical classes.

The data presented in table 2, obtained at the Smith Kline and French Laboratories in collaboration with L. Cook and C. A. Gill, illustrate the point. The lever-pressing of squirrel monkeys was maintained by concurrent variable-interval 30-rft/hr variable-interval 10-rft/hr schedules of food-pellet reinforcement, with a 3-sec changeover delay. The schedules were arranged according to the changeover-key procedure (6) described above: Each schedule was correlated with the illumination of one of two pilot lamps over the left lever, and presses on the right lever served as changeover responses. Summarized in the table are the effects of four drugs on output (overall resp/min on the food schedules), changeovers (changeover-lever presses/min), and relative rate (responses maintained by variable-interval 30-rft/hr as a proportion of the total responses main-

TABLE 2

Effect of drugs on several measures of squirrel monkey performances maintained by concurrent variable-interval variable-interval schedules of food reinforcement (changeover-key procedure)

All doses (mg/kg, p.o.) were administered immediately before standard daily 2-hr sessions, except for chlorpromazine (1-hr pretreatment). Data entries are percentages relative to control sessions, averaged across four subjects. (Meprobamate, over a range of 12.5 to 100 mg/kg, had effects generally similar to those of chlordiazepoxide, but variability precluded presentation of averaged data.) See text for details.

	d-Amphetamine sulfate				Chlorpromazine HCl		
mg/kg	0.06	0.12	0.25	0.50	1.0	2.0	
Output	106	104	96	80	84	27	
Change-overs	132	156	158	78	82	18	
Relative rate	98	100	99	100	101	97	
	Chlordiazepoxide HCl				Imipramine HCl		
mg/kg	1.25	2.50	5.0	10.0	5.0	10.0	20.0
Output	106	100	72	69	92	87	61
Change-overs	171	86	69	64	71	72	20
Relative rate	100	103	94	101	99	103	109

tained by both concurrent variable-interval schedules).

None of the drugs produced substantial increases in total output (baseline levels in the range of 30 to 60 resp/min), and relative rates were not affected at any dose by the drugs tested (baseline levels were in the range of 0.60 to 0.65, systematically undermatching the relative reinforcement rate of 0.75). The relatively low-rate changeover response (baseline levels in the range from 5 to 10 resp/min), however, was significantly increased by both *d*-amphetamine and chlordiazepoxide. These data provide another example of the rate-dependency of drug effects, and also provide an important control for procedures that use concurrent variable-interval variable-interval performances to assess the punishment-specific effects of drugs [*e.g.*, fig. 10 (3); fig. 26 (4)]. Unfortunately, data for direct comparison with drug effects on squirrel monkey performances in two-key concurrent procedures are unavailable, but Smith (18) has reported that drugs that produce increases in response rate in two-key concurrent performances of pigeons (*e.g.*, *d*-amphetamine) affect the lower-rate response of two concurrent responses rather than changeover responding. Although more data are needed, the point here is that the changeover-key and the two-key concurrent procedures have generally been assumed to be functionally equivalent. But if drugs affect the low-rate change-over response in the changeover-key procedure, when that response is a key peck or a lever press, but do not affect it in the two-key procedure, when it is a movement from one key or lever to another, then some assumptions either about the equivalence of these two concurrent procedures or about the nature of drug effects must be re-evaluated. On the one hand, such differential drug effects might imply that changeover-key concurrent procedures are not in fact functionally equivalent to two-key concurrent procedures; on the other hand, they might lead to the conclusion that at least some drug effects are not specific to the functional properties of behavior, but are instead specific only to its topographical properties [*e.g.*, the effects of apomorphine on pecking in pigeons (7a)]. Whatever the resolution of these issues, they will probably have implications for the interaction between pharmacological and behavioral research.

Reinforcement and punishment of drug-taking behavior and self-control procedures. Drugs may have aversive or punishing effects as well as reinforcing effects. Further, a drug that has consequences that follow different time courses may combine both reinforcing and punishing effects in a single administration (*e.g.*, alcohol ingestion may provide relatively immediate reinforcing effects, but a subsequent hangover may provide punishing effects, albeit after a delay). The combination of reinforcing and punishing consequences at different delays after a response provides the cornerstone of a behavioral analysis of self-control (14, 15). The analysis must consider both the conditions under which it is appropriate to speak of behavior in terms of self-control and the empirical properties of such behavior. For example, the alcoholic who foregoes the immediate reinforcing consequences of a drink because of its potential later aversive consequences is said to exhibit self-control. But the aversive effect is more likely to outweigh the reinforcing effect if the opportunity for a drink is some time in the future than if the drink is presently available; because of its greater immediacy, the reinforcing effect of the drink increases relative to its aversiveness as the time of availability approaches. The alcoholic, therefore, is most likely to make a commitment to abstain at the least useful time: when the next opportunity to drink is far in the future. The commitment, for example, might be the taking of a drug that induces nausea when alcohol is ingested, thereby reducing the subsequent likelihood of drinking by making its aversive consequences more immediate. Commitments, therefore, are classes of behavior. The anal-

ysis of self-control procedures may suggest ways in which an organism's likelihood of making commitments can be modified. Although a detailed account is beyond the scope of the present discussion, Johanson's observation (p.343) of a preference for delayed rather than immediate cocaine administration within a concurrent procedure is of particular interest. If an organism is given a choice at one time whether or not a drug will be available at a later time, and its preference for drug rather than no drug increases as the time between the choice and the drug availability decreases, an analysis in terms of self-control is appropriate. The extension of self-control procedures to drug self-administration has obvious implications not only for the behavioral analysis of drug effects but also for its potential application to the training of drug abstinence in human drug users. This final example therefore not only illustrates another possible area of interaction between pharmacological and behavioral research, but also suggests how such an approach may have practical relevance for human drug-reinforced behavior.

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