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AN ANALYSIS OF BEHAVIOR ACQUISITION AND MAINTENANCE WITH
CONDITIONED REINFORCERS DEVELOPED THROUGH PAIRING

by

Marion M. Walton, Jr.

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Doctor of Philosophy

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Marion M. Walton, Jr.

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INTRODUCTION

A conditioned reinforcer¹ is a previously neutral stimulus which, after association with an unconditioned reinforcer² or an already effective reinforcer,³ will strengthen an operant response which it follows, or will maintain it or change its response pattern in ways similar to that of an already effective reinforcer. Stimuli which function as reinforcers prior to association with other effective reinforcers are considered as unconditioned reinforcers rather than conditioned reinforcers, and are not the object of investigation here.

The basic operations required to establish conditioned reinforcers are still unclear despite much research on the topic. Stated another way, in terms of specific operations, the meaning of the words "association with" in the first sentence above is controversial. Two hypotheses, one based upon temporal contiguity with an effective reinforcer--the pairing hypothesis--and one based upon initial discrimination learning--the discriminative stimulus hypothesis--are most frequently advanced as stipulating the necessary and/or sufficient

¹This term is synonymous with learned reinforcer, acquired reinforcer, and secondary reinforcer.

²This term is synonymous with primary reinforcer and unlearned reinforcer.

³An "already effective reinforcer" is one which acts as a reinforcing consequence, strengthening an operant response which precedes it; its strengthening effects derive from its unconditioned reinforcing properties and/or its reinforcing properties which have been acquired through prior association with another already effective reinforcer.

conditions, or set of historical relationships, for establishing a previously neutral stimulus as a conditioned reinforcer or punisher.⁴

The purposes of this paper are 1) to review and analyze the literature dealing with the pairing hypothesis as it relates to positive conditioned reinforcers; 2) to report the results of six experiments which expand the body of information surrounding the pairing hypothesis by testing for conditioned reinforcing effects using pairing procedures theoretically designed to be conducive to success; 3) to relate the results of these studies to other experimental evidence available at this time; 4) to suggest theoretical interpretations based upon the body of information surveyed, and to describe experimental procedures for evaluating them; and finally, 5) to provide tentative recommendations for the use of conditioned reinforcers in human settings based upon current information.

Overview of Introduction

The two basic hypotheses concerning the development of conditioned reinforcers will be described. Several experimenters who support the basic discriminative stimulus (S^D) hypothesis explain the crucial stimulus-response relationships which are involved in different terms, and three such views will be presented in the S^D description. Then studies which support the pairing hypothesis will

⁴Conditioned punishers, which derive their response weakening properties from association with effective punishers, will be treated only as the analysis of conditioned reinforcers requires.

be described. These supportive studies will then be criticized in terms of research evidence which questions the efficacy of the pairing hypothesis. Often such contradictory studies also provide support for the S^D procedure; thus, much of the evidence in support of the S^D hypothesis will appear in the criticisms of supportive pairing studies. The studies supportive of the discriminative stimulus procedure are also criticized. Concluding remarks will indicate those studies whose results, in the opinion of the author, continue to be favorable to the pairing hypothesis despite critical review; evaluation of the procedures used in these studies will provide the experimental rationale for the experiments to be reported here.

Two Alternative Hypotheses

What is the nature of the association between the previously neutral stimulus and the unconditioned reinforcer which will endow the neutral stimulus with conditioned reinforcing properties? The pairing hypothesis (Skinner, 1938; Hull, 1943; Kelleher and Gollub, 1962) suggests that a previously neutral stimulus will acquire reinforcing properties as a result of temporal pairings of the neutral stimulus and unconditioned reinforcer. The pairing procedure was first described by Pavlov (1927), who rang a bell at the same time meat powder was placed in the mouth of a food-deprived dog. Prior to pairing, the sound of the bell produced no consistent response, while meat powder in the mouth produced salivation. After several pairings, the sound of the bell alone elicited salivation. The pairing hypothesis suggests that such temporally contiguous associations

of neutral stimulus and unconditioned reinforcer are sufficient to establish the neutral stimulus as a conditioned reinforcer. It should be noted that this description implies periods of time during which both neutral stimulus and unconditioned reinforcer are absent. In addition, the unconditioned reinforcer does not occur in the absence of the neutral stimulus (see Rescorla, 1967). In the Pavlovian experiment, the bell should have acquired response-strengthening properties since meat powder delivered contingently is an unconditioned reinforcer.

The discriminative stimulus hypothesis described by Skinner (1938) and later developed by Keller and Schoenfeld (1950) states that in order to serve as a conditioned reinforcer the neutral stimulus must first be established as an S^D which reliably controls an operant response. In other words, unless the dogs in Pavlov's experiment made an operant response in addition to the reflexive salivation response in the presence of the bell, the bell would not function as a reinforcer.⁵ In the usual S^D training situation, the experimenter (E) requires a specific response after the neutral stimulus appears and before the unconditioned reinforcer can occur. Stimulus contiguity between the neutral stimulus and the unconditioned reinforcer is also an integral part of the usual S^D procedure;

⁵The distinction between operant and respondent behavior has been questioned by Perkins (1968), among others; Perkins argues that inherent contingencies exist in the respondent conditioning paradigm in that conditioned responses maximize the positive effects and minimize the aversive effects of unconditioned stimuli. They are thus capable of being controlled by consequences, an operant characteristic.

however, the S^D procedure differs from pairing in that once the neutral stimulus appears, it usually remains present until the E-required response occurs, which initiates the reinforcement sequence and thus pairs the neutral stimulus with the unconditioned reinforcer. The laboratory training procedure also specifies periods during which the neutral stimulus is not present and responses have no effect. The symbol S^Δ will be used to represent discriminated situations in which an unconditioned reinforcer does not occur following the specified response. Differential responding in the presence of S^D and S^Δ is the requirement for the neutral stimulus to be classified as an S^D . According to the S^D hypothesis, once a neutral stimulus functions as an S^D , it will also function as a reinforcing consequence.

Three alternative explanations of conditioned reinforcement, all based upon the S^D procedure, will appear later. Briefly, Baum (1973) suggested that a neutral stimulus will serve as a conditioned reinforcer once it has begun to serve as a signal of situation transition from a less valued to a more valued state, condition or circumstance for the organism. A reinforcing transition would be a change from one condition to a second which provided more positive consequences and/or less aversive ones than the first. Schuster (1969) proposed that the response strengthening effects of a stimulus are related to the conditions of primary reinforcement with which the stimulus is differentially related, and, parenthetically, which controls some behavior of the organism. Attention has been described as a response

and could therefore qualify as behavior in this respect.⁶ Fantino (1977) proposed that the strength of a conditioned reinforcer varies directly with the reduction in delay to primary reinforcement which it signals. Common to all three explanations, and to the general ^D S procedure, is an hypothesis of conditioned reinforcement based upon prior discrimination learning; the transformation of the neutral stimulus into a reinforcer is not assumed. The pairing hypothesis, on the other hand, suggests that "...the reinforcing property of a stimulus [the unconditioned reinforcer] is supposed to be transferred to an arbitrary stimulus [the neutral stimulus] , after which the arbitrary stimulus can be used to reinforce responding." (Schuster, 1969, p. 193)⁷

⁶We conversationally use the phrase "attention to a stimulus" and speak of an organism "attending to a stimulus" when the more technical expression is "a stimulus which controls some behavior of the organism." Attention is the relationship between a stimulus and a particular response established through discrimination training. Skinner defines attention as "...a relation--the relation between a response and a discriminative stimulus. When someone is paying attention he is under special control of a stimulus." (Skinner, 1953, p. 123) The control by that particular stimulus he explains in another publication: "We discern the important things in a given setting because of past contingencies in which they have been important." (Skinner, 1974, p. 106) Thus a particular response made either toward a stimulus or in its presence is explained by the organism's past history of reinforcement with respect to behavior emitted in the presence of that stimulus, and attending to an environmental event is one category of such stimulus-response relationships which is established and maintained by its consequences.

⁷Schuster contrasts the two approaches to explaining conditioned reinforcement, descriptive versus transformational, this way: "When analyzing the effects of discriminative stimuli on subsequent responding, the two factor model (Mowrer, 1960) is not used; that is, the stimuli are not endowed with any eliciting power corresponding to the reinforcing power ascribed to conditioned reinforcers, even though both kinds of stimuli derive their effects from association with a primary reinforcer."

Keller and Schoenfeld (1950) were the first to question the efficiency of the pairing procedure; they recommended the S^D procedure as necessary and sufficient to establish conditioned reinforcers. Admitting that all the evidence was not available yet, they cited three experiments which supported their position. Schoenfeld, Antonitis and Bersh (1950) showed that a stimulus paired with food pellet consumption--the neutral stimulus was a 1 sec illumination of a light which occurred after the rat had begun eating the pellet--would not support lever pressing in a test which followed. The light, a 12-16 V., 2-A. indicator lamp (GE1487) was located 6 inches above the food tray. Apparently, laboratory lighting provided general illumination to the chamber through a wire ceiling. It should be noted that conditions favoring the rat's attending to the neutral stimulus were not present; he was food-deprived and engaged in eating when the light flash occurred. Notterman (1950) demonstrated that the more discrimination training subjects received, the more strongly the S^D functioned as a conditioned reinforcer. During extinction, traversing a runway resulted in a brief presentation of the previously established S^D , and the average trial speed for various groups varied directly with the number of discrimination training trials. Finally, Dinsmoor (1950) showed that once an S^D was established, it would support an identical rate of responding in extinction whether it was presented following a

Instead the analysis of discriminative stimuli is entirely descriptive and functional. A discriminative stimulus is said to control responding because of, and appropriate to, the reinforcement contingencies that are cued by the stimulus (Terrace, 1966)." (Schuster, 1969, p. 194)

response as a conditioned reinforcer, or prior to a response as an S^D . In summary, these three studies suggested that pairing was not effective in establishing conditioned reinforcers, and that conditioned reinforcer effectiveness was directly related to prior discrimination learning.

Tests of the Pairing Hypothesis

A number of different experimental procedures provide evidence bearing upon the efficacy of the pairing hypothesis. They can be separated into two broad categories, depending upon how the test for the effectiveness of the conditioned reinforcer is accomplished. In extinction testing, only the potential conditioned reinforcer is presented following some designated response, with the number of responses in extinction accepted as a measure of the reinforcing strength of the stimulus. Once the extinction test has begun, no further pairings occur because unconditioned reinforcer presentations are discontinued, and responding eventually ceases. The other testing arrangement, the behavior maintenance procedure, evaluates the conditioned reinforcing strength of a stimulus in a situation in which responding is maintained through unconditioned reinforcer presentations. Since unconditioned reinforcers are scheduled, the continued association of the neutral stimulus and the unconditioned reinforcer can also be arranged. When a potential conditioned reinforcer is programmed in a setting in which unconditioned reinforcers maintain overall responding, conditioned reinforcer testing can occur indefinitely. When the extinction procedure is used, however, all responding eventually ceases, preventing

the assessment of durable conditioned reinforcer effects.

Tests During Extinction

Bersh (1951) investigated the relationship between the number of neutral stimulus-unconditioned reinforcer pairings and the strength of the conditioned reinforcer developed through such pairings. Once rats had pressed a lever and received varying numbers of neutral stimulus-unconditioned reinforcer pairings--a lever press was followed by a 3 sec light, with food pellet presentation occurring 1 sec after light onset--all consequences for lever pressing were removed, and responding eventually ceased for all subjects. The test phase of the experiment followed in which a 1 sec light was presented following each lever press; groups which had received more light-food pairings emitted more responses during the test. Thus the number of pairings was directly related to conditioned reinforcer strength as measured by the number of responses emitted during the test, and the effectiveness of pairing in establishing conditioned reinforcers was argued.

A number of problems follow from this interpretation of the results. The light flashes could have increased the similarity between the test situation and the preceding pairing condition, thereby contributing to increased responding in the test. For groups receiving more light-food pairings, the test situation would be more similar to the pairing setting, and they would thus emit more responses. A frustrative non-reward effect (Amsel and Roussel, 1952) is a possibility: frustration due to withdrawal of reinforcement could

result in increased responding. Similarly, increased general activity in the presence of a food-related stimulus has been observed (Gilbert and Sturdivant, 1958), and may account for the results. Finally, Fantino's (1977) "confusion" argument applies; it relates responding in extinction tests to the subject's "failure to discriminate" the neutral stimulus from neutral stimulus-unconditioned reinforcer sequences. This argument will be explained more fully below.

A Skinner (1938) study exemplifies an extinction test procedure termed the new response method; its advantage is that if the test of the neutral stimulus involves a new response, appeals to situation similarly resulting in test behavior similar to that of the pairing condition lose their significance. In the first condition of Skinner's experiment, rats received periodic food pellet deliveries in a chamber containing a disconnected lever. After all subjects were reliably approaching the food dish only when the food dispenser sound occurred, the lever was connected and responses resulted in the sounds of the operating food dispenser. However, the pellets had been removed from the dispenser and no food followed the sounds. Responding was considerably higher than responding when no consequences were scheduled, and Skinner concluded that the dispenser sounds functioned as a conditioned reinforcer in strengthening lever pressing.

An activity increase produced by the food-paired noises could account for increased general behavior and thus increased lever pressing. In addition, the "confusion" argument mentioned above also pertains here. It should be noted that while the procedure used in this experiment is called a pairing procedure with respect to the experimenter's

arrangement of the events, discrimination learning actually occurred; the sound of the dispenser served as an S^D , immediately after which an approach to the food dish would result in the rat's obtaining a pellet. This exposure to S^D training provides the conditions necessary for the noise of the dispenser to be "difficult to distinguish" from food arrival. (Fantino, 1977) Responding will continue in extinction, according to this view, until such "confusion" is replaced with a new discrimination of the S^Δ characteristics of the situation with respect to food. The eventual cessation of responding which occurs in extinction testing is consistent with this "confusion" explanation.

Kelleher (1961) trained pigeons to peck a key with grain delivery occurring on the first keypeck following each fixed interval of 5 minutes (FI - 5 min). Then during extinction with respect to food, brief grain hopper operation sounds were programmed either after a fixed number of responses (FR) or after a period without a response (DRO). Rapid responding occurred during the FR-scheduled hopper sounds, while low rates characterized the DRO condition. The increased activity argument does not account for the DRO behavior, and neither pattern of responding was similar to that during the initial FI schedule. Alternative explanations of responding in the test which appeal to generalized responding and to increased activity are thus weakened by these results.⁸

Although this study's results tended to minimize the likelihood

⁸The above survey of conditioned reinforcer tests in extinction relies heavily upon Nevin (1973), pp. 156-164.

of the two alternative explanations mentioned above, Fantino's "confusion" argument pertains equally strongly to the Kelleher results. As long as hopper sounds and food presentations control similar behavior--for example orientation to the hopper, hopper approach, and/or attention to the hopper noises--the bird's keypeck responding would be controlled by whatever schedule of hopper sound presentation is in effect.⁹

One of the strong criticisms of all the above-mentioned studies is that an E-required response is not the only response which can occur in the presence of the neutral stimulus. If any response emitted in the presence of the neutral stimulus is strengthened by the unconditioned reinforcer, discrimination learning has occurred even though it was not required by E. Whenever the organism must obtain the unconditioned reinforcer himself, movements to the unconditioned reinforcer only when it is available eliminates wasted food-search effort and also reduces the delay in obtaining it, both of which should strengthen any response which produces them. The Skinner (1938) study mentioned above is a case in point: approaches to the food dish reliably occurred immediately after the noises associated with food dispenser operation, not before.

Recognizing these potential confounding operations, Stein (1958) scheduled neutral stimulus-unconditioned reinforcer pairings

⁹The expression "as long as hopper sounds and food presentations control similar behavior" is often stated more conversationally as "if the bird cannot distinguish hopper sounds from food".

with unconditioned reinforcer delivery independent of the subject's behavior. Electrical stimulation to the brain (ESB) was used as the unconditioned reinforcer so that deliveries could be arranged without any approach or consummatory behavior required by the organism. After pairings were completed, Stein found that the neutral stimulus, a 0.5 sec tone, served as a conditioned reinforcer--a lever press was strengthened when only the tone served as the consequence--for those rats which, in a later phase of the experiment, maintained lever press responding when brain stimulation followed each response. In other words, when the implant stimulated an area of the brain which functioned as a reinforcer for the rat, the tone which was paired with those stimulations functioned alone as a conditioned reinforcer.

That Stein was attempting to minimize the possibility of an S^D interpretation of his results is clear in the following statement:

The operations that imparted secondary reinforcing properties to the tone in the study described in this report (that is, the pairings with brain shock) did not provide, at the same time, the conditions favorable to its development as a discriminative stimulus. This is because the effective delivery of the brain-shock reward requires no (operant) response on the part of the animal, in contrast to conventional reward situations, which involve approaching and consummatory behavior. In a case such as this, it is hard to see how particular responses could have been selectively reinforced with brain shock in the presence of the tone to permit formation of a discrimination. (Stein, 1958, p. 467)

Although no operant responses were required during the neutral stimulus, they were not precluded. Any responding which began to occur regularly during the tone may have arranged events in the temporal sequence appropriate to discrimination learning. The fact that the experimental procedure does not require responses does not in any

way prevent them. This point will be developed further below.

Lovaas, Schaeffer and Simmons (1965) examined the question of establishing and maintaining conditioned consequences with twin 5 year old boys, both diagnosed as schizophrenic. Prior to the experiment, neither subject showed any responsiveness to other persons; self-stimulatory and tantrum behavior predominated. During one phase of this lengthy study, an attempt was made to develop the word "No" spoken by E as a conditioned punisher. Shock was administered to a subject immediately following the word "No" whenever a self-stimulatory or tantrum behavior occurred. A test was then conducted to determine if the word "No" had developed conditioned punishing properties. The subject had been taught to press a lever, every twentieth press of which resulted in the delivery of a small candy. The word "No" followed some lever presses toward the middle of each session; sessions were conducted both prior to and after the pairing of the word "No" and shock. "No" suppressed responding only after such pairings, demonstrating the acquisition by a neutral stimulus of conditioned punishing properties through pairing.

It could be argued that development of conditioned punishers through pairing of a neutral stimulus with electric shock is a qualitatively different process from that of producing conditioned reinforcers by pairing a neutral stimulus with an appetitive reinforcer. As unconditioned stimuli, shock and electrical stimulation to the brain are events different in kind from food reinforcement delivered to a food-deprived organism. Their presentation may affect more sub-systems of the organism, and such possible differences should be taken into

consideration when comparing the effectiveness of conditioned consequences. Another possible explanation, increased attention due to sensitization of the organism to environmental stimuli during the occurrence of certain unconditioned stimuli, will be developed later.

Finally, general criticisms of all extinction analyses of the conditioned reinforcing properties of a stimulus have been made by both Schuster and Fantino. Schuster (1969) argues that extinction testing is flawed because pairing failures can be attributed to the decay of conditioned reinforcer effectiveness which occurs following termination of the unconditioned reinforcer. Thus any test outcome, positive or negative, can be explained as being due to continued effectiveness of the conditioned reinforcer or its decay, thereby reducing the value of the test. Also, both the pairing and S^D hypotheses predict with equal accuracy the results of extinction tests, and of chained procedure tests to be discussed below, suggesting the need for a more discriminating test procedure. With respect to extinction tests, both procedures predict initial responding followed by gradual decline to pre-experimental levels. The pairing hypothesis attributes this decrease to a decay of the reinforcing properties of the stimulus resulting from discontinuation of pairing with the unconditioned reinforcer; the S^D hypothesis, on the other hand, predicts a decline in responding when the stimulus is no longer differentially related to the unconditioned reinforcer. A more adequate test of the two theories, according to Schuster, would isolate the potential conditioned reinforcer from all effects of the unconditioned reinforcer. In extinction tests the conditioned reinforcer appears in complete absence of

the unconditioned reinforcer--it predicts S^{Δ} with respect to the unconditioned reinforcer; in a chained schedule, as will be seen later, it is positively related to the forthcoming unconditioned reinforcer, and should maintain responding simply because of the contingent relationship involved.¹⁰ He therefore recommends a test which presents a previously neutral stimulus which at times is paired with the unconditioned reinforcer, but which is totally unrelated to that unconditioned reinforcer when presented as the potential conditioned reinforcer. The pairing hypothesis would predict the effectiveness of the stimulus as a conditioned reinforcer in this situation, while the S^D view of conditioned reinforcement would predict the opposite because the stimulus is not functionally related to reinforcement in any way. Prolonged maintenance of responding by an unconditioned reinforcer unrelated to the potential conditioned reinforcer permits the continued testing of the reinforcing properties of the stimulus, while the confounding effect of response maintenance due to a contingent relationship with the unconditioned reinforcer is minimized.

Fantino (1977) argues that responding is maintained by conditioned reinforcers in extinction until a discrimination is formed concerning the S^{Δ} condition with respect to the unconditioned reinforcer,

¹⁰A supporter of the S^D hypothesis may view the expression "simply because of this contingent relationship [between neutral stimulus and unconditioned reinforcer]" as the necessary requirement for establishing a conditioned reinforcer.

the only evidence of which would be cessation of responding.¹¹ Responding prior to that time is a result of "confusion", the "failure to discriminate" the S^Δ condition.

