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THEORETICAL REVIEW

Schedule Induced Behavior: A Review of its Generality, Determinants and Pharmacological Data[1,2]

MEREDITH WALLACE AND GEORGE SINGER

Department of Psychology, La Trobe University, Bundoora, Victoria, AUSTRALIA 3083

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WALLACE, M. AND G. SINGER. *Schedule induced behavior: a review of its generality, determinants and pharmacological data.* PHARMAC. BIOCHEM. BEHAV. 5(4)483–490, 1976. – Adjunctive or schedule induced behavior can be defined as an increase in the frequency of occurrence of an unreinforced behavior in the presence of conditions requiring an intermittent reinforced response, compared with the frequency of that behavior when no intermittent response is required. Although recognition has been given to the occurrence of other schedule induced behaviors it has most frequently been studied as schedule induced polydipsia in a rat on a food delivery schedule. In the present paper recent work on other schedule induced behaviors is reviewed including behaviors occurring in conjunction with nonconsumatory schedule parameters. These range from wheel running in the rat to game playing and maze solving in humans. This paper is also concerned with the review of pharmacological variables including the effects of peripheral and central administration. It is concluded that there may be either quantitative or qualitative differences in drug effects when schedule induced drinking is compared with deprivation induced drinking. A general activation theory [61] that adjunctive behavior is the result of an increase in the excitability of motor pathways which lead through the lateral hypothalamus can account for the data presented in this and earlier reviews but is too broad in its conception to make specific predictions about the relationships between schedule induced and schedule controlled behavior.

Adjunctive Schedule induced Schedule controlled Polydipsia Cholinergic Adrenergic Lateral hypothalamus

FOOD deprived but water satiated rats will drink copious quantities of water when placed in a Skinner box on a variable interval 60 (VI 60) food delivery schedule [11]. This phenomenon, known as schedule induced polydipsia, can also be brought about by a fixed interval schedule of the same length [15] or by delivery of the pellet at 60 sec intervals without an operant response by the animal [12]. Schedule induced behavior has been described as adjunctive behavior [15] and in this paper the terms are used interchangeably. Adjunctive behavior can be defined as an increase in the frequency of occurrence of an unreinforced behavior in the presence of conditions requiring an intermittent reinforced response, compared with the frequency of that behavior when no intermittent response is required. The type of behavior which occurs depends on the available stimuli and the unreinforced behavior usually differs from the reinforced response. The term schedule controlled appropriately characterises the operant; that is, the response for which the organism is being reinforced.

Explanations of adjunctive behavior in terms of traditional behavior models and physiological homeostatic models have been discussed elsewhere [17,56] and will receive only limited attention in the present review. Adjunctive behavior is difficult to explain in terms of existing learning paradigms. Schedule induced polydipsia interpreted as a result of adventitious reinforcement of drinking [8] does not accord with the fact that drinking occurs immediately after the pellet ingestion and during the remainder of the interval, even on a three minute schedule [17], many other behaviors such as grooming, bar biting and rearing occur. Adjunctive behavior is sustained by a 30 response fixed ratio schedule (FR30) where, regardless of whether the animal drinks after consuming a pellet, the next pellet is still 30 responses distant. Similarly the introduction of a change over delay (COD) consisting of a 15 second waiting period interposed between the last drink and the next barpress on a VI 60 schedule does not diminish polydipsic drinking when compared to a VI 60 schedule without COD [17]. These instances constitute an interruption to any possible chain of superstitious responses. Attempts to account for it as frustration or emotional pacification do not add to our understanding. Physiological explanations incorporating a homeostatic mechanism are equally unsatisfactory. In fact schedule induced polydipsia has been described as an unusual, outright absurd phenomenon: ". . . . because heating a large quantity of room temperature water to body heat and expelling it as copious urine is wasteful for an animal

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already pressed for energy stores by food deprivation". ([18], p. 577) Schedule induced polydipsia has been regarded as a form of nonregulatory drinking.

Earlier reviews of schedule controlled behavior have concentrated on polydipsia as an adjunct to control schedules based on food delivery. The purpose of this paper is to review schedule induced behaviors which have been observed in addition to drinking and schedule controlled behaviors which are not based on consumatory responses. Recent data on brain behavior relationships will also be reviewed.