The powerful effects of shock in establishing a conditioned consequence through pairing are underscored by Lovaas, Freitag, Kinder, Rubenstein, Schaeffer and Simmons (1966). This study reported the failure to establish a conditioned reinforcer when a neutral stimulus was paired with food given to food-deprived schizophrenic twin boys. Food intake was restricted to the two daily (morning and afternoon) experimental sessions, with water freely available after 6:00 p.m. The word "Good" spoken by E was paired several hundred times with bites of food, and subsequent tests for conditioned reinforcing properties of the word were negative. The subjects did not seem to hear, attend to or respond to the word, in marked contrast to the successful conditioned punisher acquisition obtained via pairing a word with electric shock (Lovaas et al., 1965).

Then a discriminative stimulus procedure was initiated; after the word "Good" (plus a pat on the back for one subject) occurred,

¹¹This descriptive statement is often expressed more conversationally by a phrase such as "responding is maintained...until the subject discriminates the S^Δ condition with respect to the unconditioned reinforcer." This expression, however, suggests that the failure to discriminate or lack of discrimination by or in the subject somehow produces the continued responding. It also implies that as soon as the discrimination is made by the subject, this will cause him to stop responding. The words "is made" and "cause" suggest internal causation. However, the word "discrimination" is arbitrarily assigned to an observed relationship between stimuli and responses, and cannot be used as an explanatory variable without introducing circularity to the explanation.

an approach to E would result in a bite of food; approaches to E at all other times had no consequence. Both subjects eventually approached E only following the word "Good". The lever pressing test mentioned above was used to determine whether this S^D would also function as a conditioned reinforcer. Lever pressing was maintained by this stimulus, but only in sessions in which special discrimination training trials were conducted concurrently to maintain the strength of the conditioned reinforcer. In these special superimposed trials, after periods in which no lever press had occurred, "Good" signaled the availability of a bite of food if the subject (S) approached E. Thus if S consistently pressed the lever, he received the word "Good". If he did not press, occasionally the word "Good" signaled food if S approached E.

Conditions were then changed so that E provided food occasionally in a non-contingent fashion without the prior presentation of the S^D and subsequent approach response. The purpose of these trials was to extinguish the social stimulus as discriminative for food, and in these sessions lever pressing ceased. Reversals with both subjects demonstrated experimental control, and the authors stated that the most important operation in the experiment was the establishment of the social stimulus as a discriminative stimulus. They argued that this procedure forced the children to discriminate or attend to the stimulus, after which it could serve as a reinforcer. They also concluded that the conditioned reinforcing effects of a previously neutral stimulus would be maintained only in situations in which it continued to be discriminative for reinforcement:

It is likely that a discrimination between the two schedules (or behaviors) would eventually develop; i.e., the child would stop responding on the bar. The more difficult it was to make such a discrimination, the longer the effectiveness of the schedule combination should be maintained. In this particular study, efforts were made to make this discrimination difficult. (Lovaas et al., 1966, p. 125)

Lovaas et al. (1966) also discussed possible reasons for the failure of the pairing approach to endow a neutral stimulus with conditioned reinforcing properties when food served as the unconditioned stimulus, while such a pairing approach was successful (Lovaas et al., 1965) in establishing a conditioned punisher when electric shock was paired with the word "No". They suggest that the variable accounting for the different results might have been some aspects of the child's attention to the social stimulus. While the child may not have attended to the stimulus paired with food, shock may have increased his sensitivity to environmental stimuli. Work by Maltzman and Raskin (1965) is cited to support this hypothesis. They showed that persons displaying a quantitatively larger orienting reflex to a neutral stimulus learned faster in a classical conditioning paradigm than persons displaying a weaker orienting reflex.¹² In addition, Sokolov (1963) has shown that after an orienting reflex has been evoked by one stimulus, a second stimulus, previously not detected either behaviorally or physiologically by the subject, is detected in

¹²The orienting reflex was defined as follows: "Its antecedent condition is a change in stimulation, while its objective measures include depression of the cortical alpha rhythm, the galvanic skin response, pupillary dilation, and a complex vasomotor response consisting of cephalic vasodilation and peripheral vasoconstriction." (Maltzman and Raskin, 1965, p. 1)

the presence of the orienting reflex. Thus a pairing procedure which evokes an orienting reflex in a subject may provide the conditions necessary for the subject to attend to the neutral stimulus sufficiently for it to acquire conditioned strengthening or weakening properties. However, if pairing does not evoke the orienting reflex, this hypothesis would predict that some other procedure for obtaining attention to the neutral stimulus would be required. As was mentioned above, the authors felt that the discriminative stimulus procedure forced the children to discriminate or attend to the social stimulus. If this attention-response hypothesis is correct, it follows that any procedure including a pairing procedure which generates attention to a neutral stimulus would result in that stimulus acquiring conditioned properties, and measures of such attention to the neutral stimulus would predict, in advance of any empirical test, whether the stimulus would affect the operant response which produces it.

The authors suggest that normal children may acquire conditioned reinforcers through pairing procedures because they "...do discriminate (selectively attend to) social stimuli--probably on the basis of their histories of discrimination training with respect to these stimuli." (Lovaas et al., 1966, p. 123) One might say alternatively that an already effective S^D evokes a(n) (attending) response when it appears, and this response is followed by a reinforcing event. Thus pairing is the procedure which the experiment arranges, but discrimination learning actually occurs.

Steinman (1968) employed an S^D procedure with retarded children in an attempt to strengthen the reinforcing properties of verbal

approval, defined as the words "Good" and "Fine" spoken over an inter-com. Reinforcers were M&M candies which could be eaten at any time or exchanged for other items at the end of the session. When candies were presented after button presses only when they immediately followed the words "Good" and "Fine" uttered by the experimenter, four of the five subjects learned the discrimination: they responded only following the two words. These same four subjects also showed slight, temporary increases in responding over baseline rates when, after termination of discrimination training sessions, the words "Good" and "Fine" were presented following presses to an available lever as a test of their conditioned reinforcing strength. The fifth subject responded at the same rate throughout the discrimination training sessions, both in the presence of and absence of the S^D . The words did not function as discriminative stimuli. This subject showed no increase in lever-press responding when the verbal stimuli followed responding in the test. These results provide further evidence concerning the relationship between successful discrimination training and the conditioned reinforcing effectiveness of a previously neutral stimulus.

It should be noted at this point, however, that demonstrations of the success of the S^D procedure do not question the effectiveness of the pairing procedure. They simply show consistently that the stronger the S^D , the stronger its response-strengthening effects when presented as a consequence. While this is an important finding in its own right, it may simply illustrate that the more an organism attends to (responds to) the relationship between a neutral stimulus

and an unconditioned reinforcer, the greater the potential "confusion" at a later time when only the neutral stimulus follows responding. This in itself says nothing about the pairing hypothesis except to suggest the possibility of operant discrimination occurring during, though not required by, pairing operations when effective conditioned reinforcers are established.

In conclusion, all testing of conditioned reinforcer effectiveness in extinction is subject to the general criticisms of Schuster (1969) and of Fantino (1977). Fantino (1977) argues that higher rates of responding and larger numbers of responses occurring in extinction when responding produces the conditioned reinforcer are the result of a failure of a discrimination to form concerning the S^{Δ} situation with respect to the unconditioned reinforcer. For the organism, at the time of its appearance, the "conditioned reinforcer" is identical to the stimulus which had previously always preceded the unconditioned reinforcer. Responding is maintained, according to Fantino, until the subject discriminates that the neutral stimulus is no longer discriminative for the unconditioned reinforcer. Squires, Norborg and Fantino go so far as to say: "The utility of the concept of conditioned reinforcement lies in the prediction that an arbitrary stimulus may become a conditioned reinforcer. If only those stimuli that at the moment of presentation cannot be discriminated from primary reinforcement are effective, a separate concept of conditioned reinforcement is no longer required." (Squires, Norborg and Fantino, 1975, p. 170) Thus the usual pairing procedures do not permit the separation of the effects of historical discriminative stimulus

relationships from any response strengthening effects which may result solely from pairing. The subsequent results may therefore indicate the joint effects of pairing and discrimination learning.

Schuster (1969) argues that extinction testing is inadequate because pairing failures can be attributed to the rapid decay of weak conditioned reinforcer effects upon termination of the unconditioned reinforcers. Thus any test result obtained is explainable. Also, such test procedures yield results predictable with equal accuracy by both the pairing and S^D hypotheses. Each of these deficiencies renders the test procedure less scientifically acceptable.

In addition, the fact that no organismic response is required in the pairing procedure does not, as was argued earlier, rule out the possibility of a consistent response occurring during the neutral stimulus. The ease with which such (an) as yet undetected orienting or preparatory response(s) could occur should be recognized. The response could be strengthened by a positive enhancement of the effects of the unconditioned reinforcers or a reduction in the effects of an aversive stimulus. That this is possible is suggested by the work of Hutchinson (1977), who has shown that brief electric shocks presented on a fixed time basis generate a biting response during and immediately after shocks, and that later similar biting begins to occur in an anticipatory manner just prior to shock onset. The organism's biting response has obviously come under the control of temporal variables.

That responding prior to shock occurs in advance of stimulation reduces the possibility that it is reflexive; an operant view would

then suggest that some consequence of the response is serving to maintain it. In addition, biting involves striped muscular movements as opposed to the smooth muscle movements and glandular secretions generally accepted as implicating reflexive behavior. Given both the opportunity for their occurrence and the means of detecting them, Hutchinson (1977) also observed the initiation and maintenance of muscular movements, chain pulls and lever presses prior to the periodic shocks. He demonstrated that their occurrence and temporal patterns were modified by the withdrawal and reintroduction of the manipulandum which permitted biting, suggesting again their non-reflexive malleability. The hypothesis that another neutral environmental event preceding shock could control an "anticipatory" response is not unreasonable. It could even be asked whether such (a) response(s) is not likely given this situation: a food-deprived or non-shocked subject which begins to receive food or shock (or brain stimulation) intermittently. A previously neutral stimulus, perhaps very brief, serves as the only neutral stimulus which is reliably related to the unconditioned stimulus. Should a response be made in the presence of the neutral stimulus, discrimination learning could occur and any subsequent effects on a response by a neutral stimulus presented as a consequence could be the result of prior discrimination learning rather than simple pairing.

Although not explicitly advocating it, Nevin (1973) mentioned a contrasting pairing explanation based upon respondent processes. Portions of this position are presented below to highlight the experimental questions involved:

The possibility remains that it is not operant behavior under stimulus control that determines the effectiveness of conditioned reinforcement, but rather some respondents elicited by the unconditioned stimulus as a result of classical conditioning...To study the relations between classically conditioned respondents and conditioned reinforcement for operant behavior, it is necessary to make concurrent measures of both classes of behavior. Research of this sort has been reported... but no firm conclusions about conditioned reinforcement have emerged.

In connection with Stein's [1958] experiment, it is far from clear that one could isolate and measure respondent behavior elicited by the brain stimulation and conditioned to the tone. Brain shock does not usually elicit any obvious unconditioned responses, although Malmö (1965) has reported classical conditioning of heart-rate changes elicited by stimulation of the brain. It remains to be determined whether the strength of any single respondent conditioned to a stimulus paired with primary reinforcement can serve to predict the conditioned reinforcing effect of that stimulus. (Nevin, 1973, p. 188)

Whether the heart rate changes mentioned above, or similar behavior changes first elicited by an unconditioned stimulus, are entirely respondent in nature is the significant issue in question.

Finally, as discussed above, Lovaas et al. (1966) suggested the possibility that the presentation of certain powerful or salient stimuli can evoke an orienting reflex, in the presence of which attention responses to other environmental stimuli are more likely. Again the thrust of the argument was to suggest an S^D or operant reinforcement explanation of what has previously been accepted as an effect of pairing. The S^D procedure is so robust, they argued, because attention is not only possible but required. That normal children would acquire conditioned reinforcers through pairing would be a result of unrequired (by E) discrimination learning.

The criticisms levied at the use of extinction tests to evaluate

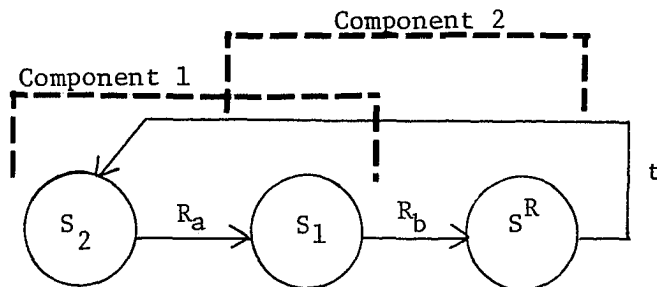
the conditioned reinforcing effects of stimuli produced through pairing suggests to the author the advisability of searching for other procedures with which to test the pairing hypothesis.

Behavior Maintenance Testing

The chaining procedure

In a chained schedule of reinforcement, the completion of two or more individual schedule components, each signaled by its own unique stimulus, is required before the unconditioned reinforcer is delivered. An example of a simple two-component chain may be diagrammed as follows:

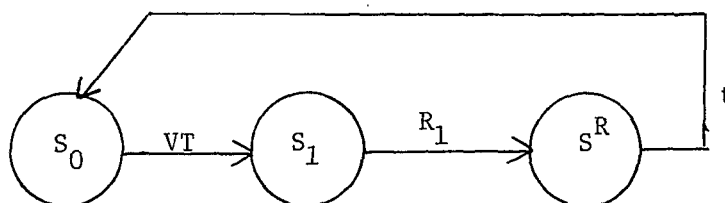
DIAGRAM 1



where S_2 and S_1 are the unique stimuli continuously present during their respective components, and R_a and R_b can be the same or different responses. Completion of the first component produces only the change from S_2 to S_1 , while responses in the presence of S_1 yield the unconditioned reinforcer, (S^R), which is scheduled for a definite

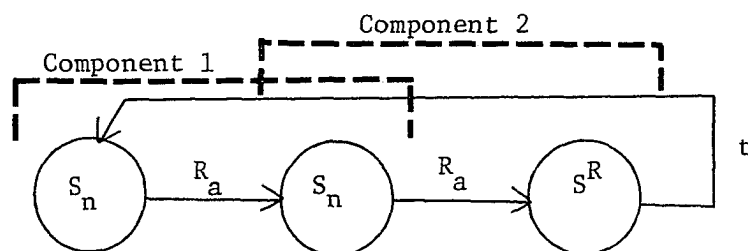
period of time (t), after which S_2 occurs. It should be noted that Diagram 1 represents a variation of the simple S^D training procedure which is presented below:

DIAGRAM 2



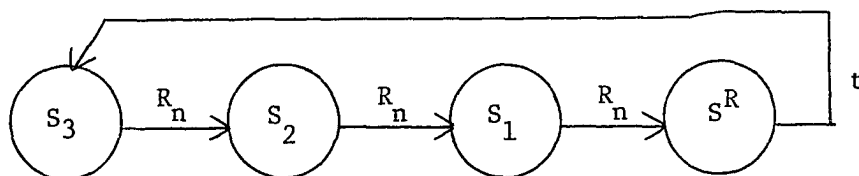
in which a specific response, R_1 , emitted in the presence of S_1 , yields the unconditioned reinforcer. In the absence of $S_1 - S_0$ in the diagram--reinforcement is not produced by any response. S_0 indicates any other possible stimulus situation except S_1 ; VT indicates that the change from S_0 to S_1 occurs after a variable period of time.

When Component 2 follows Component 1 in a simple chain, discrimination learning is evidenced by either the appropriate response topographies or by different rates and patterns of responding characteristic of different schedules of reinforcement associated with S_2 and S_1 . It has been argued that the stimulus change from S_2 to S_1 is a conditioned reinforcer since responding which produces S_1 is maintained in S_2 (Kelleher and Gollub, 1962). A tandem schedule control procedure has been used to demonstrate conditioned reinforcer development:

DIAGRAM 3

The same contingent relationships between responding and the unconditioned reinforcer exist in the tandem schedule as in the chained schedule, except that there is no stimulus change at the completion of the first component. Response rates are typically higher in the first component of the chained schedule than in the tandem, indicating that the stimulus change from S_2 to S_1 in Diagram 1 serves as a reinforcing consequence; and according to a pairing hypothesis, its reinforcing properties are said to result from S_1 's eventual pairing with the unconditioned reinforcer at chain completion.

It should be noted that the two-component chain can be lengthened to three components simply by requiring a response before S_2 is presented, as Diagram 4 indicates.

DIAGRAM 4

Pierrel and Sherman (1963) demonstrated that the extending of response sequences into complex behavior chains with the unconditioned reinforcer delayed until chain completion was possible in laboratory rats; an albino rat learned a 12-component chain which included such complex discriminated responses as pulling a toy car, peddling the car through a tunnel, raising a flag with a chain, and finally pressing a lever which delivered a food pellet into a dish which he approached and ate.

Schuster's (1969) previously mentioned criticism of extinction procedures, their failure to separate the neutral stimulus from any relationship with the unconditioned reinforcer, applies to chained schedules as well. Token reinforcement procedures (Cowles, 1937; Kelleher, 1958; Ayllon and Azrin, 1968) are subsumed under the chained schedule category since tokens are exchangeable for unconditioned reinforcers and these serve similar functions as S_2 and S_1 in Diagram 4: tokens are required before the unconditioned reinforcer can be obtained. This relationship between S_2 , S_1 and the unconditioned reinforcer in Diagram 4 and between tokens and the unconditioned reinforcer in token reinforcement settings prevents a separation of the role of the contingency from the question of whether pairing alone endows reinforcing properties to a neutral stimulus in chained schedules. An advocate of the S^D position could argue that the only reason S_2 and S_1 in Diagram 4 serve as conditioned reinforcers is that they have been related in a contingent fashion to an unconditioned reinforcer and have thereby developed control of some behavior of the organism. The unconditioned reinforcer occurs in no other circumstances than when

S_1 is present, and S_1 only occurs after S_2 . The chaining view of conditioned reinforcement and the more general S^D view maintain that prior discrimination learning, resulting from the contingent sequencing of stimulus changes which occur following required responses, accounts for the response strengthening and/or maintenance effects of all conditioned reinforcers. Higher rates occur in the first component of a 2-component chain simply because the contingency is more discriminable there than in the tandem control. A different procedure would be required to assess any conditioned reinforcing effects of S_2 and S_1 in Diagram 4 which are independent of those arising from the contingent requirements of the schedule.

Schuster recommends an alternative test situation for evaluating the conditioned reinforcing properties of a previously neutral stimulus, one "...in which a stimulus and a primary reinforcer are continually paired even though the stimulus is not a cue for reinforcement when it is programmed as a conditioned reinforcer." (Schuster, 1969, p. 196) A pairing hypothesis would predict that in such a test the "added stimulus" would function as a conditioned reinforcer, while an S^D analysis would suggest that if a discrimination forms with respect to the superfluous nature of the "added stimulus", that is, when it no longer controls similar responding as does the unconditioned reinforcer, its response-strengthening properties should decline to zero. The procedure and results of Schuster's test experiment will be described below. However, his criticisms concerning chained schedule tests of conditioned reinforcer effectiveness suggest to the present

author the advisability of searching for less questionable techniques for assessing the acquired reinforcing properties of a stimulus which are independent of responding required by schedule contingencies.

Concurrent schedules

Zimmerman's (1963) approach for testing the pairing hypothesis incorporated portions of the procedural requirements later suggested by Schuster. Zimmerman exposed pigeons to two concurrently available keys, each of which delivered its consequences on equal and independent variable-interval 3 minute schedules of reinforcement (VI - 3'). The consequence on one key was 4 sec of grain, while on the other key only stimuli associated with grain presentation were presented--grain hopper sounds, darkening of key lights and houselight, and illumination of the hopper opening. No feeding was possible on this stimulus-only key because the hopper operation was too brief, 0.5 sec. Under these conditions pecking on the stimulus-only key was maintained indefinitely at a rate approximately one-tenth that on the grain key. Subsequent control manipulations suggested that adventitious reinforcement following pecking on the stimulus-only key could not account for the responding there.¹³ The fact that responding was maintained on a key never associated with grain led Zimmerman to conclude that the consequent stimuli associated with responding on that key, hopper sounds, had acquired reinforcing properties. Indefinite maintenance argued

¹³Zimmerman later stated that it did not appear that the pigeons, who were observed through one-way mirrors, were inspecting the hopper opening when brief hopper presentations were delivered. (Reference Note 1)

against a "confusion" explanation, and constituted strong evidence in support of his contention. Subsequent work summarized by Zimmerman (1969) confirmed and extended these findings.

In a later study which is pertinent to the present report, Hanford and Zimmerman (1971) attempted to generalize the above findings to rats in an automated runway apparatus in which the subject initiated successive trials himself. The S was required to traverse the runway twice (FR-2) before the unconditioned reinforcer was delivered, with each run requiring a lever press for termination. The lever press ending the first run resulted in the signals associated with the opportunity to initiate another run. The second run's lever press initiated an unconditioned reinforcer, which was terminated by the reappearance of an opportunity-to-run signal. After running rates were stable, a brief presentation of all the stimuli associated with the unconditioned reinforcer occurred following lever presses terminating the first runs of each FR-2 schedule. Running times for first runs consistently decreased (the rats ran faster) to that of unconditioned reinforcer trials with the addition of these brief stimuli associated with food delivery, and the authors concluded: "These results, therefore, support the assertion that the continued pairing of stimuli with primary reinforcer is a sufficient condition, if not a necessary one, for the maintenance of the CR [conditioned reinforcer] strength of the stimuli." (Hanford and Zimmerman, 1971, p. 211)

Schuster (1969) argued that rate measures were poor indicators of whether a stimulus was in fact reinforcing. Citing Amsel and

Roussel (1952), he suggested that frustration due to non-reinforcement could account for Zimmerman's (1963) results; stimulus-only presentations repeatedly led to frustration and an increase in responding. Whether one should expect frustration effects of the kind proposed by Schuster to be maintained indefinitely is for the author a valid question. In any case, Schuster recommended choice measures to determine the reinforcing properties of various stimuli. Choice behavior would more clearly demonstrate which of two situations were more reinforcing, he argued, since an organism should choose to expose itself to the most favorable set of circumstances.

Thus Schuster recommended a test in which the neutral stimulus is paired with the unconditioned reinforcer but is not a cue predicting (systematically related to) the unconditioned reinforcer when presented alone in the test of its conditioned reinforcing effects. And since rate measures are suspect, a choice procedure should be included. To accomplish these ends, Schuster first exposed pigeons to a two-key, two-component multiple schedule; identical VI-30 sec schedules alternated on the two keys, each terminating in the presentation of a set of arbitrary stimuli paired with 5 sec of grain. In one component, the set of arbitrary stimuli was also produced by every eleventh key peck (FR-11), and rates on this "added stimulus" key were higher. Schuster argued that since response rates could increase for reasons other than reinforcement, rate comparisons alone were poor indicators of the reinforcing properties of the arbitrary stimulus package. He therefore presented the same pigeons with the two components

via a concurrent chains procedure,¹⁴ and seven of nine birds responded more frequently on the key in the initial component which was not associated with the terminal component containing the added stimulus presentations. On those occasions in which the added stimulus component did occur, however, response rates continued to be higher there than in the component without the added stimuli. The "avoidance" of the added stimuli when given a choice, Schuster argued, demonstrated that even though they generated higher rates, this did not indicate that they were in fact reinforcing.

Other researchers have criticized Schuster's interpretation of his results (Gollub, 1977; Fantino, 1977). They suggest that his choice data simply confirm the fact that animals will, if given the opportunity, avoid situations in which more effort is required for the same reinforcer. Thus Schuster may not have succeeded in his goal of arranging an uncontaminated choice situation, and his results cannot therefore be considered a refutation of the pairing hypothesis. But his attempt at designing an adequate test situation and his statement of the necessary elements of such a procedure provide the basis from which further test methods can develop. The purpose of one of the experiments reported below was to attempt to improve upon

¹⁴Nevin described this procedure as follows: "In a typical experiment, a pigeon faces two response keys illuminated with white light. Pecking the left-hand key may change the key color from white to green on a VI-1-minute schedule; the right-hand key is darkened when the left-hand key is green. Alternatively, pecking the right-hand key may change the color from white to red on a VI-1-minute schedule; the left-hand key is darkened when the right-hand key is red. Then, in the presence of green on the left or red on the right, food reinforcement is made available on different schedules." (Nevin, 1973, pp. 177-178)

Schuster's design by minimizing the possibility that response rate or effort differences could effect behavior in the choice situation.

Schuster's explanation of increased rates in added stimulus components as being due to a frustrative non-reward effect has been questioned by Michael (Reference Note 2), who suggested the possibility that two different reinforcement operations occurring in the concurrent chains procedure more parsimoniously explain the results. Stimulus-on, S_n -on, is a more valued condition for the bird than S_n -off, Michael argued, since grain is associated only with S_n -on. When the bird is facing the added stimulus key, he will thus peck faster since pecks produce additional stimulus presentations. However, another stimulus change is relevant--the presentation of the other key to himself by moving from one key to the other during the initial choice period when both keys are lighted. When this occurs, he either works faster or slower, depending upon whether or not the added stimulus schedule is in effect. Moving from the high-effort to the low-effort key is a reinforcing change, while a switch in the opposite direction is punishing. If the added stimuli are only mildly reinforcing while the extra effort is more strongly punishing, the bird will choose the low-effort, no added stimulus key more often. But when he does select the added stimulus component, the "added stimulus" schedule there will generate a higher peck rate.

This proposed explanation by Michael of the results of Schuster's (1969) study is consistent with the method of presentation of all consequent stimuli in the Schuster experiment. Each eleventh keypeck not reinforced by a neutral stimulus-unconditioned reinforcer sequence

was followed by the neutral stimulus-only on the added stimulus key. However, the equal and independent VI-30 sec schedules of reinforcement for each key contained values ranging from 5 sec to 75 sec. Thus it was possible for keypecks during short intervals in the added stimulus component to be followed by food without the occurrence of any prior added stimuli if the bird had not pecked the key 11 times when the unconditioned reinforcer became available. Food presentation could similarly occur following exactly 11 pecks, thus pairing the neutral stimulus with the unconditioned reinforcer and thereby increasing the difficulty of discriminating the superfluosity of the added stimuli. Fantino's (1977) "conditioned confusion" argument seems to apply; while Schuster attempted to schedule added "conditioned reinforcers" which would have no predictive relationship to food, the method of presentation may have in fact reduced the probability that a discrimination between them and food would occur. Schuster's conditioned reinforcer test requirement may best be met by a method of presenting the added stimuli which facilitates the formation of a discrimination of their superfluosity.¹⁵

¹⁵Such a test could be arranged as follows: in one compartment, C, a food-deprived subject could earn tokens exchangeable for food. Alternatively, food could be provided non-contingently, with token (the neutral stimulus) delivery always accompanying food. Such sessions could occur 2-3 times daily in Compartment C to permit the subject to obtain sufficient food to maintain a determined body weight. The subject could spend all remaining time (except that required in Compartment C) either in equally accessible living Compartments A or B. These compartments would be identical except for a supply of tokens in one room which always remained there and were of no value with respect to the food available in Compartment C only. Time spent in A and B would serve as an indication of the effect of pairing on the reinforcing properties of the tokens. General stimulatory effects of tokens could be controlled by placing tokens of another color in the other living compartment.

It is worth considering whether discrimination of the superfluity of the added stimuli in Schuster's (1969) experiment would lead to their being responded to as neutral events. An additional effect of these "added" stimuli could be to signal a passage of time and thus indicate that the unconditioned reinforcer is temporally closer (van Haaren, Reference Note 3). This suggestion is compatible with Fantino's (1977) view that signals which indicate relatively less "psychological distance" or subjective delay to reinforcement can become reinforcing to the organism. Such a possible confounding variable adds another restriction or control requirement to the presentation of potential "conditioned reinforcers" to insure their complete unrelatedness to the unconditioned reinforcer.

Considering the Zimmerman (1963) experiment specifically, however, the criticism that frustrative non-reward effects would maintain responding indefinitely on the stimulus-only key seems to the present author sufficiently debatable to warrant further investigation. Maintenance of responding could be related to the fact that pigeons, highly visually sensitive organisms, readily peck salient stimuli in feeding situations (Staddon and Simmelhag, 1971).¹⁶ Or, as Zimmerman argued, the pairing procedure may be effective, with the concurrent schedules test situation sensitive enough to detect those effects. Therefore, as part of the investigation of pairing, the Zimmerman procedure was

¹⁶ Relevant also is the body of literature dealing with autopecking, first reported by Brown and Jenkins (1968). This literature suggests that certain types of pecks are not controlled by their consequences as strongly as by stimuli which precede primary reinforcer presentation.

modified to accommodate rats as subjects in one experiment and children in another; data from these experiments are presented below.

In the runway experiment with rats (Hanford and Zimmerman, 1971), results can be attributed to several effects other than those of an effective conditioned reinforcer. Frustrative non-reward and general activity increase effects are possible, but the most likely alternative explanation may be confusion. Whether the rat can discriminate the first from the second trial in the ratio is questionable, and the data (Hanford and Zimmerman, 1971, Figure 1, p. 201) support this doubt; when the "conditioned reinforcer" was added following first trial lever presses, run times on these no-unconditioned reinforcer trials decreased to times similar to those of the food consequated trials. With the question about species generality unsettled, the above mentioned replications remain necessary.

Multiple schedules

Thomas (1969) employed a multiple schedule approach for assessing the response-maintenance effects of a previously neutral stimulus; this procedure met the Schuster requirement for separation of conditioned reinforcing effects from the unconditioned reinforcer by scheduling only "conditioned reinforcer" presentations in one component. A multiple fixed-ratio 80 fixed-ratio 10 schedule (mult FR-80 FR-10) was in effect during portions of the experiment, each component signaled by its unique stimulus. During the FR-80 component, a 4 sec presentation

of the grain hopper followed each 80th keypeck by the pigeon, while a brief 0.3 sec grain hopper operation, too brief to allow feeding, followed each 10th peck of the FR-10 component. A 4 min period of total chamber darkness separated the two 4 min FR components to minimize the possibility that pecking in the FR-10 component would be strengthened by a change to the FR-80 component.

Thomas obtained results similar to those of Zimmerman with respect to prolonged maintenance of responding in the FR-10 component which yielded only the conditioned reinforcer. Later in the experiment a 1 sec red light presentation on the response key immediately preceded grain delivery in the FR-80 component. When this 1 sec key light change replaced grain hopper sounds as the consequence in the FR-10 component, it also maintained responding in that component. Thomas argued that "...in order to develop an effective conditioned reinforcer, association with primary reinforcement is all that is needed; the conditioned reinforcing stimulus does not have to be a discriminative stimulus." (Thomas, 1969, p. 90)

The frustrative non-reward explanation for response maintenance in the FR-10 component when only the conditioned reinforcer is programmed as a consequence can also be applied to the Thomas experiment. As in the case of the Zimmerman (1963) experiment, the author questions the explanation of the Thomas results solely in terms of frustrative non-reward effects; further study is therefore indicated. It should also be noted that a "failure-to-discriminate" argument in the present case, as in that of the Zimmerman study, is not convincing. Both studies,

which used pigeons as experimental subjects, obtained data strongly supporting the efficacy of the pairing hypothesis. Therefore, systematic replications of Thomas' experiment were conducted, modifying the procedure to accommodate rats as subjects.

Second-order schedules

Results from this procedure are frequently cited as strongly supporting the pairing hypothesis. A second-order schedule consists of several identical schedule components, the termination of each being signaled by a brief stimulus which can also be paired with food which terminates the final component.

For example, Kelleher (1966) scheduled 15 components, each one an individual fixed-interval 4 minute schedule [FR-15 (FI-4 min)] . A single stimulus condition, a blue key light, was common to all components, with a brief 0.7 sec key color change from blue to white terminating each component; grain presentation immediately followed and was thus paired with the key color change at the completion of the fifteenth component. Kelleher found that pronounced scallop response patterns, similar to those established with food reinforcement, developed during each of the first 14 components when a response was followed by the key light flash upon component termination. Tandem control schedules which omitted the brief stimulus change following component-terminating responses in the first 14 components showed no such scallops. This pattern change, resembling those associated with primary reinforcers, is taken to indicate that the brief stimuli function as conditioned

reinforcers. In addition, overall session rates were higher in the second-order schedule, another factor suggesting operant reinforcement. Pairing proponents argue that this reinforcement function derives from the pairing of the brief stimulus with the unconditioned reinforcer at the termination of the final component.

Kelleher (1966) also tested an unpaired stimulus to determine if it would maintain similar scallop patterns in the early components, and results were inconclusive. Scallop patterns were maintained by the unpaired brief stimulus presentations, although not as pronounced in two of the three birds (Kelleher, 1966, right portions of Figures 11, 12, and 13, p. 483). The same was true for overall session response rates; paired stimuli maintained higher mean rates for only two of the three birds, and mean rates with unpaired stimuli were higher than rates during the random control condition. The undeniable superiority of paired stimuli was not demonstrated.

The accelerating response patterns maintained by the unpaired stimuli indicate that at least some of the pattern maintenance effects of brief stimuli in second-order schedules are not explained by their reinforcing properties derived through pairing with food. Gollub (1977) suggests that such effects may best be explained by recognizing their discriminative aspects: when the brief stimulus, whether paired or unpaired, appears in a second-order schedule with FI components, responses immediately after it are never reinforced, and the low rates following the stimulus reflect its S^Δ effects. To quote Gollub:

In the balance of response-dependent rate-enhancing effects [conditioned reinforcing effects on preceding

responses] and response-independent rate-decreasing effects [S^Δ for subsequent responses] of brief stimuli, the latter are often predominant in the stable state. The former are often stronger either earlier in training, or when the stimuli are less intense and therefore less effective as discriminative stimuli. (Gollub, 1977, p. 305)

At a later point he continues his analysis of methods for separating the discriminative effects from the reinforcing effects of a brief stimulus:

It appears that such rate enhancing effects can best be obtained when the response that produces the brief stimulus is under minimal control by food reinforcement. Thus, the clearest sustained effects are obtained when the response never produces food, as in the concurrent schedules, or is less strongly controlled by the schedule of food reinforcement, as in long DRL schedules or early in the fixed-interval period. Stated another way, the effects of the brief stimulus can be masked by the effects of food reinforcement, or by ongoing high response rates. When food delivery controls responding rather strongly, only discriminable effects of lower rate after the stimulus may appear. (Gollub, 1977, p. 308)

A defender of the effectiveness of the pairing procedure, Gollub concludes his review of response-maintenance testing procedures by stating that because stimuli have other, often more powerful, effects depending upon their method of presentation, response-strengthening effects which may appear under favorable conditions should not be overlooked. In this respect he cites Zimmerman (1963) and Thomas (1969) as examples of sensitive procedures for testing the conditioned reinforcing properties of a stimulus developed through pairing.

An experiment by deLorge (1971) provided a within-session comparison of the effects of paired versus unpaired stimuli. He employed a 2-unit multiple schedule, each unit of which was a second-order schedule containing five VI-1 minute components. In one unit, stimuli

paired with food in the fifth and final component also followed the terminating response in the first four components; unpaired stimuli terminated the initial four components in the other unit. Higher response rates during early VI-1 minute components were found to occur when their termination resulted in a brief stimulus paired with food rather than with a stimulus not paired with food in the terminal component. deLorge also reported that the subjects, pigeons, examined the grain hopper opening at the termination of early VI-1 minute components only when the terminating brief stimulus was identical to the one paired with food in the fifth component. (deLorge, 1971, p. 24)

Kelleher's (1966) comparison of paired versus unpaired stimuli did not clearly favor paired stimuli as being more "reinforcing" than unpaired stimuli. Such inconclusive evidence is not uncommon, as Gollub's review of second-order schedule effects shows (Gollub, 1977, pp. 303-304).

The fact that scallop response patterns may be more pronounced for paired rather than unpaired brief stimuli is consistent with the S^D as well as the pairing hypothesis. Scallop patterns can develop with either stimulus, paired or unpaired, simply because rates at component terminations are higher when terminations are consequted by a brief stimulus rather than being unconsequated; the brief terminating stimulus, paired or unpaired, may permit a more precise discrimination to be formed of the response requirements imposed by the schedule. Poor temporal discrimination as to when such component-terminating responding is required, and/or poor discrimination concerning

the quantitative aspects of the response requirement can result in the accelerating scallop pattern prior to consequence delivery. Paired stimuli can also control higher rates at component termination due to greater "failure to discriminate" that early brief stimuli are never followed by food. Thus two factors contributing to the high terminal rate may summate: the more clearly signaled response requirement coupled with the poor temporal and/or quantitative discrimination as to when and how it must be met; and "confusion" as to whether food will follow the brief stimulus.

Fantino (1977) also presented evidence which supported the conclusion that second-order schedule experiments, often appealed to as being most supportive of the pairing hypothesis, may not in fact do so. He argued that brief stimuli in these schedules were effective as "reinforcers" only when their presentations confuse the organism--when the organism cannot discriminate that the brief stimulus is not signalling a reduction in delay to primary reinforcement.

A study by Squires, Norborg and Fantino (1975) suggested that pigeons could not discriminate between early and late brief stimulus presentations in second-order schedules, and that such a schedule actually functions as a percentage reinforcement schedule in which reinforcement is scheduled for each component only following a certain percentage of terminations. A second-order schedule was modified by illuminating a second key for 2 sec following the terminating response of each FI component, but a response to this second key was required only after the final component of the schedule. The authors argued that if early brief illuminations of the second key were discriminated

from later ones, responding on the second key should occur only following later components. However, the pigeons pecked the second key virtually every time it appeared, including presentations immediately following reinforcement. This suggested that the birds were not sensitive to the number of brief stimuli which had occurred since prior grain reinforcement. Even when such unnecessary responses delayed grain, they still persisted.

It should be noted, however, that a pigeon keypeck was the response studied. If the peck is not representative of arbitrary operant responses with respect to consequent control, that is, if pigeons do tend to peck salient stimuli in feeding situations as suggested earlier, the results of this experiment should be accepted cautiously. Notwithstanding, Fantino concluded that only those stimuli which, at the instant of presentation, cannot be discriminated from primary reinforcement will function as conditioned reinforcers in second-order schedules. In other words, responding is maintained by "conditioned confusion" created by the schedule rather than as a result of pairing of the stimulus with food. This would mean that as long as a "conditioned reinforcer" supports responding in extinction, that stimulus is still functioning as an S^D for some response which either permits the organism to obtain the unconditioned reinforcer more efficiently, or which heightens the effect of the unconditioned reinforcer in some way. When the stimulus loses its S^D function with respect to the unconditioned reinforcer--when the organism discriminates the S^Δ situation with respect to the unconditioned reinforcer--it will also cease to support responding.

Fantino did not review either Zimmerman (1963) or Thomas (1969), but did suggest that the deLorge (1971) experiment exemplified a procedure sufficiently sensitive to detect "...some real, albeit small, effect of pairing" (Fantino, 1977, p. 317). Such small effects are often overshadowed in other test procedures by high response rates generated by the failure of the appropriate discriminations to form. Only by testing paired versus unpaired stimuli during a single experimental session might the weak effects of pairing be demonstrated. The conditioned confusion argument, however, seems appropriate to the deLorge results also; the brief stimuli in the paired component could transform that component into a percentage reinforcement schedule. In the unpaired component, grain reinforcement could signal a period of time in which unpaired stimuli would not result in grain. The fact that the birds in the experiment examined the hopper opening only when brief paired stimuli were presented lends support to the view that the paired stimuli had developed strong discriminative control of hopper approach. In fact, deLorge wrote, "The food-paired stimulus apparently acquired discriminative properties in the present study." (deLorge, 1971, p. 24)

Experiments using the second-order procedure were not undertaken by the author. However, much use is made throughout this paper of Fantino's "conditioned confusion" explanation of stimulus effects which heretofore have been taken as evidence of their reinforcing properties developed through pairing with an unconditioned reinforcer.¹⁷

¹⁷ Another experimental paradigm not considered in this review is the observing response procedure (Wyckoff, 1952). For a concise

Summary of Introduction

As can be seen, a critical analysis of the relevant experimental literature does not justify unquestioned acceptance of the efficacy of the pairing hypothesis at this time. Effects detected are often temporary or small (Gollub, 1977), and are open to other alternative explanations. For example, it was suggested earlier that just because the pairing procedure does not require or measure a response during neutral stimulus presentation, a response is not precluded. Should a response be made, discrimination learning could occur, with subsequent responding in extinction attributable at least in part to "confusion", the lack of formation of a discrimination with respect to the S^{Δ} food condition. It is not without possibility that such as yet undetected response(s) occur, but evaluation of this possibility may have to await the development of more sophisticated response-detection technology. In concrete terms, however, the issue is whether an organismic response was occurring during the brief tone when tone-ESB pairings were scheduled in the Stein (1958) experiment. That such responding is possible, and that it could be maintained once begun if it were controllable to any extent by its consequences, is suggested by the fact that dispenser noise-food pairings in the Skinner (1938) experiment resulted in reliable food dish approaches immediately

review of this method of assessing the reinforcing effects of previously neutral stimuli, the reader is referred to Fantino (1977, pp. 318-326). This presentation argues against both an information and a pairing explanation of the observing response. Rather, a position based upon contingent relationships is developed which is consistent with the discriminative stimulus hypothesis of conditioned reinforcer establishment.

following such noises. The ease with which such an as yet undetected attention response could occur was also mentioned.

The basic question in actuality is whether a stimulus can acquire reinforcing properties simply through pairing with an effective reinforcer in one setting such that in another setting it will function as a conditioned reinforcer when its relation to the unconditioned reinforcer in the new setting is completely nonexistent, and when responding is not due to a "failure to discriminate" this second setting as S^{Δ} with respect to the unconditioned reinforcer. The extreme S^D position would view any successful pairing demonstration as the result of prior, unrequired S^D formation.

At this point it may be useful to examine a phenomenon first demonstrated by Pavlov (1927) and termed conditional discrimination. In the respondent conditioning paradigm, if food is delivered immediately following a brief tone only when another stimulus is present, for example a flashing red light, the salivation response will eventually occur during tone presentations which occur when the red light is flashing. Tones occurring in the absence of the red light will not elicit salivation; the effect of the tone is conditional upon the flashing red light. The pairing hypothesis, which is closely related to Pavlov's work with conditioned reflexes, should predict that the tone would eventually function as a conditioned reinforcer only in the presence of the flashing red light.