Adjunctive Behaviors Induced by Schedules Controlling Consumatory Responses

Although Falk's description [11] of polydipsia in the rat is frequently cited as the initial demonstration of schedule induced or adjunctive behavior, an early study reported wheel running as a concurrent activity in rats under a fixed-interval reinforcement schedule [56]. The study of drinking as a schedule induced response was followed by many experiments on the parameters of adjunctive drinking but eventually interest was focussed on other schedule induced responses till then overlooked. These include air licking [7, 39, 40], wheel running [31, 36, 48], vocalisation and fighting in rats [58], ingestion of wood shavings by a monkey [23], and pecking of a target bird or dummy by pigeons, which has been interpreteted as attack behavior [e.g. 6, 21, 26, 33].

It is probable that this is only a small sample of the behaviors which may become schedule induced. This point has been confirmed by a study [9] which showed that when the drinking tube was empty or absent, previously polydipsic animals exhibited large increases in all other behaviors recorded, e.g. bar pressing, locomotor and exploratory behaviors, floor gnawing, grooming and attacking the drinking tube. Further evidence comes from reports where such behaviors were not systematically studied, but were described as interferences in experiments designed for other purposes; for example, the comment has been made that "the presence of strong competing behavior with a definite pattern of occurrence has considerable nuisance value" ([8], p. 61). Another example of interference is a report of one monkey regularly jerking its head to one side and a second monkey regularly licking its water bottle holder while on a schedule of differential reinforcement which required low rates of responding (DRL) [25]. Stereotyped tail chewing has been described in a white rat [34], and it has been reported as a fortuitous observation [23] that some rats manipulated or chewed cellulose material instead of becoming polydipsic. When this material was unavailable, the rats reverted to polydipsia. Behavioral abnormalities have been observed in isolate reared monkeys such as self-slapping, self-biting, floating limbs, rocking, swaying and other stereotyped whole-body movements [41]. It should be mentioned that the schedule intervals in this case were extremely long (two meals per day, 7.30 a.m. and 3.00 p.m.). Caution must be exercised in the identification of a schedule, otherwise all behavior could be seen as an adjunct to normal meal periods.

Although it has been shown that the frequency of occurrence of adjunctive behavior increases as a function of schedule interval, this increase need not be linear. It is known that schedule induced drinking in the rat reaches a maximum at FI 180 sec and declines with increased schedule intervals [15]. The following points can be raised in relation to behaviors which may become schedule induced. First, it is possible that many more behaviors than those listed have occurred at some stage in conditioning experiments but because they have not been systematically observed, have not been reported. Second, some of these behaviors can occur only when there is an appropriate stimulus in the environment. Polydipsia would not have occurred had the drinking tube not been in the training cage. The test situation, particularly that of a learning experiment, is usually designed to minimise the variety of responses an animal may emit. Third, it is possible that the behavior which does appear may be partly determined by the individual animal's experience and partly by genetic differences. Although schedule induced polydipsia has been reported in the rat [e.g. 13, 14, 16], the mouse [43], the pigeon [52], the Rhesus monkey [44,47], the Java macaque [29] and macaque monkeys reared in isolation for the first 12 months [41], no systematic comparison of the parameters relevant to these points has been carried out.

Aggression as a form of schedule induced behavior has been studied in rats (for example [27]), in children [22], and perhaps most frequently in pigeons [1, 6, 21, 33]. The last group of animals are probably preferred as subjects because of the comparative ease with which their aggressive responses can be identified and measured. Fixed interval [6] and DRL schedules [33] have resulted in attacks on restrained target pigeons.

Some studies have examined what is termed extinction induced aggressive behavior [2,58] where birds have been given, for example, 10 sessions each consisting of a five minute extinction period, preceded by 50 CRFs and followed by 100 CRFs. Although this is described as extinction it is possible that inclusion of this extinction period produces the equivalent of a 5 min fixed interval schedule, and the aggressive behavior is being induced by the scheduling rather than the extinction. The same suggestion has been made from the opposite viewpoint [2], the argument being that "many schedules of intermittent reinforcement will probably possess aversive properties since intermittency necessarily involves periods of extinction" ([2], p. 203).