With respect to the Zimmerman (1963) experiment, the conditional stimulus was the side of the chamber on which the bird was standing, along with the stimuli associated with that side. These stimuli were

similar and may not have controlled different behavior even after many experimental sessions--a conditional discrimination may not have formed. This failure to form a conditional discrimination may also explain pecking in early components of second-order schedules. However, such an analysis cannot be applied as convincingly to the Thomas (1969) results in which pecking persisted in the S^{Δ} component of the multiple schedule in which only the potential conditioned reinforcer followed responses. Thus the failure of a conditional discrimination to form--or "confusion"--may explain part of what has previously been accepted as effects of a conditioned reinforcer. But the nature of the pigeon and the keypeck may also explain such responding, and is most clearly suggested by response maintenance during S^{Δ} components of multiple schedules. In this respect, Zimmerman stated: "We did attempt to replicate the 1969 (Hendry book) [Zimmerman, 1969] findings with rats. Although we found results in the same direction with rats, they were weak and short lasting." (Reference Note 1)

The above statement of the basic question under investigation seemingly overlooks the powerful response-strengthening and maintenance effects of component transition stimulus changes in behavior chains. However, the contingency requirements which exist between responding in early chain components and the eventual delivery of the primary reinforcer itself render the questions raised by chaining procedures different from the one stated above. Specifically, it is widely accepted that the S^D procedure establishes stimulus changes which can maintain long, complex behavior sequences. The question is whether pairing alone is also a sufficient procedure.

Rationale for and overview of studies

In terms of the experiments to be reported here, the author chose to test the pairing hypothesis with several procedures which have previously yielded supportive results, or which were likely to do so when modified. While positive results would not answer the question about the possibility of as yet undetected responses occurring during neutral stimulus presentations, negative results would cast further doubt about the efficacy of the pairing procedure. Subjects were chosen for the experiments to insure that previous supportive results are generalizable with respect to species. It was hoped that the results would contribute to further interest and research on conditioned reinforcers and also provide a basis for tentative recommendations as to whether the widespread acceptance of the pairing procedure in human settings is warranted.

As seen in this review, results from some procedures used to test pairing's effectiveness in establishing conditioned reinforcers are more suspect than others. Specifically, the response-strengthening effects of potential conditioned reinforcers observed during extinction tests and in chained and second-order schedules are open to many interpretations. Conversely, the recommendation by Schuster that the conditioned reinforcer be scheduled such as not to be predictive of the unconditioned reinforcer minimizes several such alternative explanations. Experiments by Zimmerman (1963), Thomas (1969), and Schuster (1969) exemplified variations of this recommendation, as have others. In Experiment I reported below, for example, a variation of the

Lockhard (1963) shuttlebox procedure was used to test whether rats would prefer the side of a shuttlebox correlated with the presentation of "extra" or "added" stimuli which were also paired with food whenever food delivery occurred. Since food presentations occurred on a variable time schedule to whichever side of the box the animal was standing when a VT period terminated, the added stimuli programmed to occur on one side bore no systematic relationship to the unconditioned reinforcer. If simple pairing establishes conditioned reinforcers, subjects should prefer the side of the shuttlebox which is correlated with the added stimulus presentations.

Both Zimmerman (1963) and Thomas (1969) obtained results strongly supportive of pairing. However, the question exists as to whether these results are restricted in any way to pigeons and/or to the keypeck response, both of which were common to the Zimmerman and Thomas studies. Therefore, systematic replications of both experiments were conducted using rats as subjects in two experiments and children in another, reported as Experiments II, III, and IV below. In addition, a similar species generalization replication test was conducted of a portion of Schuster's (1969) experiment in which multiple schedule components were equal with respect to food but one component also contained a superimposed added stimulus schedule. The added stimulus component was associated with higher rates for pigeons, and the question arises as to whether such increased rates would occur with rats (Experiment V). Finally, a modification of Schuster's (1969) concurrent chains choice procedure was developed and tested in Experiment VI. The modified procedure was designed to control

for the rate-confounding effects generated by Schuster's procedure while retaining the two other advantages of the design: first, the behavioral choice of the organism as evidence of which of two alternatives is most reinforcing; and second, the presentation of the test stimulus in such a way that its potential reinforcing effects are separable from schedule requirements.

Each experiment was conducted to contribute to the assessment of the effects of pairing on the question of the establishment of conditioned reinforcers. The experiments are therefore not related to each other in any systematic way except that they all ask the question: "Can the specific pairing procedure selected, when combined with a specific subject, establish a previously neutral stimulus as a conditioned reinforcer?"

EXPERIMENT I

Method

The purpose of this experiment was to determine whether rats would prefer a side of a shuttlebox correlated with the presentation of extra or "added" stimuli which were consistently paired with food. Food was presented on a pre-determined variable time (VT) schedule and delivered to the side of the shuttlebox on which the subject was standing when a VT period timed out.

Subjects

The subjects were two naive male albino rats, randomly selected from an original group of 20 obtained from The Upjohn Company colony in Kalamazoo, Michigan, and 90-120 days old at the start of the experiment. They were individually housed, provided free water except in the shuttlebox, and maintained at 80% of their free feeding weight by restricting Purina Laboratory Chow intake.

Apparatus

The shuttlebox measured 48 x 21 x 19 cm and was divided in the middle by a metal-covered partition containing an 8 cm diameter hole through which the animal could pass from one side to the other. The shuttlebox was hinged in the middle such that total time spent on each side could be measured. Centered on each end wall was a food dish into which could be delivered 45 mg Noyes food pellets. Centered

on the ceiling was a Sonalert (Model No. 5C628H) which could provide tones during the experiment. The chamber was situated on a table and isolated from the rest of the laboratory by partitions. Noises produced by the electro-mechanical scheduling of two other simultaneous experiments provided masking noise; illumination was supplied by laboratory ceiling lights.

Procedure

Following two sessions in which subjects were trained to eat from each food dish, daily experimental sessions of approximately 30 minutes duration were conducted. For the first eight days, a 1 sec tone immediately followed by one food pellet was delivered into the food dish on whichever side of the shuttlebox the subject (S) was standing to determine what percentage of time an S would spend on each side when consequences were the same on the two sides. Spacing of the tone-pellet deliveries was arranged by a variable time 30 sec (VT-30 sec) schedule constructed from the Catania-Reynolds formula (Catania and Reynolds, 1968) for determining interval lengths in VI schedules. The single VT-30 sec timer ran continuously, and no change-over delay was in effect to postpone food pellet delivery if S changed sides immediately prior to a scheduled pellet presentation.

Conditions were then changed so that for the next 39 sessions "extra" 1 sec tones, the potential conditioned reinforcer, were scheduled on a variable time 15 sec basis whenever the subject was standing on the left side of the shuttlebox. The VT-15 sec timer also ran continuously, but delivered its consequences only when the

subject was on the pre-determined side of the shuttlebox. Then for seven days these "extra" tones were scheduled on the VT-15 sec schedule for the right side of the chamber. The VT schedule for added tones was then changed to VT-25 sec for 16 days, and finally to VT-10 sec for the last 6 days of the experiment; all extra tones for the last three conditions occurred on the right side only. Diagram 5 represents the case in which extra tones were scheduled for the left side. The VT timer which controlled the presentation of the extra tones also ran continuously, with no COD in effect. Therefore, if the subject moved from S-1 to S-2 during an S_{na} (extra tone) presentation, the S_{na} terminated. A move from S-2 to S-1 during a scheduled S_{na} presentation on S-1 initiated the S_{na} for the portion of the time remaining of its 1 sec duration. Should the subject move from one side to the other during an S_n (tone) presentation prior to the unconditioned reinforcer, the S_n was not interrupted but continued, with the unconditioned reinforcer, the food pellet, being presented to the side of the box on which the animal was located the instant the 1 sec tone terminated.

Results

The percentage of time spent on the left side of the shuttlebox is displayed for S1 and S2 in Figure 1 and Figure 2, respectively. For each session, the number of seconds spent on the left side was divided by the total number of seconds of the session.

S-1 spent approximately the same amount of time on each side of the shuttlebox when the 1 sec tone plus food pellet was delivered on

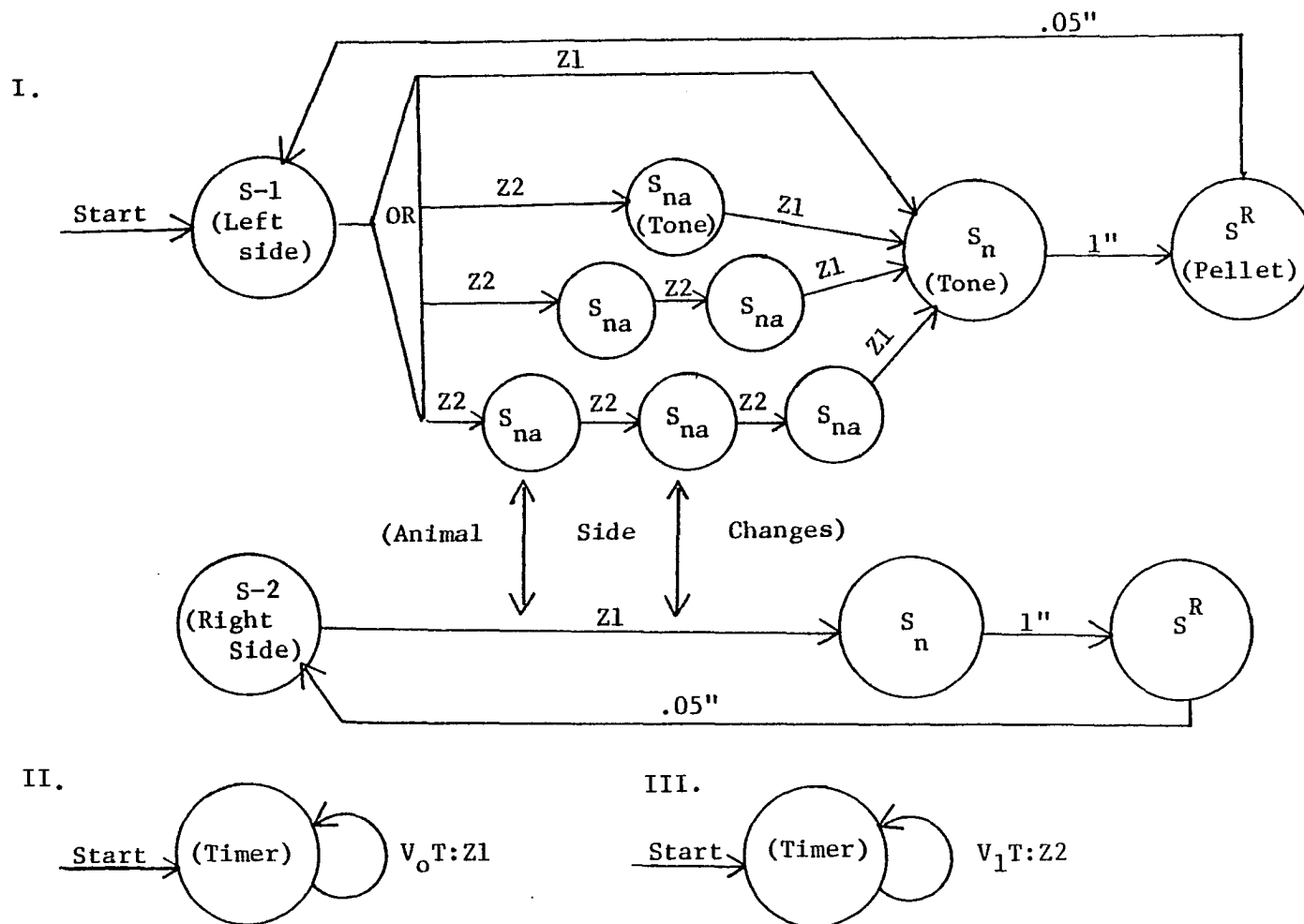


Diagram 5. Simplified state diagram of Experiment I, Condition 2: added (extra) stimuli on the left side of the shuttlebox. S-1 indicates State 1--the subject is on the left side; S_n indicates a 1-sec (1") tone presentation; S_{na}, the added 1-sec tone; and S^R, the food pelletⁿ. The appearance of S_n was always controlled by Z1. The $\triangle OR$ indicates that before a Z1 occurred, 0 to 3 S_{na} presentations were possible. Both timers ran continuously, and no changeover delay was in effect. If the subject moved from S-1 to S-2 during an S_{na} presentation, the S_{na} terminated. A move from S-2 to S-1 during a scheduled S_{na} on S-1 initiated the S_{na} for the portion of the 1-sec remaining.

Figure 1: The percent of time Subject 1 spent on the left side of the shuttlebox in Experiment I. Numbers in parentheses indicate percentages for datum points falling outside the boundaries of the graph.

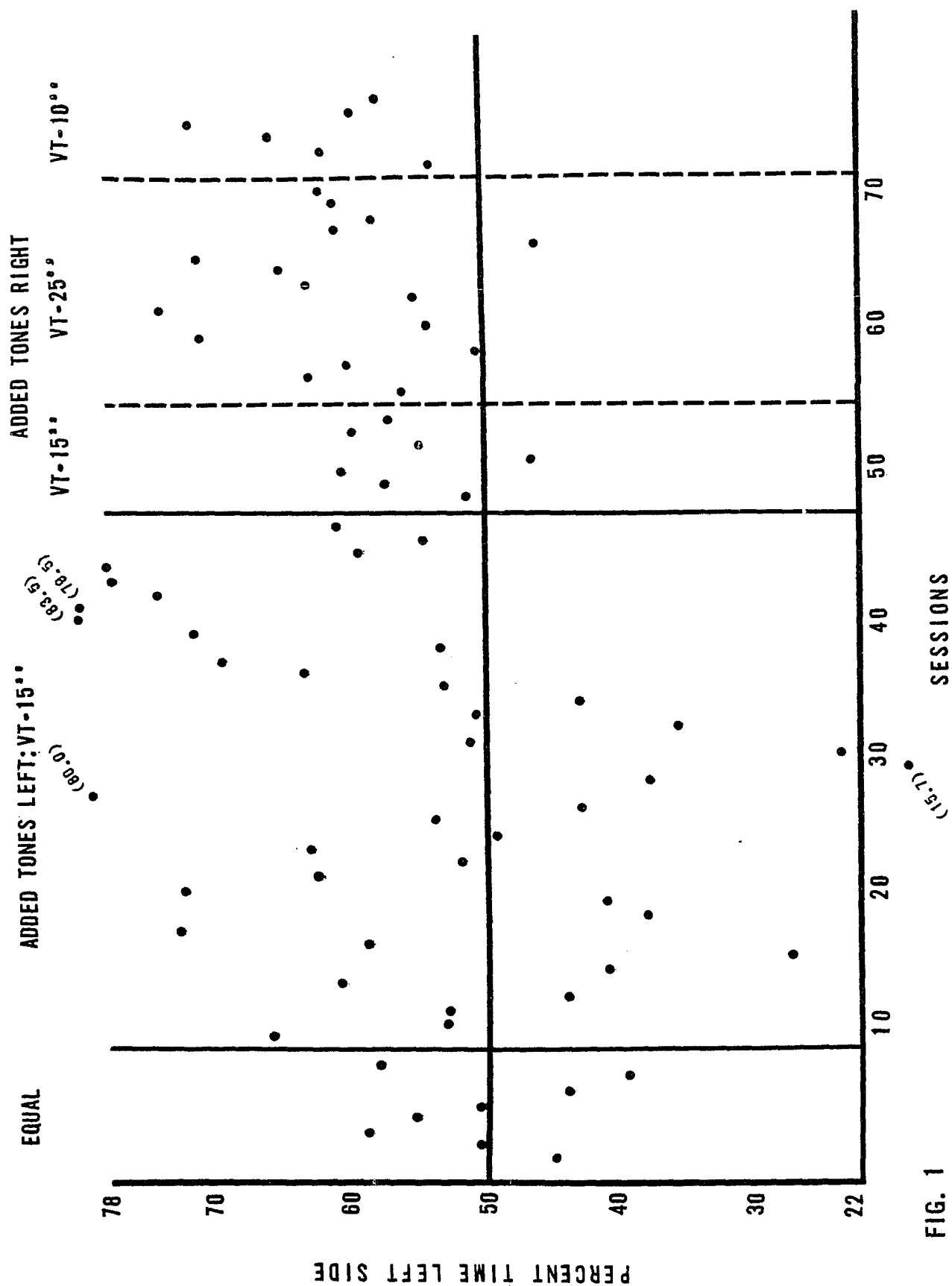


FIG. 1

Figure 2: The percent of time Subject 2 spent on the left side of the shuttlebox in Experiment I.

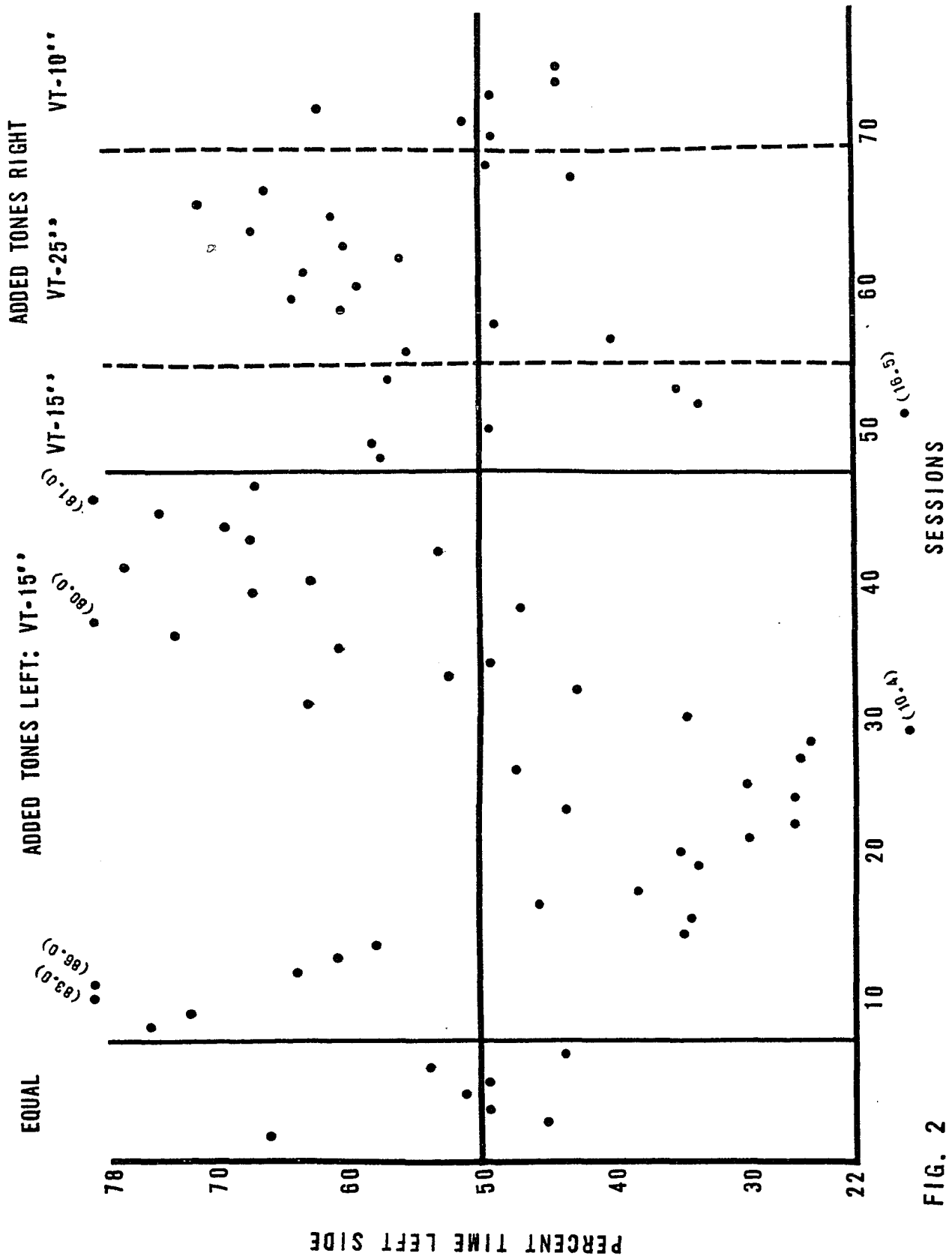


FIG. 2

the VT-30 sec schedule to whichever side of the shuttlebox the animal was located; this condition is labeled EQUAL in the figures. When additional 1 sec tones delivered on a VT-15 sec schedule were superimposed when the rat was on the left side of the box--labeled ADDED TONES LEFT--the percent of time spent on the left side showed more variability than during the EQUAL condition. In the last nine days of the condition, more time was spent on the left side; however, the variability during the condition was large, as was the variability during the last nine days of the condition.

When the additional 1 sec tones were switched from the left to the right side--labeled ADDED TONES RIGHT--the percentage of time spent on the left side remained relatively constant with respect to that of the last three days of the ADDED TONES LEFT condition, approximately 58 percent. Thus the moving of the superimposed tones from the left to the right side did not result in any change in the amount of time S-1 spent on the left and right sides of the box. This was true whether the added tones were delivered on a VT-15 sec, VT-25 sec, or VT-10 sec schedule.

After having divided his time equally between sides in the EQUAL condition, S-2 initially increased time spent on the left side of the shuttlebox to approximately 70 percent when the ADDED TONES LEFT condition began. However, during the middle sessions of this condition time spent on the left side dropped to approximately 30 percent for more than ten days, and then increased to approximately 68 percent during the last nine days of the condition.