In one of these studies [58] the duration of fighting decreased over successive extinction sessions until it returned nearly to baseline duration by the fifth extinction period. It would be interesting to know whether any substitute behavior occurred which was not reported (or perhaps not observed) by the experimenters. Aggression has been studied on a schedule where the aggressive act itself was reinforced (therefore not schedule induced, but schedule controlled), on a variety of fixed intervals [1]. There is no mention of whether this procedure led to any adjunctive behaviors on the longer schedules (1-min, 2-min and 4-min FI schedules).

A drop in responses, in this case aggressive ones, over sessions is not a usual feature of schedule induced behavior, which tends to be gradually acquired and then maintained at a constant rate. When schedule induced polydipsia and schedule induced aggression were directly compared it was noted that the latter occurs on the first occasion as soon as the animal is exposed to the experimental treatment [27]. This study failed to demonstrate schedule induced aggression under conditions conducive to schedule induced polydipsia, suggesting that important differences exist between the two. While it cannot be expected that all

schedule induced behaviors will show identical characteristics there seems sufficient variability in the characteristics of the experimentally-produced aggression to raise some doubts about whether it is, in fact, schedule induced [27]. The nonconsumatory control schedules to be reviewed in the next section provide data on further varieties of schedule induced behavior.

Adjunctive Behavior Induced by Schedules Controlling Nonconsumatory Responses

In the majority of early studies the schedule controlled behavior involved a consumatory response, that is, delivery of either food or, less commonly, water. The range of schedule controlled behaviors which have been used so far to produce adjunctive behaviors is much smaller than the number of schedule induced behaviors reported. This may result from a bias toward certain conventional experimental paradigms. To our knowledge, only one study of adjunctive behavior in animals has schedule controlled a behavior which did not involve eating or drinking. When access by rats to a running wheel was scheduled, schedule induced behaviors such as licking-poking, rearing-locomotion and grooming were observed [55].

Studies with humans show that the range of schedule controlled behaviors may be extensive. Acquisition of a bar press response in animals for food reinforcement is dependent on acute or chronic deprivation. It is claimed [18] that only animals which are reduced in body weight develop adjunctive behavior. It is not practicable to reduce the body weight of humans for experimental purposes, nor is it easy to control their food intake prior to the experiment, but studies of humans confirm that nonconsumatory behaviors may be placed under schedule control in order to elicit adjunctive behavior.

Although the occurrence of schedule induced aggression has been reported in nursery school children following continuous reinforcement with pennies interspersed with time-out or extinction periods [22,24], there is doubt about whether the resultant behaviors can be regarded as schedule induced since these experiments show the same shortcomings as the animal studies on aggression discussed in the previous section. In the first study of adjunctive behavior in adult humans [28], hospitalised schizophrenic patients were required to pull a string to earn pennies [1], FI 60 and other longer schedules. They were tested in a small room which contained nothing but a drinking fountain and the penny dispensing unit. All subjects developed various adjunctive behaviors including pacing, polydipsia, and idiosyncratic behaviors. It has been demonstrated that psycho-geriatric patients tested under the same conditions produce similar adjunctive and idiosyncratic behaviors [32]. In the first experiment reported to date with normal adults [60] a computer console was used to simulate a jackpot machine and subjects were tested on FI 5 and FI 60 schedules. Some subjects consumed large amounts of soft drink and cheezels, and all showed a considerable rise in overall activity on the FI 60 schedule. On some occasions bizarre behaviors occurred. Baselines in this case were a half-hour FI 5 session and a listening session, when subjects heard a tape recording of a scientific meeting. Other observations from our laboratory with normal adult humans suggest that with some other schedule controlled tasks, adjunctive behaviors will also occur. We have found that solving a maze (where access is permitted for 8 secs on FI 60 or longer) is more successful in producing adjunctive behaviors such as fiddling, tapping and doodling, than when 10 second bursts of peddling an exercise bicycle are used as the schedule controlled behavior. With the use of 3 schedules (FI 60, FI 120 and FI 300) the frequency of adjunctive behavior was found to increase as a function of schedule interval [59] – this was previously shown only with regard to schedule induced drinking [18].

Since humans have an enormous repertoire of responses, and society provides a variety of schedules, it is not unlikely that a considerable amount of human behavior occurring outside the laboratory is adjunctive. There may be differences in schedule induced behaviors resulting from the influence of cultural norms; for example, it may be permitted to scratch in one society, but not another. Humans do emit nonregulatory behavior such as peanut eating and cigarette puffing and it has already been suggested that a clever bar tender could ration small titbits to induce polydipsia [61]. Other situations where adjunctive behaviors might be expected are in piece work, driving in traffic, monitoring tasks where an event is regular but infrequent, and so on. It may be of value to conduct field research in some of these areas, both from the point of view of the behavioral scientist and the worker. A problem for this kind of research is that humans may be subject to several overlapping, concurrent schedules.

This raises the general question of how much variability is to be expected in schedule induced behaviors, and what criteria might be used to distinguish them from other behaviors which may appear similar. A distinction in terms of inducing conditions is probably the easiest to apply and here it seems that an important characteristic is whether the behavior occurs only in response to a specific range of schedules; that is, whether the schedule induced behavior disappears when the same schedule controlled behavior is increased or decreased in frequency. This, by definition, would exclude extinction produced behaviors.

Research into the relative frequency of various schedule induced behaviors in the presence of a range of environmental stimuli has not been systematically pursued. Polydipsia may occur in preference to wheel running but not food intake [31]. Other rats preferred chewing cellulose material lining the cage to drinking water [23]. This research may be complicated by the possibility that when several alternative stimuli are available, activity may be spread amongst them, thus making difficult the identification of an increase in schedule induced behavior over baseline. It would be interesting to know whether there is a different preference hierarchy for species other than the rat. Another question of interest is whether the hierarchy of adjunctive behaviors matches reinforcement strength, which can itself be independently determined.

In summary, polydipsia is not the only schedule induced behavior; nor are food-reinforced operants necessary to produce adjunctive behavior. Because of the variety of behaviors which may occur in either situation, it will not be an easy task to identify a lawful relationship between controlled and induced behaviors.

Brain Behavior Relationships

Although in the previous section it has been shown that a variety of adjunctive behaviors occur, pharmacological and brain-behavior studies have been confined to schedule

induced polydipsia. The reason for this is partly historical and partly pragmatic; historical since the early work largely concentrated on polydipsia and little recognition was given to other forms of behavior, and pragmatic since drinking behavior is a response which can be readily observed and distinguished from other activities. This may place some limitation on the interpretation of data which will be discussed later.

Recently brain-behavior relationships underlying drinking and eating have been studied extensively using a wide variety of techniques such as lesioning and electrical and chemical stimulation. The findings from these studies suggest that hypothalamic structures are involved in the regulation of deprivation induced eating and drinking. Studies using chemical stimulation of the hypothalamus have shown a reciprocal cholinergic-adrenergic interaction [54]. The findings are illustrated in Table 1.

It has already been pointed out that schedule induced drinking differs from deprivation induced drinking with regard to quantity and temporal patterns. It is therefore of interest to examine the differences in anatomical and pharmacological variables involved in these two types of drinking behavior. In this section of the paper, evidence of the effects on schedule induced polydipsia of peripherally and centrally administered drugs will be reviewed. To the authors' knowledge there are only two reports available which deal with the effects of lesions on schedule induced polydipsia. An early paper [13] reports that any lateral hypothalamic lesion will stop the acquisition and maintenance of polydipsia. Subsequent cannulation of a number of midbrain areas [5,53] have shown that this is not the case. Septal lesions have been reported to enhance schedule induced polydipsia and decrease an apparent palatability-related inhibitory effect on drinking [63]. No systematic exploration of the effects of lesioning on both acquisition and maintenance of this behavior has been carried out, and anatomical locations studied in electrical and chemical stimulation experiments are few.

Since schedule induced polydipsia has both an eating and a drinking component, the pharmacological agents which seem most relevant to the comparison of regulatory and nonregulatory drinking are compounds related to cholinergic and adrenergic functioning. Amphetamine which leads to a net increase in synaptic norepinephrine was reported to increase bar-pressing, but decreased water intake when administered intraperitoneally (IP) [50]. Another study [49] showed that amphetamine increased the rate of operant licking but the high rate of polydipsic licking decreased in duration and regularity.Data on amphetamine are difficult to explain since amphetamine depresses both deprivation induced drinking and eating, and increases stereotyped activity [45]. Intraperitoneal injections of the muscarinic blocking agents, atropine sulphate and atropine methyl nitrate, reduced schedule induced polydipsia [3]. However, since atropine in the form of methyl nitrate does not cross the blood brain barrier, both a peripheral and central site of drug action may be involved. In particular, changes in salivation resulting from atropine administration may affect the water intake. Trihexyphenidyl, another muscarinic blocker which causes less salivation when injected IP, was reported to reduce water intake [30].