When added tones occurred only when the subject was on the right

side, S-2's percent of time spent on the left side varied widely. The first and last days of the VT-15 sec schedule of added stimuli were in the 56 percent range, while substantially lower percentages were recorded on the fourth, fifth, and sixth days of the condition. When the ADDED TONES RIGHT schedule was changed to VT-25 sec, time spent on the left side increased to approximately 60 percent, although day-to-day variability continued to be present. When the ADDED TONES RIGHT schedule was increased to one tone on the average of every 10 seconds, VT-10 sec, S-2 divided his time equally between sides as had been the case in the initial EQUAL condition. This equal division of time was also similar to that of the last two days of the VT-25 sec schedule of added tone presentation on the right side.

Discussion

The wide variability in time spent on each side of the shuttle-box given the different conditions of tone-plus-food and added tones scheduled for the two sides warrants no statement about preference. Neither the added tones side nor the no-added tones side seemed to be "preferred" consistently by either subject.¹⁸

The lack of "preference" for the added stimulus or the no-added stimulus side in the present case could be a result of a weak preference--no preference is another viable possibility--in combination with a weak procedure. The weakness of the procedure derives from the

¹⁸The basic design of this experiment was suggested by one reported by Lockhard (1963), whose rats preferred the side of a shuttle-box with signaled as opposed to unsignaled shock presentations.

fact that all consequences were scheduled without regard to the subject's behavior, and thus possibilities of adventitious reinforcement were legion. It was possible, for example, for an S to move from one side of the chamber to the other just prior to the delivery of a scheduled consequence. As no changeover delay was in effect, such switching behavior could be reinforced adventitiously. Other behavior or behavior sequences occurring just prior to consequence delivery were subject to similar accidental strengthening.

Long experimental sessions and/or experimental conditions may be required for a weak preference to be detected with such a procedure. The problems associated with the procedure may have been magnified by the similar stimuli associated with the two choice options. For example, both sides of the chamber were identical, and tones and food were presented when the rat was located on either side, the only difference being that extra tones occurred on only one side in each condition. Floors constructed of different materials or walls with different light-dark patterns may have increased the possibility for the discrimination of the different contingencies to be learned.

Of course such learning would require a basic preference for one of the two sides, and whether such a preference existed was the question under study.

EXPERIMENT II

Method

This experiment systematically replicated one by Zimmerman (1963) and sought to determine if results obtained with rats would be similar to those obtained by Zimmerman with pigeons as the experimental subjects. In that experiment, Zimmerman's birds maintained responding on both keys in a concurrently available two-key procedure when responding produced grain on one key and only grain hopper sounds on the other according to independently-running VI-3 min schedules.

Subjects

Subjects were two naive male albino rats randomly selected from an original group of 20 obtained from The Upjohn Company colony in Kalamazoo, Michigan. They were 90-120 days old at the start of the experiment. Each S was individually housed, provided free water except in the experimental chamber, and maintained at 80% free feeding weight by restricting Purina Laboratory Chow intake.

Apparatus

The experimental chamber measured 29 x 25 x 19 cm and was housed in a styrofoam insulated chest which was equipped with an exhaust fan and white noise. The 29 cm wall contained two rodent levers, each 8 cm from the floor with 8 cm separating them. A food dish recessed into the same wall rested on the floor and was equidistant between the

two levers. One cm above and 4 cm to the left of the left lever, and 1 cm above and 4 cm to the right of the right lever were amber stimulus lights. The houselight was centered in the ceiling. Scheduling and recording of events was accomplished by standard electro-mechanical devices.

Procedure

Two experimental sessions of approximately 30 minutes duration each were conducted daily, with 30 minutes separating each. Graphed session data consisted of the sum of the data from all 30 minute sessions on a given day under a single experimental condition. Subjects were first trained to press both levers. Then for 19 sessions equal and independent variable-interval 30 second (VI-30 sec) schedules of consequence presentation were arranged on both levers concurrently using the formula described in Catania and Reynolds (1968) to space intervals; a lever press after an interval timed out was followed by a 1 sec period of darkness--the houselight and lever lights were turned off--and the immediate presentation of a 45 mg Noyes food pellet as the lights were reilluminated. The timers associated with the two levers ran independently of each other. Thus if one timer terminated and set up a consequence which would occur following the next response to that lever, the other timer continued to operate. It continued to operate independently during all consequence presentations associated with the other lever. No changeover delay was in effect during the experiment. Thus during Condition 1 a switch from pressing Lever A to Lever B could result in an immediate stimulus-plus-food presentation

if such a presentation had been set up by the timing out of the VI timer associated with Lever B while the subject was pressing Lever A. It should also be noted that the occasional pressing of both levers during Condition 1 could potentially double the stimulus-plus-food presentations; pressing both levers thus yielded a greater density of reinforcement than pressing only one lever.

Conditions were then changed so that for 27 days the VI-30 sec schedule of 1 sec light flash followed by food remained in effect for the left lever only, while the right lever yielded only the 1 sec light flash on its independent VI-30 sec schedule. This condition tested the response-maintenance effects of the light-flash-only when its occurrence followed responding on one key; see Diagram 6 for a simplified state diagram of this condition. Thus in Condition 2 presses only to the left lever resulted in occasional stimulus-plus-food deliveries. Presses to the right lever were occasionally followed by the presentation of only the stimulus which on the other lever always immediately preceded food delivery. As in Condition 1, no changeover delay was in effect.

The order and duration of each of the several experimental manipulations during the experiment are listed in Table I: each entry shows the number of sessions the condition was in effect and the schedule of consequence presentation on each lever during that condition. The purpose of each subsequent manipulation was to test the extent to which responding observed on the light-flash-only lever was due to the pairing of that light flash with food on the other lever. Conditions remained in effect until the experimenter determined

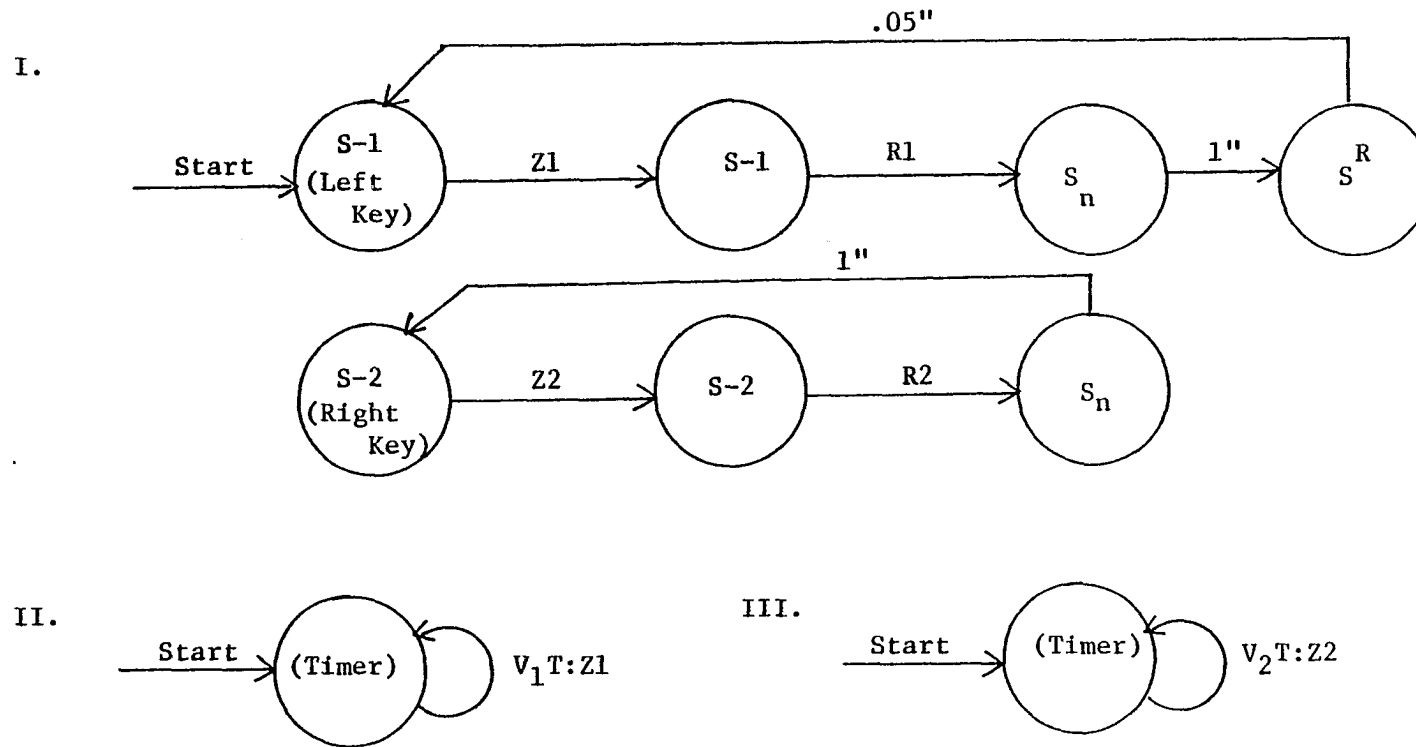


Diagram 6. Simplified state diagram of Experiment II, Condition 2: left key-light flash plus food pellet; right key-light flash only. Both timers ran continuously and no change-over delay was in effect. S_n indicates the previously neutral stimulus, the 1-sec light flash, which always precededⁿ presentations of S^R , the food pellet. Consequences for pecking ($S + S^R$ and S_n -only) occurred twice as often if each key was pecked occasionally. Food availability was thus doubled when food was the consequence associated with both keys, as was the case in Condition 1. ($R1$ and $R2$ are left and right keypecks, and $Z1$ and $Z2$ are the variable time outputs of the timers.)

TABLE I: Sequence and duration of experimental conditions for each subject in Experiment II.

TABLE I

SEQUENCE AND DURATION OF EXPERIMENTAL CONDITIONS
FOR EACH SUBJECT IN EXPERIMENT II.

Subject 1				Subject 2		
<u>Experimental Conditions</u>	<u>Number of Sessions</u>	<u>Consequences on VI-30" Schedule</u>		<u>Number of Sessions</u>	<u>Consequences on VI-30" Schedule</u>	
		<u>L. Lever</u>	<u>R. Lever</u>		<u>L. Lever</u>	<u>R. Lever</u>
Condition 1	19	1" F+P	1" F+P	19	1" F+P	1" F+P
Condition 2	27	1" F+P	F Only	27	1" F+P	F Only
Condition 3	16	P Only	F Only	16	P Only	F Only
Condition 4	15	1" F+P	F Only	9	1" F+P	F Only
Condition 5	19	F Only	1" F+P	29	F Only	1" F+P
Condition 6	16	Ext.	1" F+P	10	F Only	P Only
Condition 7	--	---	---	6	F Only	1" F+P
	114	Sessions Total		136	Sessions Total	

F = Light Flash (1")

P = Pellet

Ext. = Extinction

from visual inspection of the plotted data that consistent response patterns were being maintained.

Results

Response rates are shown for S-1 and S-2 in Figure 3 and Figure 5, respectively. The ordinate of each figure displays the logarithm of the response rate in responses per minute (rpm) on each lever while sessions extend across the abscissa on a non-logarithmic scale. Rates below 0.1 rpm are shown at 0.1 rpm, with the asterisk (*) beneath any such rate indicating 0.0 rpm. Consequences associated with the independent VI-30 sec schedules are abbreviated within condition boundaries across the top of each figure. The schedule of consequence delivery remained at VI-30 sec on each lever throughout the experiment except in Condition 6 for S-1.

S-1 pressed both levers at similar rates in Condition 1 when the equal and independent VI-30 sec schedules yielded a 1 sec light flash followed by the food pellet. When consequences associated with the right lever were changed to present only the 1 sec light flash on the VI-30 sec schedule, rates on the right lever fell to approximately 0.3 rpm, while rates on the unchanged left lever rose from 8.0 to 15.0 rpm.

In order to determine whether responding on the right lever was a function of the pairing of the light flash with pellet delivery on the left lever, the 1 sec light flash preceding pellet delivery associated with the left lever was discontinued in Condition 3. This change was correlated with a continued rise in the rate on the left

Figure 3: Responses per minute displayed along a logarithmic ordinate for Subject 1 across sessions of Experiment II. Experimental conditions appear at the top of the figure. L: and R: indicate left and right lever presses; Lt indicates the 1 sec light flash, the potential conditioned reinforcer; S^R indicates food pellet delivery; X indicates that one stimulus is immediately followed by the second; and Ext. indicates an extinction situation with respect to consequences.

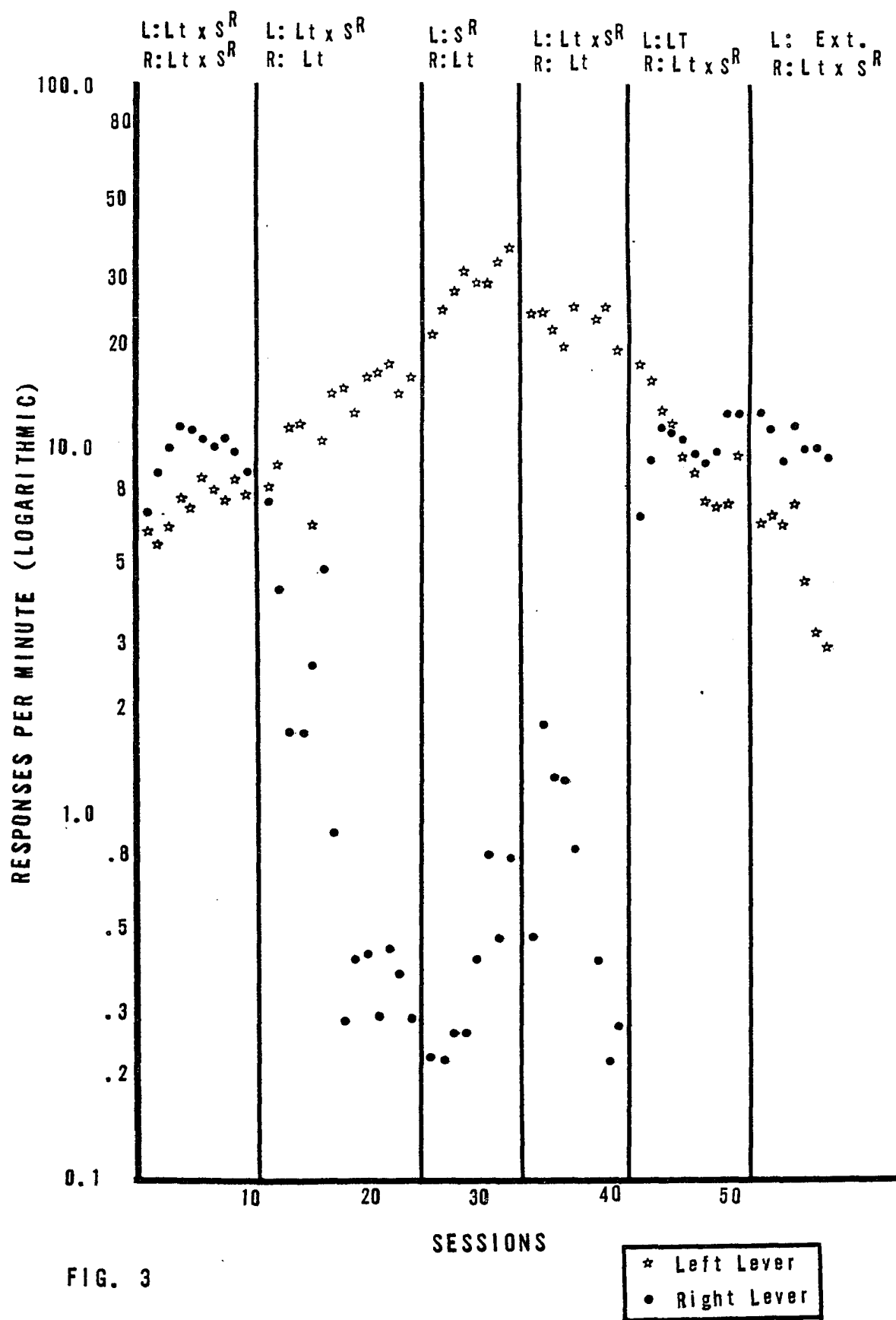


FIG. 3

lever to 30 responses per minute. Rates rose to 0.6 on the right lever which continued to be associated with the presentation of the 1 sec light flash-only. Reinstatement of the 1 sec light flash preceding pellet delivery associated with pressing the left lever was correlated with a leveling off of the rate of left lever pressing at 23 rpm. By the end of Condition 4 the rate on the right lever, still associated with the 1 sec light flash-only, dropped to approximately 0.3 rpm.

In Condition 5, the schedules associated with the two levers were reversed from that in Condition 4; pressing the left lever now yielded only the 1 sec light flash while a 1 sec light flash plus pellet was programmed on the right lever. Rates of lever pressing were 10 per minute on both levers. Figure 4A shows a portion of the 4-pen event record of S-1 in the eighth session of Condition 5. The consequence pens operated at the termination of the 1 sec light flash. The rat would press the left lever and during the 1 sec light flash which occasionally occurred he would move to the right lever. Visual observation by the author indicated that this move from the left to the right lever was immediate and direct, with no apparent inspection of the fooddish occurring during the move. Occasionally a press to the right lever would extend the dark period another 1 sec, at which time pellet delivery would occur. Thus an alternating pattern of pressing one lever and then the other was adventitiously strengthened. Observation of S-1's behavior within the chamber confirmed this pattern of lever pressing and consequence occurrence pictured in Figure 4A.

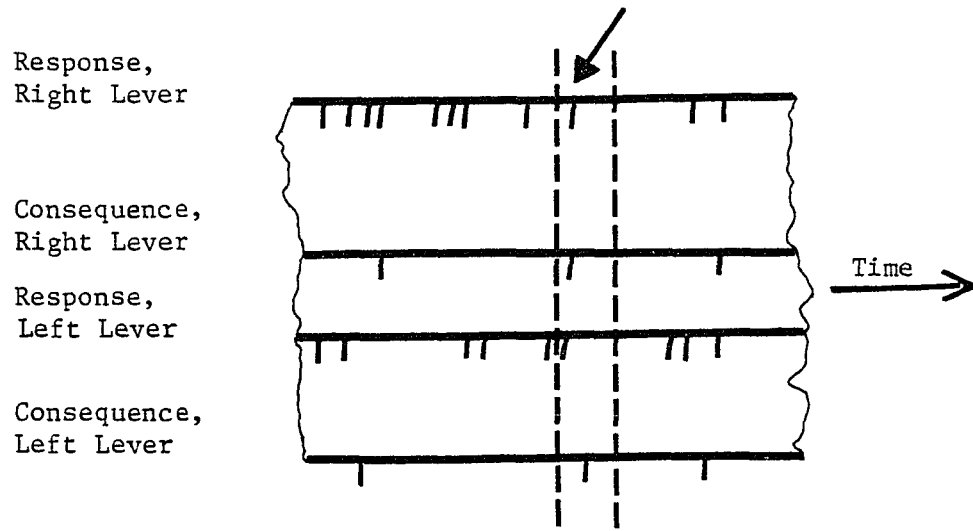


Figure 4A. The reconstruction of a portion of the 4-pen event record of S-1 during the 8th session of Condition 5. Consequence pens operated at the termination of the 1 sec light flash. During the 1 sec light flash following some left lever presses, S-1 would press the right lever and obtain a pellet (see portion of event record bounded by dotted lines).