When both salts of atropine were injected into either the lateral hypothalamic or lateral preoptic area, schedule

TABLE 1

CHOLINERGIC/ADRENERGIC STIMULATION EFFECTS ON DEP RIVATION STATES

State of Deprivation	Central Chemical Stimulation	Behavioral Effects
Water	Cholinergic agonist (carbachol)	increased drinking
Water	Cholinergic antagonist (atropine)	decreased drinking
Water	Adrenergic agonist (noradrenaline)	decreased drinking
Water	Adrenergic antagonist (phentolamine)	not tested
Food	Cholinergic agonist (carbachol)	decreased eating
Food	Cholinergic antagonist (atropine)	not tested
Food	Adrenergic agonist (noradrenaline)	increased eating
Food	Adrenergicnantagonist (phentolamine)	decreased eating

TABLE 2

CHOLINERGIC/ADRENERGIC STIMULATION EFFECTS ON AD-JUNCTIVE DRINKING

	Central chemical stimulation (LH)	Earpresses	Licks
Schedule Induced Polydipsia	Cholinergic agonist (carbachol 2 doses)	increases	increases
	Cholinergic antagonist (atropine 2 doses)	no change	no change
	Adrenergic agonist (noradrenaline)	no change	no change
	Adrenergic antagonist (phentolamine)	no change	no change

duced drinking was decreased [4]. Since both lick rate and bar pressing were affected it is possible that the high doses of atropine employed had a general sedating effect either directly in the brain or by way of diffusion into the peripheral nervous system. Lower doses of intra-hypothalamic atropine, although sufficiently high to block deprivation induced drinking, had no effect on licking or bar pressing in polydipsic rats [53] which is in contradiction to the earlier findings [4]. Carbachol increased both forms of drinking and did not change the typical schedule induced licking pattern [53]. A dose response curve for three doses of norepinephrine (72, 216, 846 $\times$ 10^{-4} m) injected into the same hypothalamic area showed no effects on schedule induced drinking but the highest dose of norepinephrine blocked deprivation induced drinking. Results of cholinergic/adrenergic effects on schedule induced drinking are summarised in Table 2.

These data seem to indicate that the two forms of drinking behavior may be regulated by different biochemical systems. However, this conclusion must remain tentative, since general activation and sedation effects may

have been involved and the central chemical stimulation studies were confined to one or two anatomical loci. To the extent that these conclusions are based on failure to reduce the frequency of a behavior, it is also possible that there is a quantitative difference in the intensity of these behaviors. Higher doses may be necessary to block schedule induced drinking, but higher doses have side effects which may mask other pharmacological actions. This latter point is illustrated by a report [65] that a low dose of IP amphetamine tended to enhance adjunctive licking and water consumption whereas higher doses decreased the same behavior.

A further difficulty in the interpretation of these data arises from the fact that although certain drugs are capable of reducing the licking response this may only be a limited effect similar to the removal of the water tube [9] and that other behaviors may displace drinking. So far there is a lack of data to show whether the pharmacological agents used are involved in localised blocking or in decreasing generalised motor activity. In future experiments this question should be given serious consideration by providing for the measurement of other behaviors.