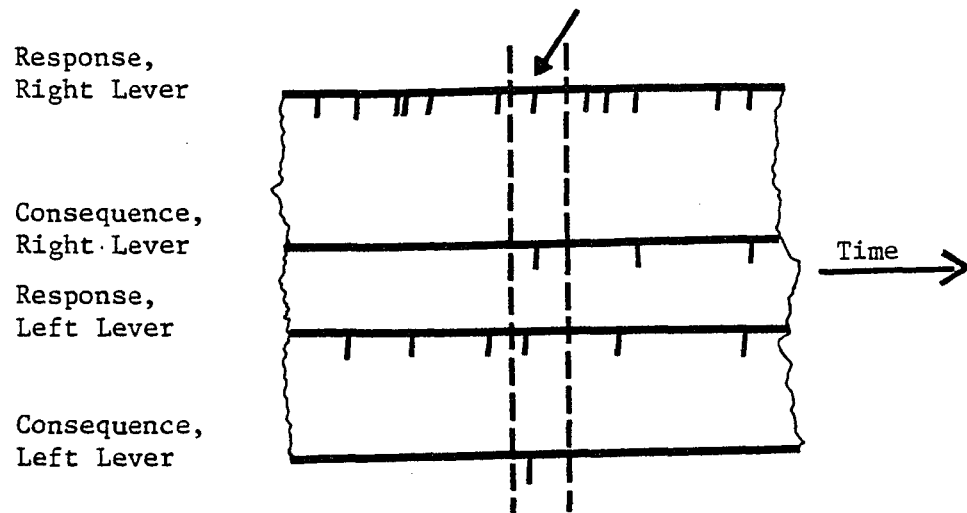


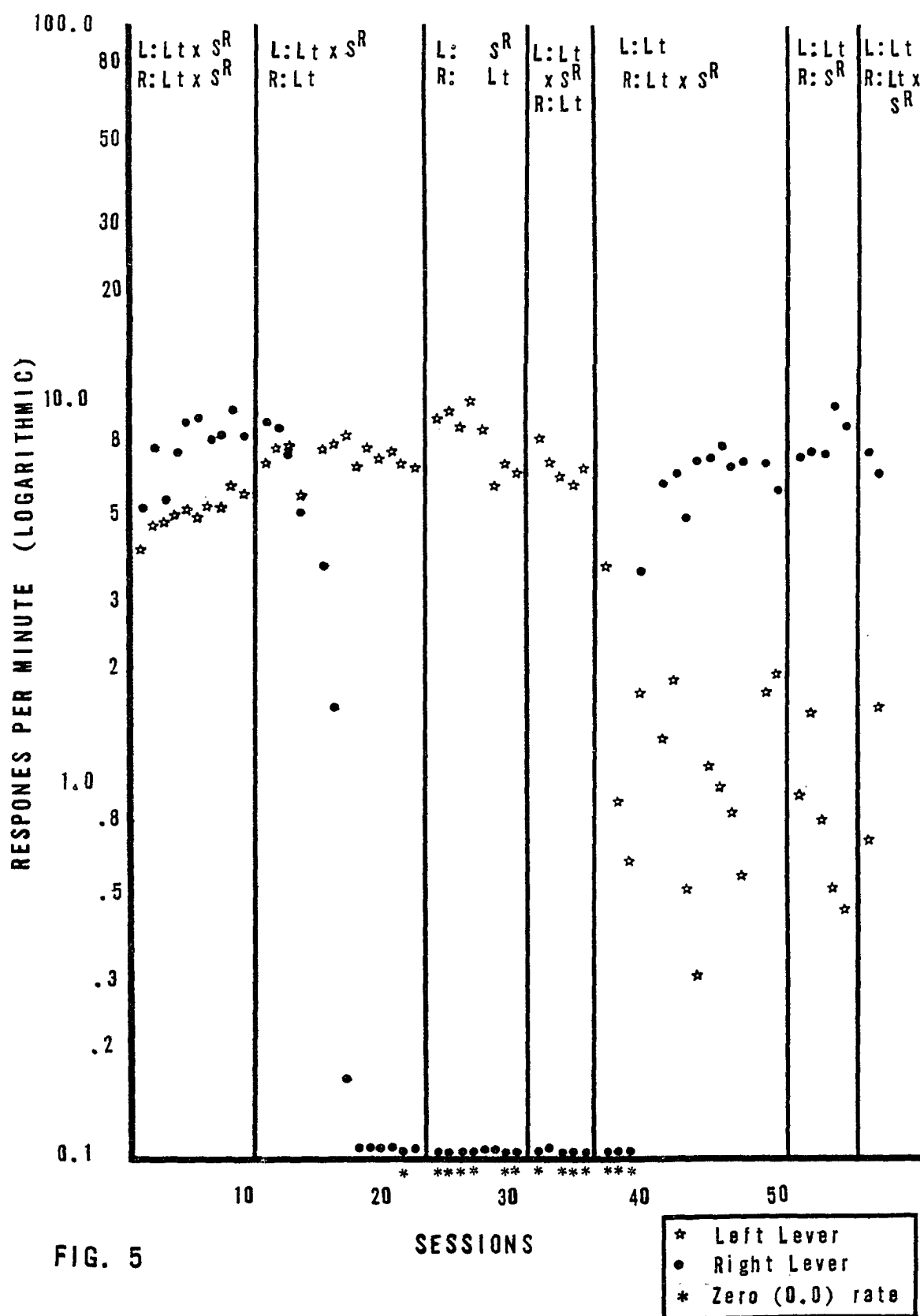
Figure 4B. The reconstruction of a portion of the 4-pen event record of S-1 during the 4th from last session of the experiment. No consequence was scheduled for the left lever; the left lever consequence pen indicates where a consequence would have occurred, if scheduled. S-1's pattern of pressing the left lever and then the right lever persisted into this session (see portion of event record bounded by dotted lines).

When no consequence was scheduled for pressing the left lever, Condition 6, the chained behavior sequences established in Condition 5 persisted; rates of responding on the left lever continued for four sessions and only then began to decline. Figure 4B shows a portion of the event record of S-1 taken from the fourth from last session of the experiment. The same pattern of alternating responding between left and right levers was still present, as were the maintaining consequences. Note that the reinforcer marks for the left lever in Figure 4B indicate where the consequence would have occurred if one had been presented during Condition 6.

Somewhat similar rates were obtained when S-2 was exposed to Conditions 1, 2, 3 and 4 which were identical to those to which S-1 was exposed. S-2 differed in that the light flash consequence associated with pressing the right lever in Conditions 2, 3 and 4 supported an even lower rate, which for 11 days was zero. In addition, the rate on the tone-plus-food lever in Conditions 2 and 3 did not increase. (See Figure 5.)

When the reversal of schedules associated with the two levers occurred in Condition 5, S-2's rate of response on the left lever, associated with the light flash only, dropped to 1.0 per minute as compared to the 7.0 rpm maintained by the light flash plus pellet on the right lever. Figure 6A presents a portion of the event record of S-2 from the eleventh session of the condition which suggests that an alternating response chain similar to that seen with S-1 was responsible for maintaining at least a portion of this 1.0 rate of lever pressing. Visual observation of S-2 substantiated this fact. No major change in

Figure 5: Responses per minute for Subject 2 in Experiment II.
An asterisk (*) appearing below a datum point situated
on the 0.1 response per minute line indicates a response
rate of zero.



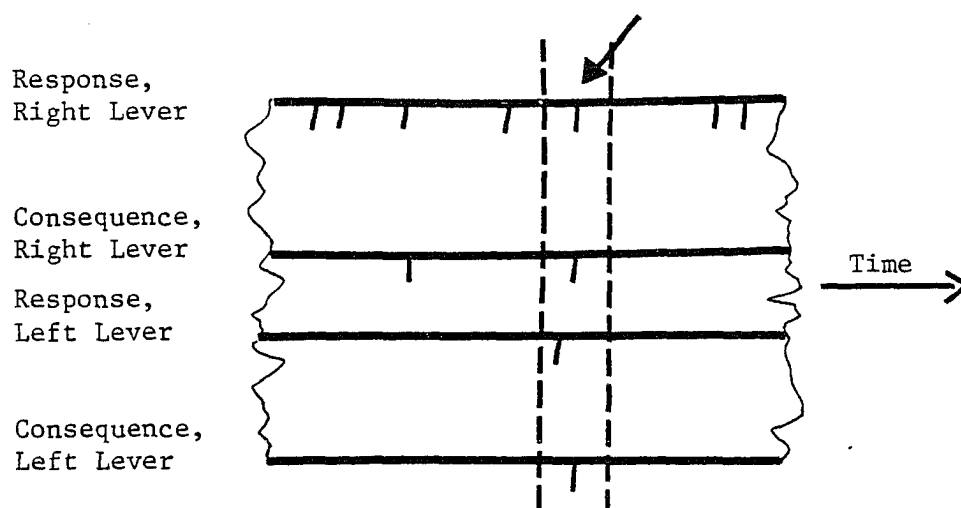


Figure 6A. The reconstruction of a portion of the event record of S-2 during the 11th session of Condition 5. Consequence pens operated at the termination of the 1 sec light flash. During the 1 sec light flash following some left lever presses, S-2 would press the right lever and obtain a pellet (see portion of event record bounded by dotted lines).

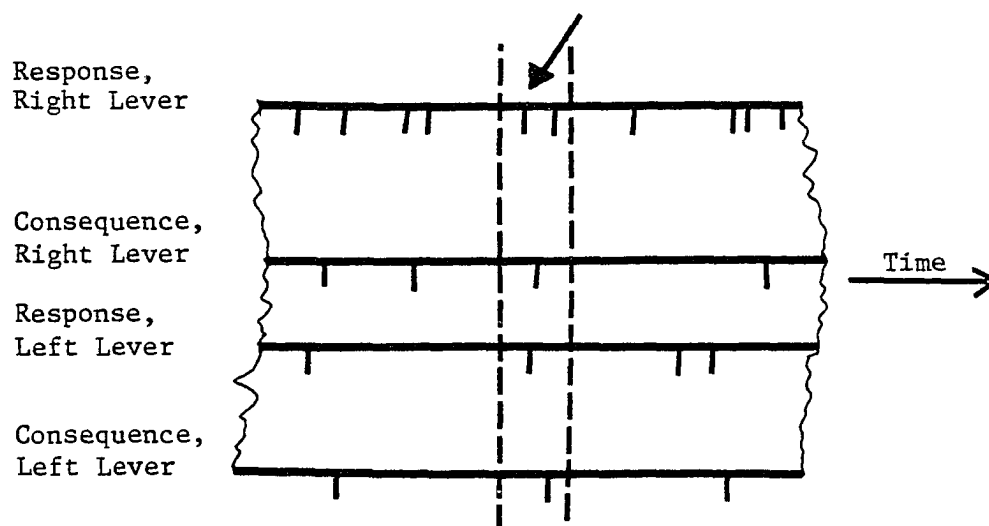


Figure 6B. The reconstruction of a portion of the event record of S-2 during the 2nd session of Condition 6. The light flash preceding pellet delivery on the right lever was discontinued. The left lever-right lever response pattern continued to occur, and was occasionally followed by a food pellet (see portion of event record bounded by dotted lines).

rate on the left lever occurred when the light flash preceding pellet delivery was removed from the schedule associated with the right lever, Condition 6, or when it was reinstated in Condition 7. Figure 6B shows the event record of the second session of Condition 6, in which reinforcement occasionally followed sequences of left lever-right lever response patterns.

For comparison purposes, Zimmerman (1963) reported keypeck rates on the food key of 90-120 rpm, and of 9-12 rpm on the key associated with delivery of only the potential conditioned reinforcer as consequence. The cumulative records presented in Figure 1 (Zimmerman, 1963, p. 683) appear to represent rates of 7-9 rpm on the potential conditioned reinforcer key.

Discussion

When the light flash alone occurred as the consequence for pressing one lever in Condition 2 for S-1, it maintained a response rate lower than one-twentieth that of the light-plus-food lever. Removal of pairing in Condition 3, which should have lowered the light-only rate, actually was associated with an increase, though slight. Reinstitution of pairing also had an effect opposite to that which would be predicted by the pairing hypothesis, since the rate on the light-only lever actually decreased when pairing was reinstituted. Behavioral contrast effects (Reynolds, 1961a) appeared on the unchanged lever in Condition 2, and continued to increase in Condition 3, as would be predicted by the pairing hypothesis since the schedule on the light-only lever was further worsened by the

termination of pairing. But the failure of the rate on the light-only lever to drop--it actually increased--questions this contrast interpretation. Similar conflicting results appeared in Condition 4.

Since no changeover delay was in effect, left lever-right lever response sequences which occurred in Condition 5 were not weakened by a delay between their completion and food presentation. Responding on the light-only lever was maintained adventitiously by primary reinforcement delivered for presses to the other lever. Condition 6, which provided no consequences for presses to the former light-only lever, demonstrated how durable this response chain was, once established. For S-2, the light-only lever supported an even lower response rate in Conditions 2, 3 and 4, and no contrast effects appeared on the lever associated with the light flash-plus-food. Chaining maintained a lower rate for S-2 than for S-1 on the light-only lever in Conditions 5, 6 and 7, a rate similar to the one-to-ten ratio reported by Zimmerman (1963) with pigeons.

It is difficult to find any support for the effectiveness of the pairing procedure in this experiment with rats as subjects and lever pressing as the observed response. That Zimmerman's subjects maintained responding indefinitely on the stimulus-only key, and later showed rate and pattern changes on this key in a control condition when different schedules of stimulus presentation were programmed, may have been species specific. Increased pecking of environmental stimuli has been observed in pigeons during those times in periodic food presentation schedules when food is not

present. (Staddon and Simmelhag, 1972) This increased probability of responding could be enhanced through conservation of pecks to salient stimuli, the illuminated light flash-only key in this case, by other stimuli, hopper sounds, which are temporally paired with food in another setting (on another key as in this experiment, or in another component, etc.). The pairing hypothesis could explain any keypeck rate enhancement in this way. However, the relative ease of the response may have been a contributing factor, plus the fact that the anatomical features of the pigeon make pecking and the use of the beak the single most likely means of exploring, interacting with his environment, and eating in feeding settings.

Other stimulus associations are also possible in the two-key concurrent schedule situation. As an alternative explanation, a somewhat prominent feature of the environment in the Zimmerman (1963) experiment, the illuminated light flash-only key, is similar to a stimulus continually associated with food, the lighted key on the other side of the chamber. With pigeons this stimulus similarity may be sufficient to maintain keypecking on the lighted stimulus-only key. In the autoshaping procedure (Brown and Jenkins, 1968) pigeons peck a key which is illuminated just prior to intermittent free-food presentations. They continue to do so even when such pecks postpone food (Williams and Williams, 1969). In Zimmerman's procedure, a food-paired stimulus, the lighted stimulus-plus-food key, is similar to another prominent stimulus, the lighted key on the stimulus-only side. The stimulus-only key may become more salient due to this stimulus dimension "association", and pecks to this key would then be an example

of the stimulus generalization phenomenon. Evidence related to this alternative is available.

Thomas (1969) has shown, for example, that the pairing of the previously neutral stimulus with food is necessary if its presentation as a consequence is to be correlated with response maintenance in the stimulus-only component of multiple schedules. And Davol, Steinhauer and Lee (1977) reported data to support the hypothesis that initial keypecks in the autoshaping procedure arise due to the generalization of pecking from the lighted grain hopper to pecking at the key illuminated with the same color light as that in the grain hopper. To evaluate this stimulus generalization alternative, one could vary the color of the light-flash-only key and measure any resulting changes in rate on that key.

It is also possible to suggest that the hopper-sounds consequence associated with the stimulus-only key repeatedly associates this food-related sound with the lighted stimulus-only key, and that generalized pecking therefore continues to occur occasionally to the stimulus-only key. This second category of stimulus generalization suggests generalization across stimulus modes.

EXPERIMENT III

Method

This experiment systematically replicated one by Zimmerman (1963) and sought to determine if results obtained with children would be similar to those reported by Zimmerman with pigeons.¹⁹

Subjects

Three children, a six and a three year old girl (S-1 and S-3) and a four year old boy (S-2), served as subjects. The oldest girl and the boy were brother and sister; they had never met the younger girl either before or during the experiment. All children were living with their parents in family housing apartments at Western Michigan University in Kalamazoo, Michigan. They were selected as experimental subjects because of their ages, their willingness, and the fact that their parents permitted their participation in the experiment. The father of the brother and sister was a Ph.D. candidate in the Psychology Department and a friend of the author. The mother of the youngest girl was a neighbor of the experimenter.

Apparatus and experimental setting

The apparatus consisted of two white wooden boxes, 21 x 18 x 9 cm.

¹⁹ This experiment was conducted by Priscila R. Derdyk under the supervision of the author and her M.A. thesis committee (Derdyk, 1977).

Each box was equipped with a green button and one red and one white stimulus light. The red light was inoperative. The two boxes were situated on a rectangular platform, 150 x 30 x 30 cm, and were separated from each other by a distance of 100 cm. The platform was located on the floor in front of a table. Between the two white boxes and resting on the platform was a metal pan. An automatic dispenser (Davis Scientific Instruments; Universal Feeder, Model No. 310) was placed in the middle of the table. Beans and/or small candies, nuts and dried fruit could drop from the dispenser into the metal pan. A source of auditory stimulation (Mallory Sonalert No. SC628H) was located approximately 2.25 meters in front of the S as (s)he responded on the buttons. The lights, buttons, Sonalert and automatic dispenser were connected to standard electro-mechanical relay programming equipment which arranged the presentation of stimuli and counted button presses and delivery of consequences. A second set of relay devices was in operation throughout the experiment to provide masking noise. A stopwatch was used to measure session time. The experiment was conducted in an experimental laboratory which contained normal experimental apparatus and tools.

Procedure

Token training. It was determined that since primary (food) reinforcers would not serve as the principal consequence for responding, a token reinforcement procedure would be useful. In this way a large consequence, for example an intact toy, could be presented at the end of the session if sufficient tokens, presented separately

on some schedule of response-contingent delivery, had been obtained by the subject during the session. Before beginning the formal experimental sessions, a token training phase was conducted with each child to establish the tokens as reinforcers. This consisted of two sessions of approximately 10 minutes each for each of the youngest children and one session for the oldest child. Garbanzo beans (chickpeas) were used as tokens. Each child was shown the experimental room individually and was allowed to explore the area. Toys, candies and fruits, restricted according to parental approval, were displayed on the floor. In front of each item was a 7 x 2 cm piece of white cardboard on which one or more red spots had been drawn. In front of the spots was a piece of masking tape with the adhesive part turned upward. To teach that tokens could be exchanged for items, the experimenter (E) explained to the child that he/she could win any item, but to do so he/she had to have as many beans as the number of spots on the cardboard. The experimenter showed the subject the pan into which the beans fell from the dispenser and demonstrated how to stick them onto the tape in front of the spots. The dispenser was operated manually during token training by E. When the number of beans equalled the number of spots, the child received what he/she had chosen. When the number of beans did not equal the number of spots, the child had to obtain more beans from the pan and then stick them on the tape. The experimenter assisted S as necessary during token training. This procedure was repeated for all the three or four displayed items the child chose to obtain.

Experimental sessions. Separate experimental sessions were

conducted for each subject; session length varied from 10 to 45 minutes. A session started with the illumination of the white lights on both buttons, and terminated when an S had obtained enough tokens to exchange for some item he/she wanted, at which time the white lights were turned off by E. Upon entering the experimental room, several toys, as well as edibles and gum, were shown to S. Each item had one of two prices; some items could be obtained by exchanging a small bottle completely filled with beans (approximately 30 beans), while others were priced a half-filled bottle of beans. The subject chose what he/she wanted that day. At the beginning of the first few sessions, S was told that a game could be played in front of the table and that the game could be played any way S wanted in order to earn beans necessary to exchange for the toy, edibles, or gum previously selected. The subject was also told that E would study while S was playing and could not talk. The experimenter answered with "I don't know" to any question concerning the correctness of the subject's performance and with the shortest possible response to any other questions.

After Session 37 for S-1 and Session 33 for S-3, instead of presenting the menu of items, E presented only one toy every session which she termed "The surprise of the day". Though S was not allowed to choose the toy, he/she could choose edibles or gum instead of the toy. Also, for S-1 after Session 22 and for S-3 after Session 33, all items were priced one bottle half filled with beans.

Subjects could press either of the two buttons which were available concurrently.

Training involved a shaping program to teach the S to press both buttons and to systematically establish responding on identical concurrent and independent variable interval 30 second (VI-30 sec) schedules on both buttons. The timers associated with the two buttons ran independently of each other. Thus if one timer terminated and set up a consequence which would occur following the next response to that button, the other timer continued to operate. It continued to operate independently during all consequence presentations associated with the other button. By pressing each of the buttons occasionally, the subject obtained a higher density of reinforcement than if (s)he consistently pressed only one. A changeover delay (COD) of 3 seconds was in effect to prevent immediate reinforcement of a switch from one button to the other; the first response associated with switching from one button to the other started a 3 sec clock, and only a second response after that 3 sec clock timed out could be followed by a consequence. Pressing the left button or the right button intermittently produced a 1 sec sound of the tone followed immediately by the delivery of a token, or sometimes a token plus an edible (approximately one every fourth token). Schedules of reinforcement were changed from continuous reinforcement to VI-10 sec, VI-15 sec, VI-23 sec and finally VI-30 sec as responding by S permitted. The Catania-Reynolds (1968) formula was used to determine spacing of the intervals.

Condition 1, the baseline condition, sought to determine rates on the two buttons when a neutral stimulus plus the effective reinforcer occurred following interval-terminating button presses on each lever. Pressing each button was followed occasionally by a 1 sec

sound of the tone immediately followed by the delivery of a token or sometimes a token plus edible. Throughout the remainder of the experiment this occasional concurrent presentation of token and edible was in effect. The COD was discontinued when the condition began and was never reinstated thereafter. Thus, a switching response could be followed immediately by a consequence if one had been set up on that button.

In Condition 2 pressing the left button continued to be reinforced on the VI-30 sec schedule with the 1 sec tone followed by a token. However, pressing the right button produced only the 1 sec tone, the potential conditioned reinforcer, according to its VI-30 sec schedule. Condition 3 reversed Condition 2.

Pressing the left button in Condition 4 was reinforced on the VI-30 sec schedule only with the delivery of a token; the 1 sec tone preceding the token was eliminated to determine whether pairing of the neutral stimulus (the tone) with the effective reinforcer was responsible for responding maintained by the tone on the other button. Pressing the right button was reinforced on the VI-30 sec schedule with the 1 sec tone.

Finally, in Condition 5 pressing the right button was reinforced on the VI-30 sec schedule only with delivery of a token; pressing the left button resulted in the 1 sec tone on the same schedule.

A summary of the experimental conditions is given in Table II. Table III indicates the sequence of exposure to experimental conditions for each S and the duration of exposure. Each S was not exposed to all conditions, and the order of exposure was different for each.

TABLE II: Summary of experimental conditions, Experiment III.