Alcohol

Naive rats or monkeys normally consume ethyl alcohol (ETOH) with some reluctance unless it is specially flavored. Schedule induced alcohol polydipsia provides a model of voluntary intake of alcohol suitable for the study of addiction and withdrawal symptoms. Rats will in fact drink copious quantitites of alcohol on a FI 60 sec schedule when alcohol is substituted for water [20]. A study using four concentrations ranging from 2.5%–10% [38] found an inverse relationship between fluid consumption and alcohol concentration [46]. Intakes of up to 13.1 g of ethanol per kilogram body weight daily have been reported [20]. With the removal of ethanol the rats displayed withdrawal symptoms, and in some animals death resulted from tonic-clonic seizures. These experimenters claim that the combination of over-indulgence in oral self administration combined with physical dependence approximates a model of human alcoholism. Other investigators report that the alcohol polydipsia produced in the Skinner box training was not maintained in the home cage in a free choice preference situation with water [51]. Thus, it has not yet been shown that the animal relieves the withdrawal symptoms with alcohol consumption [42]. It appears therefore that physical dependence and alcohol intake behavior can be clearly distinguished in animals like the white rat. Similar data for monkeys are reported in a study which succeeded in getting monkeys on a slow response schedule (VI I-DRL 20) to drink 5% ETOH in large quantities to an effective dose of 3 mg kilogram body weight [38]. After ten months, no change in the preference-aversion function for alcohol was observed, nor was the dose high enough to produce withdrawal symptoms. In general, while the studies cited here have provided a physical addiction model resulting from voluntary intake of alcohol which at least is applicable to the white rat, it has been demonstrated [19] that other methods such as substituting alcohol for water during a daily feeding session or replacing water with alcohol as the reinforcement in a Skinner box can also be used to establish excessive ethanol consumption with the same addiction pattern [37]. It has also been shown that rats can be induced to drink large doses of morphine (H Cl or SO_4) or methadone using the method of schedule induced drinking and become physically dependent on narcotics [35]. An interesting relationship has been shown between schedule induced drinking and the effects of IP injection of either Δ^9-tetrahydrocannabinol or ethyl alcohol [64]. Low doses of both drugs increased schedule induced drinking and high doses had no effect. This increase was more pronounced with animals on a schedule requiring a low response rate, suggesting that in some cases rats may reach an activity ceiling when polydipsic. It was suggested that these drugs as well as electrical stimulation act on sodium sensitive cells in the lateral hypothalamus and that they can enhance the positive feedback in the lateral hypothalamic mediated motor control system by the facilitation of the same mechanism which initially generated the behavior [64].

THEORETICAL CONSIDERATIONS

Despite the considerable amount of research which has been carried out on schedule induced behavior in the last fifteen years, attempts to account for the data in theoretical terms have been concerned with fitting it into frameworks such as emotional pacification [18], prandial drinking [57] and adventitious reinforcement [57]. As discussed earlier, valid arguments have been advanced to refute these explanations [18] and in addition, in most cases there are some experimental data which do not fit the explanation. On the other hand a model of consumatory behavior has been proposed which will account for both deprivation induced drinking, schedule induced polydipsia [61,62], and other adjunctive behaviors. This general activation theory has no difficulty in accounting for the data but falls short by not allowing precise prediction in relation to issues raised in the present paper. The theory will be briefly presented before these questions are discussed in the final section of this paper.

A General Activation Theory

The theory is based on a careful analysis of the behaviors which can occur prior to water intake and the analysis suggests that there is a general activation of the rat at the time of drinking. There is evidence that both electrical stimulation and physiological imbalances arising from deprivation are capable of increasing spinal reflex excitability which in turn results in an increase in readiness to respond. The level of activity is further increased by the occurrence of a response and the internal feedback from this response, as well as by external stimuli reaching the organism through all sense modalities. "Reinforcement during intermittent schedules not only increases the probability of the preceding response upon which the reinforcement is contingent but also increases momentarily the probability of all potential responses which might follow the reinforcement; that is, evoked by the available environmental stimuli. Therefore, the frequency of such motor acts as grooming, rearing, sniffing, running etc should increase following reinforcement on an intermittent schedule." ([61], p. 1321). Since the responses associated with delivery and ingestion of the pellet are brief, a schedule which generates only widely spaced responses also allows other behaviors to occur. The reinforcement associated with the food pellet has an arousal effect comparable to the excitation following electrical stimulation of the lateral hypothalamus. This excitation outlasts the consumatory response and other

responses occur. It is further suggested that the lateral hypothalamus is involved in the integration of the signals which give rise to this increased excitability. This account is plausible since the hypothalamus is one of few regions of the brain in which both afferent and efferent control mechanisms for the same type of behavior have the same locus. Further support for this position comes from the fact that electrical stimulation of the lateral hypothalamus can be substituted for pellet delivery in polydipsic drinking [66].