TABLE II

SUMMARY OF EXPERIMENTAL CONDITIONS

<u>Training</u>	<u>Condition 1</u>	<u>Condition 2</u>
CRF, VI-10", $L=S_n+T$ VI-15", VI-23", VI-30", 3" COD. $R=S_n+T$	VI-30" $L=S_n+T$ $R=S_n+T$	VI-30" $L=S_n+T$ $R=S_n$
<u>Condition 3</u>	<u>Condition 4</u>	<u>Condition 5</u>
VI-30" $L=S_n$ $R=S_n+T$	VI-30" $L=T$ $R=S_n$	VI-30" $L=S_n$ $R=T$

CRF - Continuous Reinforcement
 VI - Variable Interval
 " - Seconds
 COD - Changeover Delay

L - Left Button
 R - Right Button
 S_n - 1 Sec Tone
 T - Token (plus occasional edible)

TABLE III: Sequence and duration of exposure to experimental conditions for each subject, Experiment III.

TABLE III
SEQUENCE AND DURATION OF EXPOSURE TO
EXPERIMENTAL CONDITIONS FOR EACH SUBJECT

<u>Subject 1</u>		<u>Subject 2</u>		<u>Subject 3</u>	
Condition	Days of Exposure	Condition	Days of Exposure	Condition	Days of Exposure
Training	5 days*	Training	9 days*	Training	13 days**
1	5	1	5	1	3***
3	8	2	23	2	23
2	10	4	10	3	13
		5	5	5	7
		3	6		

* Not reported

** Only last three days reported

*** Combined with last three days of training;
reported as Condition 1 in Figure 9.

Results

Responses per minute are shown for S-1, S-2 and S-3 in Figures 7, 8 and 9, respectively. The ordinate of each figure displays the logarithm of the response rate in responses per minute (rpm) on each button, while sessions extend across the abscissa on a non-logarithmic scale. Consequence schedules associated with each concurrently available button are shown within the condition boundaries across the top of each figure.

During Condition 1, when responses to each button intermittently produced a 1 sec tone followed immediately by a token, S-1 responded on each button at approximately 10 rpm but showed a slight preference for the left button. In Condition 3, when the left button was associated only with the 1 sec tone--consequences for right button presses continued to result in occasional 1 sec tone-plus-token consequences--responding on the left button dropped quickly to almost zero. Responding on the right button was variable but substantially higher, averaging 26 rpm the last three days of the condition. Reversing the consequences associated with the two buttons, Condition 2, coincided with an immediate cessation of all presses to the right (tone-only) button and a higher response rate on the left button now associated with tone-plus-token consequences.

Subject 2 responded on both buttons in Condition 1 when equal consequences were programmed on the two buttons. Consistently higher rates on the left button (tone-plus-token) occurred in Condition 2, averaging approximately nine per minute. However, rates of five

Figure 7: Responses per minute for Subject 1 in Experiment III, shown across sessions with a logarithmic ordinate. Experimental conditions appear at the top of the figure. S_n indicates a 1 sec tone, and T indicates a token.

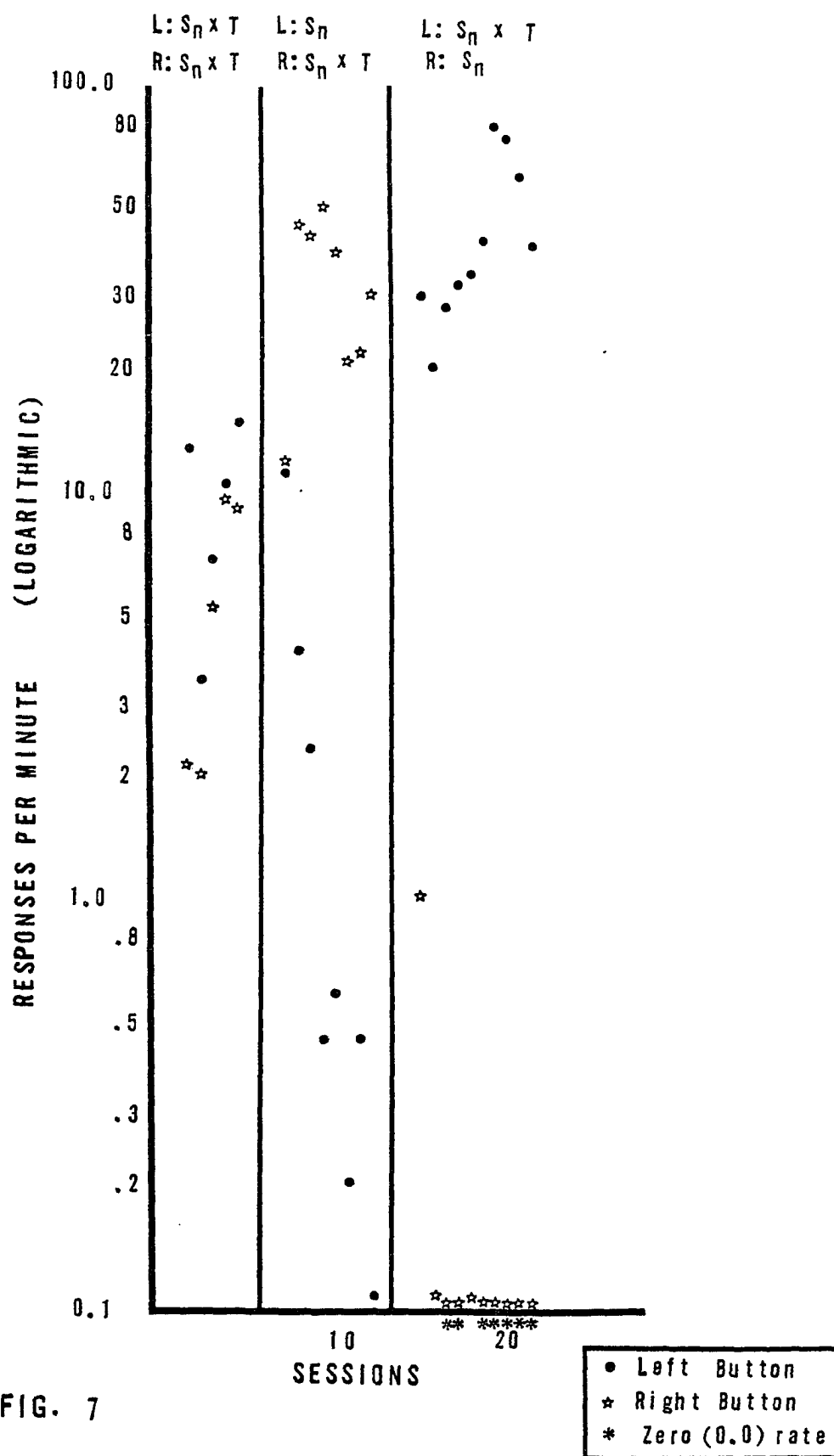


Figure 8: Responses per minute for Subject 2 in Experiment III.

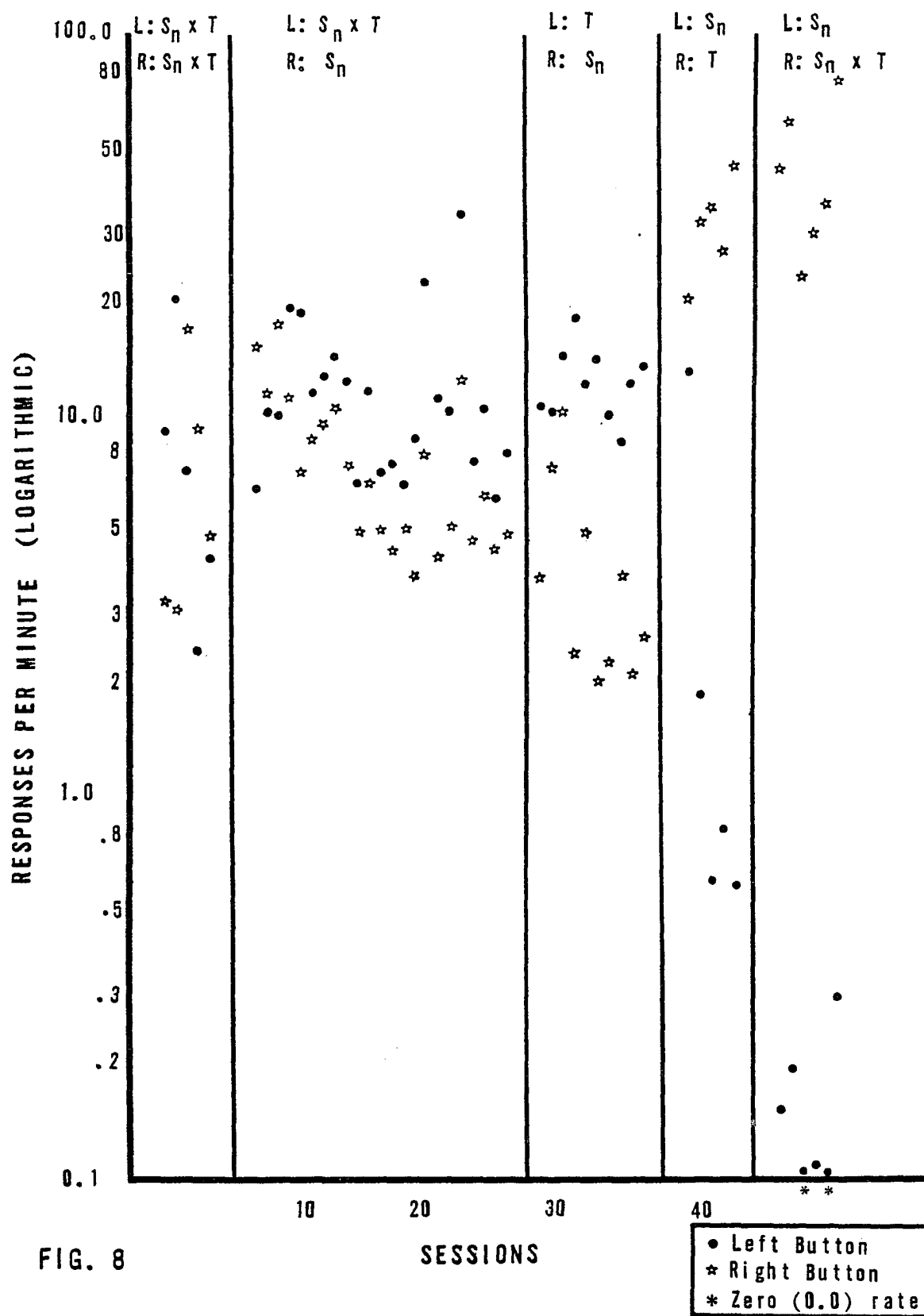
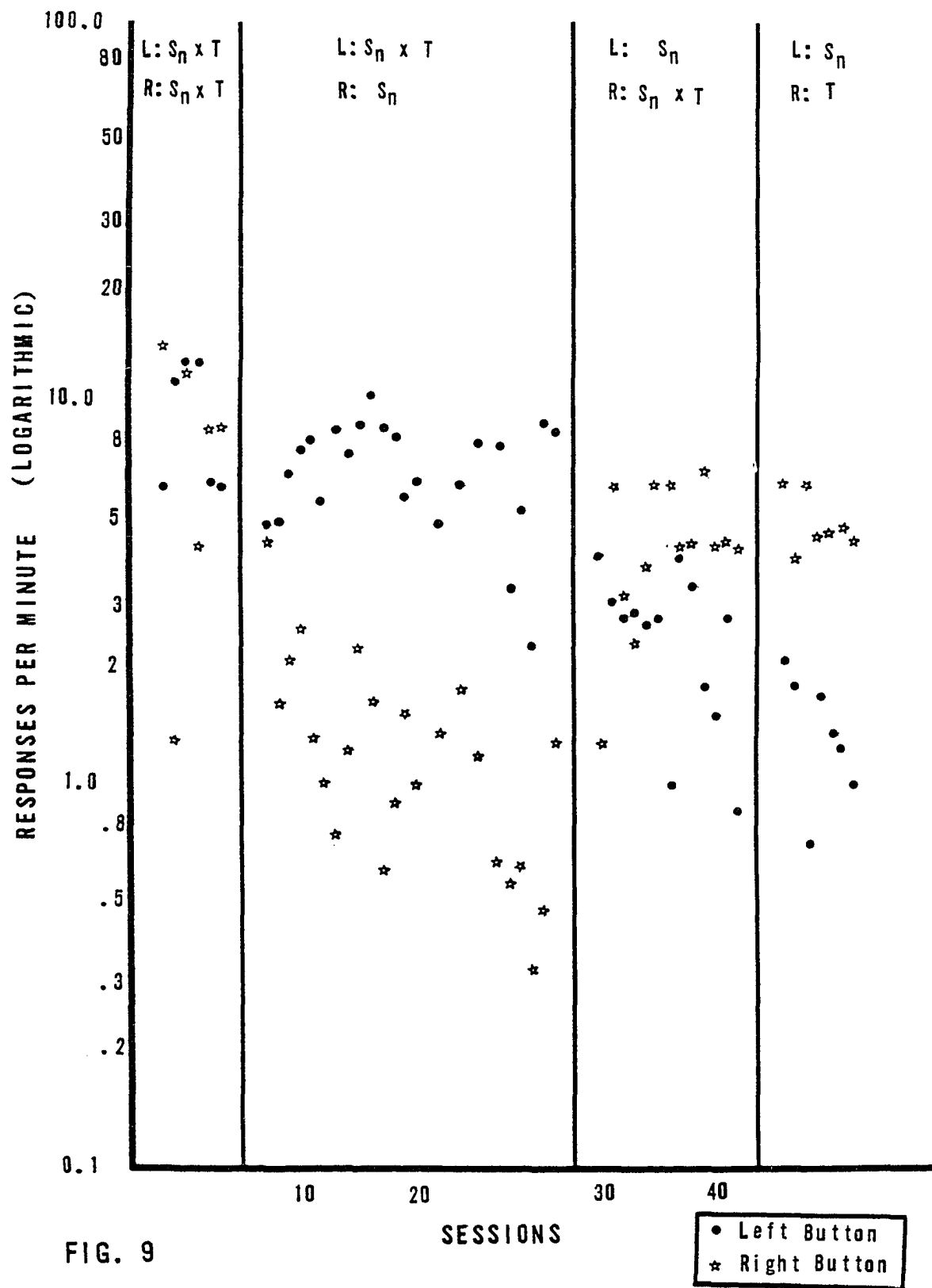


Figure 9: Responses per minute for Subject 3 in Experiment III.



responses per minute were maintained on the right button over the 23 days of the condition when the consequence associated with this button was only a 1 sec tone delivered on the VI-30 sec schedule. Removal of the 1 sec tone prior to the token on the left button in Condition 4 did not greatly affect the response rate on either button; rates of approximately 11 per minute and three per minute were maintained on the left and right button, respectively. When a reversal of the Condition 4 consequences and buttons occurred in Condition 5, rates on the token-only right button increased to an average of above 30 rpm, while rates on the tone-only left button approached zero. Reinstatement of pairing of tone-plus-tokens on the right button in Condition 3 resulted in no change in rate on either button.

Variable but approximately equal rates of button pressing were maintained by S-3 in Condition 1. Then when tokens were eliminated from the consequence associated with the right button, the response rate on this button dropped to somewhat less than 1.0 rpm by the end of Condition 2 as compared to a rate of 5-6 rpm on the left button. During the reversal of buttons and consequences in Condition 3, the rate on the tone-only left button was two per minute, while on the tone-plus-token right button a rate of slightly above four was maintained. Removal of the tone preceding the token associated with presses on the right button had no great effect on either the rate of right button or left button (tone-only) responding when compared to the last four days of Condition 3.

Discussion

Subject 1 did not respond on the tone-only button for any extended period of time, either during the original presentation of the tone-only consequence in Condition 3 or in the reversal in Condition 2; in addition, reversal to a zero rate was immediate.

Both S-2 and S-3 maintained higher rates on the tone-only button when it was first available. For S-2, removal of pairing in Condition 4 did not greatly reduce the response rate on the tone-only button, contrary to what a pairing hypothesis would predict. The rate maintained on the tone-only button was therefore not a function of the tone-token pairing which was scheduled on the other button. Finally, the reinstitution of pairing in Condition 3 did not result in an increase in the rate on the tone-only button, and S-2 did make contact with this changed set of contingencies. According to a pairing explanation of conditioned reinforcement, return to pairing should have produced an increase in rate on the tone-only button.

Removal of pairing for S-3 in Condition 5 also demonstrated that the low rate maintained by the tone-only consequence was due to some factor(s) other than pairing. Thus, in this second replication (see Experiment II also), no confirmation of the pairing hypothesis occurred when normal children served as subjects instead of pigeons with which Zimmerman (1963) obtained positive results.

It should be noted, however, that only the question of responding maintained by the tone-only consequence was tested. Whether the initial pairing of tones with the unconditioned reinforcer was necessary

for the initial response rate on the tone-only button was not analyzed.

A number of factors could account for the different rates in the tone-only conditions maintained by S-1 versus S-2 and S-3. Subject 1 was older and more verbal, and voiced aloud the contingency changes the day they occurred. For example, early in Session 6 she said, "I think something is wrong with the left button." Later in the same session, she said, "On this one [left] I don't get any beans, only the sounds." Early in the 14th session, she said, "Well, now I only get things here [pushing the left button]." And frequently her high rates on the token-only button occurred as she was making such statements to herself as, "Now I am using the typewriter." The other two subjects did not make such statements. Thus, rule-governed behavior (Skinner, 1969) may have controlled more of S-1's behavior than that of S-2 and S-3. With conditions changing as often as they did, the advantage of such rule-governed responses in the discrimination of the contingencies associated with the two buttons might have been substantial. Also, the two younger children's previous history of reinforcement may have contributed in undetermined ways to the tone-only response rates which they maintained.

In addition, for all three subjects the reinforcers and related deprivation operations were greatly different from those of animal subjects which can be deprived to 80 percent of normal body weight and consequted with food. The children here were well-fed at home, and the items for which tokens could be exchanged, while chosen by the children, were not unavailable to them in other settings during the day. The relative weakness of these consequences was seen with S-3,

who occasionally did not want to go to the laboratory, or, once there, engaged in other activities instead of pressing the buttons. The exchange procedure and resulting delay in receipt of previously effective reinforcers may have worked in opposition to the development of discrimination in the younger children. Also, the change in stimulation associated with the tones may have been more reinforcing for the younger children in the particular setting of the experiment. It would not necessarily follow, however, that social consequences alone when delivered by adults would maintain similar response rates due to simple stimulus change or some other intrinsically reinforcing property of verbal consequences.

Perhaps another important difference between the Zimmerman procedure and the present one was the effort required to respond to the two manipulandi, and the nature of the response required. Keys were close together and pecking is a high-rate response for the pigeon in most settings. The children had to walk several steps to move from one button to the other, and button pressing, while not particularly effortful, is probably not so natural to the human as pecking is for the bird in food-related settings.

EXPERIMENT IV

Method

The three variations below systematically replicate and extend Thomas (1969); the purpose of the replication was to determine if rats would respond as did Thomas' pigeons in a multiple schedule situation in which a stimulus paired with food in one component is the only consequence for responding in the other. In the Thomas study, pigeons maintained responding during the component in which responding produced only the previously neutral stimulus.

Subjects

Six naive male albino rats randomly selected (and then assigned to Experiments IVA, IVB and IVC) from an original group of 20 rats obtained from The Upjohn Company colony in Kalamazoo, Michigan, and 90-120 days old at the start of the experiment, served as subjects. Each was individually housed with Purina Laboratory Chow constantly available except in the experimental chamber. Subjects were maintained at approximately 85% free feeding weight by limiting water availability to between three and five minutes per day.

Apparatus

Six experimental chambers were used, each 13 x 20 x 17 cm. Ceilings and walls were of plexiglas, with interior wall surfaces covered with metal. A rodent lever projected 3 cm into the chamber

through the front wall, 2.5 cm from the left wall and 7 cm above the tubular grid floor. Located 6 cm to the right of the lever and 2 cm above the floor was a 3 cm diameter hole which allowed access to a liquid dipper (LVE/BRS Model 114-02; cup size 0.1 cc). Masking noise in the sound-attenuated containers housing the chambers was provided by a Grason-Stadler white noise generator (Model 901B) and by individual exhaust fans. A white light (Chicago Miniature No. 1819) mounted outside the chamber served as the houselight, and the left wall contained a recessed red stimulus light and a source of auditory stimulation (Sonalert Model SC628). This tone generator was modified to produce tones of 2900 Hz at four intensities when its operating current was passed through resistors of 0, 10,000, 20,000 and 40,000 ohms, respectively. All programming and recording of experimental events were accomplished by a PDP-8e computer manufactured by Digital Equipment Corporation of Maynard, Massachusetts, and located in a nearby room. Experimental event scheduling and data recording were coordinated by a SKED process-control system available through State Systems, Inc. of Kalamazoo, Michigan (Snapper, Stephens, Cobeze and van Haaren, 1976).

General procedure

Subjects were trained to press the lever with four seconds of dipper availability as the consequence; the dipper reservoir contained a milk solution composed of 0.75 cups of Carnation Instant Nonfat Dry Milk added to water to produce each quart of milk. The number of lever presses required for dipper availability was gradually raised to ten.

Procedure, Experiment IVA. Subjects 1 and 2 were then switched to a reinforcement schedule in which four minutes of houselight-on (HL) alternated with four minutes of darkness. Each twelfth (FR-12) lever press during the HL condition produced a 1 sec tone (through 0 resistance) followed immediately by a four second availability of the dipper. During dark periods responses had no effect except for the last five seconds of the four minute period when each lever press initiated/reinitiated a five second period of continued darkness to prevent accidental reinforcement of responding in darkness by onset of the HL condition. Sessions were conducted daily and terminated following 60 milk presentations.