The theory is consistent with the data presented in this and earlier reviews. Increased motor excitability is generated by a variety of schedules and this results in increased responding to available stimuli. The theory does not attempt to differentiate between deprivation induced and schedule induced behavior. However, schedules, when combined with body weight reduction, produce quantitatively more activity than deprivation alone. Although in the statement of the theory the example of increased excitation due to food deprivation is used, causes of excitation are not restricted to this factor. This is important because schedules which do not control food consumption also generate adjunctive behavior. When a salient stimulus such as the drinking tube is removed the organism responds at a very high rate to other stimuli [9]. The fact that intermittent electrical stimulation of the lateral hypothalamus leads to adjunctive behavior supports the postulated role of the hypothalamus in schedule induced excitation of neuronal pathways. Another fact consistent with the involvement of the hypothalamus is the finding that chemical stimulation of the lateral hypothalamus can block adjunctive behavior, although larger doses of norepinephrine seem to be required than are necessary to block deprivation induced drinking. This also agrees with the observation that a schedule plus deprivation generates more activity than deprivation alone.

Many questions remain unanswered and require further research. Some of these are listed below:

(1) What behaviors under schedule control will lead to adjunctive behavior? So far these range from food delivery to opportunities for cognitive activities. There is as yet no evidence for a limitation on the type of response which can be schedule controlled. The general activation theory is too broad in its conception to give a precise answer to this question. The prediction from this theory would be that any response which the organism is capable of producing can be either schedule controlled or schedule induced.

(2) Is there some basic relationship between schedule induced and schedule controlled behavior? It has been shown that while schedule controlled eating induces drinking or running [48], scheduled drinking induced running but not eating [31]. Are there some behaviors more closely linked and are these dependent on the past experience of the organism or are they genetically determined and perhaps species specific? It is possible that there is an inhibitory relationship for certain sequences, for example, drinking may follow eating but not vice versa. The theory does not preclude the possibility that there are some specific basic relationships and allows predictions in this regard in terms of possible, yet to be discovered, specific neural connections in the lateral hypothalamus.

(3) Are there some parameters of schedule induced behavior which are species specific other than those related to the response capacity of the species? For instance, are there optimally effective time intervals for various species and are members of some species able to produce entirely self-induced schedules?

The wider question of species universality cannot be answered until an instance of nonoccurrence of this behavior is found in one species. The theory would predict that any organism which is capable of different levels of excitation mediated by hypothalamic mechanisms is capable of showing adjunctive behavior.

GENERAL DISCUSSION

Data from studies reviewed in this paper show that adjunctive behaviors produced by organisms on schedules which require a low number of responses cannot be explained either in terms of learning theory or as part of homeostatic functioning. It has been proposed that adjunctive behavior is the result of a general motor activation of the organism. The indications at this stage are that a schedule of appropriate inter-trial interval duration is a necessary condition for the occurrence of these behaviors.

There is a difference in drug effects on schedule induced behaviors when compared with similar behaviors which have been induced through deprivation conditions. These data can be interpreted as evidence of a quantitative difference between adjunctive and deprivation induced drinking or alternately as evidence that the behaviors are regulated by different biochemical systems. The general activation theory would favor an interpretation of the drug effects as differences in the level of excitation of the same motor pathways involved in deprivation and schedule induced drinking.

The work on the special pharmacological role of alcohol and cannabis [64] supports the suggestion [10] that schedule induced or adjunctive behavior may be helpful in the explanation of drug dependent behavior. It is also possible that closer study of schedule induced behavior will enable differentiation between behavioral (psychological) and physical dependence on drugs. The work on alcohol discussed earlier would indicate that the schedule induced intake of alcohol is similar to psychological addiction. There may therefore be less need to postulate sociological factors as the sole explanation of the maintenance of psychological dependence.

Finally, schedule induced behavior may provide a new animal model for the direct testing of psychoactive drugs. The phenomenon of schedule induced behavior appears to occur in a wider variety of species than any other test behavior used in pharmacological work so far; therefore the animal model may provide a more direct comparison between species. Furthermore, symptoms such as depression which are controlled by psychoactive drugs, and behaviors (often considered bizarre) which are emitted after the use of psychoactive drugs are similar to schedule induced behaviors in that they appear to be nonregulatory in relation to the organism's adaptation to the environment. It may be possible to use this model to test the effect of drugs on similar behaviors in the animal laboratory, the human laboratory and the clinic. Such a program adds at least one new factor to a drug testing paradigm.

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