After 21 days, conditions were changed so that a two minute period of HL was followed by two minutes of darkness (DK), followed by two minutes of red stimulus light-on (Red), followed by two minutes of DK, with the sequence recycling until 30 milk presentations had occurred. The FR-12 schedule which resulted in a 1 sec tone followed by 4 sec dipper availability was in effect during the HL condition, and responses again had no effect during DK except to extend the period by 5 sec past each lever press during the last 5 sec of DK. In the Red condition, every third lever press (FR-3) was immediately followed by a 1 sec tone, the potential conditioned reinforcer. No milk presentations occurred in the Red component. This condition remained in effect for 36 days, and is pictured in simplified state diagram format in Diagram 7.

A final manipulation was in effect for the last 20 days of the experiment, the purpose of which was to determine whether a new stimulus

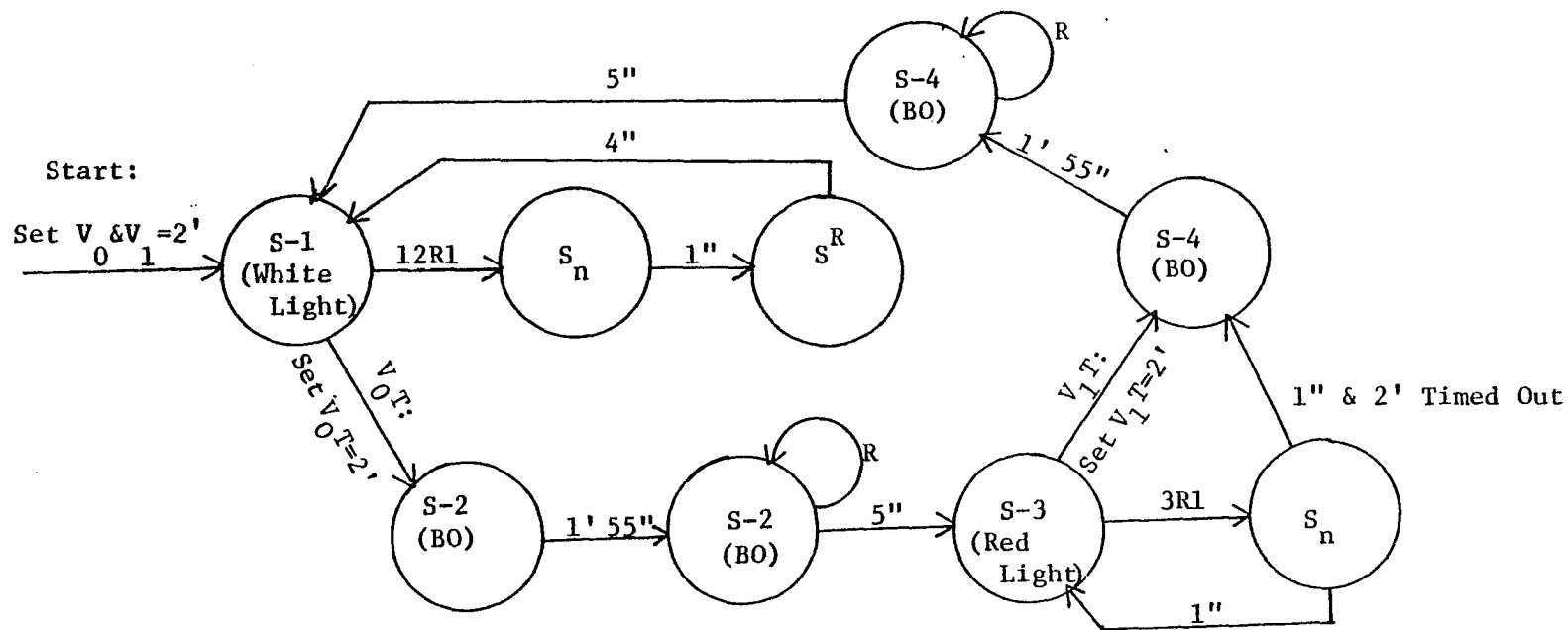


Diagram 7. Simplified state diagram of Experiment IV, Condition 2: presentations of only the previously neutral stimulus every third lever press during the Red component. The notations $V_0 T$ and $V_1 T$ are required to indicate that the variable timer did NOT reset each time S-1 or S-3 was reentered following either $S_n + S^R$ or S_n -only. BO indicates blackout.

not paired with the unconditioned reinforcer would maintain responding during the Red component. During Red, each lever press resulted in a series of brief red light flashes--each lever press turned the red light off for 0.2 sec, on for 0.2 sec, off for 0.2 sec, etc., for a total flashing period of 1 sec. Conditions during HL and DK components remained unchanged from the previous condition. Table IV summarizes the experimental conditions for Experiments IVA, IVB and IVC.

Results, Experiment IVA. Table V summarizes response rate data for the two subjects of Experiment IVA. During the last five days of the HL component in Condition 1, S-1 pressed the lever at a rate of 153.24 responses per minute (rpm). This and all rate calculations in Experiment IV excluded consequence presentation time. Response rates during DK were insignificant throughout the experiment for both subjects. Response rates in the HL component of Condition 2 averaged 129.96 rpm during the first five days and 127.02 rpm for the last five days for S-1. When the Red component providing 1 sec tones on an FR-3 schedule was introduced in Condition 2, S-1 averaged 4.09 rpm during the first five days; this average dropped to 0.07 rpm for the last five days of the condition. In Condition 3, HL rates averaged 126.65 rpm and 100.34 rpm during the first five and last five days, respectively. In the Red component, the continuous reinforcement schedule of light flashes which were not paired with milk in the HL component maintained a response rate of 0.13 and 0.05 rpm for the first and last five days, respectively.

TABLE IV: Summary of experimental conditions for Experiments IVA, IVB, and IVC.

TABLE IV

SUMMARY OF EXPERIMENTAL CONDITIONS FOR EXPERIMENTS IVA, IVB, AND IVC.

Condition	Days	<u>Description of Condition</u>		
		Experiment IVA	Experiment IVB	Experiment IVC
1	21	4' White, FR-12: 1" Tone + Milk 4' Dark - Extinction*	Same as IVA, Condition 1	2' White, FR-12: 1" Tone + Milk 2' Dark - Extinction* 2' Red, FR-12: 1" Tone + Milk 2' Dark - Extinction*
2	36	2' White, FR-12: 1" Tone + Milk 2' Dark - Extinction* 2' Red, FR-3: 1" Tone 2' Dark - Extinction*	2' White, FR-12: 1" Tone + Milk 2' Dark - Extinction* 2' Red, Extinction 2' Dark - Extinction*	2' White, FR-12: 1" Tone + Milk 2' Dark - Extinction* 2' Red, FR-3: 1" Tone 2' Dark - Extinction*
3	20	2' White, FR-12: 1" Tone + Milk 2' Dark - Extinction* 2' Red, CRF: 1" of brief light flashes 2' Dark - Extinction*	2' White, FR-12: Milk 2' Dark - Extinction* 2' Red, CRF: 6 equipro- bable events 2' Dark - Extinction*	2' White, FR-12: 1" Tone + Milk 2' Dark - Extinction* 2' Red, CRF: 1" Tone 2' Dark - Extinction

*Response in last 5" delays onset of next condition by 5".

TABLE V: Experimental conditions and results, Experiment IVA.

TABLE V

EXPERIMENTAL CONDITIONS AND RESULTS, EXPERIMENT IVA

<u>Conditions</u>		<u>S1</u>	<u>S2</u>
Condition 1	Houselight: FR-12: T&S ⁺	Houselight: FR-12: T&S ⁺	
Last 5 Days	153.24 responses per minute	111.48 responses per minute	
Length of Condition: 21 Days			
Condition 2	Houselight: FR-12 T&S ⁺	RED: FR-3 T	Houselight: FR-12 T&S ⁺
First 5 Days	129.6	4.09	75.52
Last 5 Days	127.02	0.07	58.78
Length of Condition: 36 Days			
Condition 3	Houselight: FR-12 T&S ⁺	RED: CRF Light Flashes	Houselight: FR-12 T&S ⁺
First 5 Days	126.65	0.13	48.48
Last 5 Days	100.34	0.05	49.06
Length of Condition: 20 Days			

T&S⁺ = 1" Tone followed by primary reinforcement
 T = 1" Tone only
 S⁺ = Primary reinforcer only
 Light Flashes = 1" series of 0.2" light flashes
 Houselight = Houselight-on
 RED = Red light-on
 FR-12, FR-3,
 and CRF = Schedules of stimulus presentation

Similar response rates were recorded by S-2. As with S-1, S-2's response rates tended to drop through the course of the experiment during the HL component.

Procedure, Experiment IVB. The first 21 days, Condition 1, for Subjects 3 and 4 were identical to those of S-1 and S-2. The next 36 days, Condition 2, were similar with the exception that during the Red component responding had no effect. In the final 20 days of the experiment the consequences for responding were changed. Every twelfth lever press during the HL component immediately produced only the 4 sec dipper availability (with its related dipper operation noises), while each lever press during the Red component produced one of six consequences, each of which had an equal opportunity of occurring: a) the loudest tone for 1 sec; b) the tone produced through the 10,000 ohm resistance for 1 sec; c) the tone produced through the 20,000 ohm resistance for 1 sec; d) the tone produced through the 40,000 ohm resistance for 1 sec; e) a 1 sec duration series of 0.2 sec red light flashes off and on; or f) a 1 sec duration series of 0.2 sec houselight flashes on and off. The purpose of this condition was to determine whether the random presentation of one of several novel stimuli not paired with the unconditioned reinforcer would, when presented following each lever press, maintain responding.

Results, Experiment IVB. Table VI summarizes response rates for the two subjects in Experiment IVB. Rates in the HL component declined through the course of the experiment as in Experiment IVA; rates in DK were insignificant. Rates during the Red component in Condition 2

TABLE VI: Experimental conditions and results, Experiment IVB.

TABLE VI

EXPERIMENTAL CONDITIONS AND RESULTS, EXPERIMENT IVB

<u>Conditions</u>		<u>S1</u>	<u>S2</u>
Condition 1		Houselight: FR-12: T&S ⁺ -----	Houselight: FR-12: T&S ⁺ -----
Last 5 Days		147.72	140.88
Condition 2	Houselight: FR-12 T&S ⁺ -----	RED: Extinction -----	Houselight: FR-12 T&S ⁺ -----
First 5 Days	118.24	5.76	131.40
Last 5 Days	82.72	0.35	127.48
Condition 3	Houselight: FR-12 S ⁺ -----	RED: CRF 6 Stimuli -----	Houselight: FR-12 S ⁺ -----
First 5 Days	63.30	0.84	115.68
Last 5 Days	105.30	0.72	99.54

declined to very low levels by the end of the condition--0.35 rpm for both subjects. Slightly higher rates were maintained by the presentation of one of six equiprobable events following each lever press in the Red component of Condition 3; none of the six equiprobable events were paired with primary reinforcement in the HL component.

Procedure, Experiment IVC. It is possible that a low rate of responding in the Red component in Condition 2 of Experiment IVA might be due to the novelty of the Red component there. In Condition 1 the HL and DK components alternated, and no response in Red had ever occurred or been followed by food. Subjects 5 and 6 were therefore exposed to a 4-component multiple schedule for the first 21 days; a 2 min period of HL was followed by a 2 min period of DK, 2 min of Red, 2 min of DK, and then a recycling of these conditions until 60 milk presentations had occurred. During both HL and Red components each twelfth lever press produced a 1 sec tone (through 0 resistance) followed immediately by 4 sec dipper availability. Responses during darkness were ineffective except for the 5 sec extension of DK initiated by each response in the last 5 sec of these periods.

Conditions were then changed so that for the next 36 days every third lever press during Red was followed by a presentation of only the 1 sec tone, the potential conditioned reinforcer; no milk was presented in Red. The session was terminated after 30 milk presentations. All other conditions remained unchanged.

In the final 21 days of the experiment, each lever press rather than every third during the Red component resulted in the presentation

of the 1 sec tone. This change sought to determine whether responding which produced the potential conditioned reinforcer would be maintained if its response requirement were small. In addition, for the last 15 days S-6 was placed in another identical chamber due to an equipment malfunction; and for the last nine days the food reinforcement schedule for S-6 was changed so that in the HL component every third lever press (FR-3) resulted in the 1 sec tone followed by 4 sec dipper availability because S-6's response rate on the FR-12 schedule had dropped to a low level.

Results, Experiment IVC. Table VII summarizes response rates for S-1 and S-2 in Experiment IVC. Similar response rates were maintained in the equivalent HL and Red components of Condition 1. Rates in the Red component dropped to low levels--1.34 and 1.44 rpm for S-1 and S-2, respectively--by the end of Condition 2 when the consequence for responding was the 1 sec tone presented after every third response. Rates dropped to even lower levels in the Red component by the end of Condition 3 when the 1 sec tone was presented after every response--0.39 and 0.50 rpm for S-1 and S-2, respectively.

For comparison purposes, response rates estimated from the cumulative records reported by Thomas (1969) show peck rates of 150-300 rpm in the FR-120 and FR-80 grain components, and of 50-150 rpm in the FR-10 potential conditioned reinforcer component. At times rates were highly variable, as seen in Figure 4.9 (Thomas, 1969, p. 87).

Discussion

By the end of Condition 2 the response rate of each subject

TABLE VII: Experimental conditions and results, Experiment IVC.

TABLE VII

EXPERIMENTAL CONDITIONS AND RESULTS, EXPERIMENT IVC

<u>Conditions</u>	<u>S1</u>		<u>S2</u>	
Condition 1	Houselight: FR-12 T&S ⁺ -----	RED: FR-12 T&S ⁺ -----	Houselight: FR-12 T&S ⁺ -----	RED: FR-12 T&S ⁺ -----
Last 5 Days	96.30	101.86	40.48	45.96
Condition 2	Houselight: FR-12 T&S ⁺ -----	RED: FR-3 T -----	Houselight: FR-12 T&S ⁺ -----	RED: FR-3 T -----
First 5 Days	82.26	13.94	20.17	4.20
Last 5 Days	76.42	1.34	45.28	1.44
Condition 3	Houselight: FR-12 T&S ⁺ -----	RED: CRF T -----	Houselight: FR-12 T&S ⁺ -----	RED: CRF T -----
First 5 Days	95.08	0.20	42.68	3.08
Last 5 Days	92.08	0.39	24.42 (FR-3)	0.50

in Experiment IVA was very low in the tone-only Red component although the tone was always paired with milk delivery on the FR-12 schedule in the HL component. Responding in Red in Condition 2 declined rapidly, with the highest rate of 17.4 rpm occurring for S-1 the second session after the change while for S-2 it occurred on the first day, 15.6 rpm. These low rates were probably due to the fact that subjects were first exposed to the Red component in Condition 2. The unpaired stimulus presented following every lever press in Red in Condition 3 supported an equivalent low rate when only light flashes occurred following each lever press.

The subjects in Experiment IVB also responded at very low rates in Red during Condition 2. Here, however, no consequences occurred following lever presses. This condition was to have provided general comparative data had rates been higher in the Condition 2 Red component of Experiment IVA. When any one of six unpaired and equiprobable events could be produced by each lever press in Condition 3, a rate of near 1.0 rpm was maintained at the end of the experiment. It would have been informative to have determined what rate these six equiprobable but unpaired events would have maintained for the two subjects in Experiment IVA which were never exposed to a total extinction condition.

The Red component of Condition 2 for subjects in Experiment IVC was not new, and yet rates in Red dropped quickly when the condition began. By the end of the condition, rates of 1.4 rpm were maintained for each rat while 76 and 45 rpm were occurring for S-1 and S-2, respectively, in the HL component. Presentation of the tone following each lever press in Red during Condition 3 reduced the rates for each

subject to well below 1.0 per minute.

These results taken together provide no support for the pairing hypothesis. Oberlin (1977) attempted to obtain conditioned reinforcer effects with a Thomas procedure modified for the use of children as subjects, and also found no support for pairing.²⁰ That Thomas (1969) obtained different results with pigeons as subjects raises the question of whether the results he obtained are to some extent attributable to species-specific differences. Current literature on autopecking suggests this possibility. That pigeons show a tendency to peck salient stimuli in food-related situations has been demonstrated (Staddon and Simmelhag, 1972; Wessels, 1974). A somewhat dissimilar but salient stimulus in whose presence pecks are occasionally followed by stimuli closely associated temporally with food may make the stimulus situation similar enough to that of food presentation that the high operant level pecking behavior generalizes to a stimulus which is both salient and related to food.

Current literature suggests that this hypothesis is not untenable. That pigeons peck their surroundings during the time in periodic food presentation situations when food is not available has been shown by Staddon and Simmelhag (1972). That they direct those pecks to salient stimuli in the environment is seen in the work by Wessels (1974) and in the literature dealing with the autoshaping phenomenon first described by Brown and Jenkins (1968). A more recent finding is that the auto-shaped keypeck appears to originate in the pecking of a lighted grain

²⁰ This experiment was conducted by Michael B. Oberlin under the supervision of the author and Oberlin's Master's Thesis Committee.

hopper which then generalizes to pecking a key of similar color whose illumination precedes food delivery (Davol, Steinhauer and Lee, 1977).

A somewhat dissimilar but salient stimulus, the lighted key during the conditioned reinforcer-only (S^{Δ}) component, in whose presence pecks are occasionally followed by stimuli closely associated temporally with reinforcement in the other (S^D) component, may make the S^{Δ} component of the multiple schedule similar enough to the S^D component that the bird's generalized responding is maintained. Such could be the case if the parameters of the two components were sufficient to generate "pecking in a feeding situation" which then maintained more control over responding in the pigeon than did the S^{Δ} stimulus associated with the stimulus-only component. To begin to test this hypothesis, one could vary the lengths of the components of the multiple schedule, and also analyze the S^{Δ} component response rate in terms of rates in early versus later periods of the component. Whether other species would show similar behavior under specific conditions is also an empirical question.

EXPERIMENT V

Method

This experiment systematically replicated a portion of one by Schuster (1969); the purpose of the replication was to determine whether rats would show similar rate increases as did pigeons in a multiple schedule situation when a schedule of "added" stimuli was superimposed on one of two otherwise identical variable interval food components.

Subjects and apparatus

These were the same as in Experiment IV except that two rats and two chambers were used.

Procedure

Subjects were trained to press the lever with 4 sec of dipper availability as the consequence. Once lever pressing was established, the schedule requirement for dipper availability was changed to variable interval 10 seconds (VI-10 sec), in which the first lever press after 10 sec on the average resulted in dipper presentation. Two sessions of VI-10 sec were followed by two sessions of VI-20 sec.

A multiple VI-30 sec VI-30 sec schedule was then instituted for 35 sessions, with the houselight-on (HL) or the red stimulus light-on (Red) being the two stimuli correlated with the two components of the schedule. When either light was illuminated, responding was consequted

according to a VI schedule with a 1 sec tone (through 0 resistance) followed by 4 sec dipper availability. Red and HL components alternated after every second dipper presentation; the formula described in Catania and Reynolds (1968) determined the spacing of intervals in the equal and independent VI-30 sec schedules. The variable interval associated with the HL component was active only when that component was in effect. It was not timing when the Red component was in effect, and a reinforcer could not therefore be set up for a HL component lever press when the Red component was in effect. Schuster (1969) did not make specific reference to this aspect of his reinforcement procedure. Daily sessions terminated after 60 milk presentations. Data from this condition are not reported.

The 1 sec tones immediately preceding milk presentation were then replaced by a 1 sec period in which both red light and house-light flashed off and on every 0.2 sec. This change occurred in both components and was initiated in order to minimize the chance that the potential conditioned reinforcer would be aversive, since it might be argued that the tone was excessively loud. In all other respects this condition was identical to the preceding one, and remained in effect for 13 sessions. Data from the last six sessions of this condition are presented; they provide baseline rates of responding during each component when identical contingencies were in effect.

The Red component was then modified; every fourth lever press (Fr-4) which was not consequated with the 1 sec series of light flashes-plus-milk sequence was followed by only the 1 sec series of light flashes, the potential conditioned reinforcer. Thus an FR-4 schedule of light

flashes was superimposed on the VI-30 sec schedule of light flashes-plus-milk in the Red component. A simplified state diagram of this condition is shown in Diagram 8.

This Red component change remained in effect for 40 sessions, at which time the FR-4 superimposed schedule of the 1 sec series of light flashes was switched from the Red to the HL component. Sixteen sessions of this reversal terminated the experiment.

Results

Relative response rates in each of the three conditions for the two subjects are shown in Figures 10 and 11, respectively. A relative response rate was calculated for each session by dividing the response rate during the HL component by the response rate during the Red component. Thus a relative rate of 1.0 indicates equal rates in the two components during a session. A relative rate below 1.0 indicates a higher response rate during the Red component, while a relative rate above 1.0 indicates a higher rate during the HL component.

In the multiple schedule when equal VI-30 sec presentations of a 1 sec series of light flashes followed by primary reinforcement were scheduled in each component, labeled EQUAL in the figures, relative response rates for both subjects were approximately 1.0, indicating similar rates in the two components. When additional 1 sec series of light flashes were also programmed to occur following every fourth lever press during Red, the relative rate of S-1 fell to approximately 0.75 by the end of the ADDED FR-4 RED condition, indicating a higher rate in the Red component. Rates for both components increased from

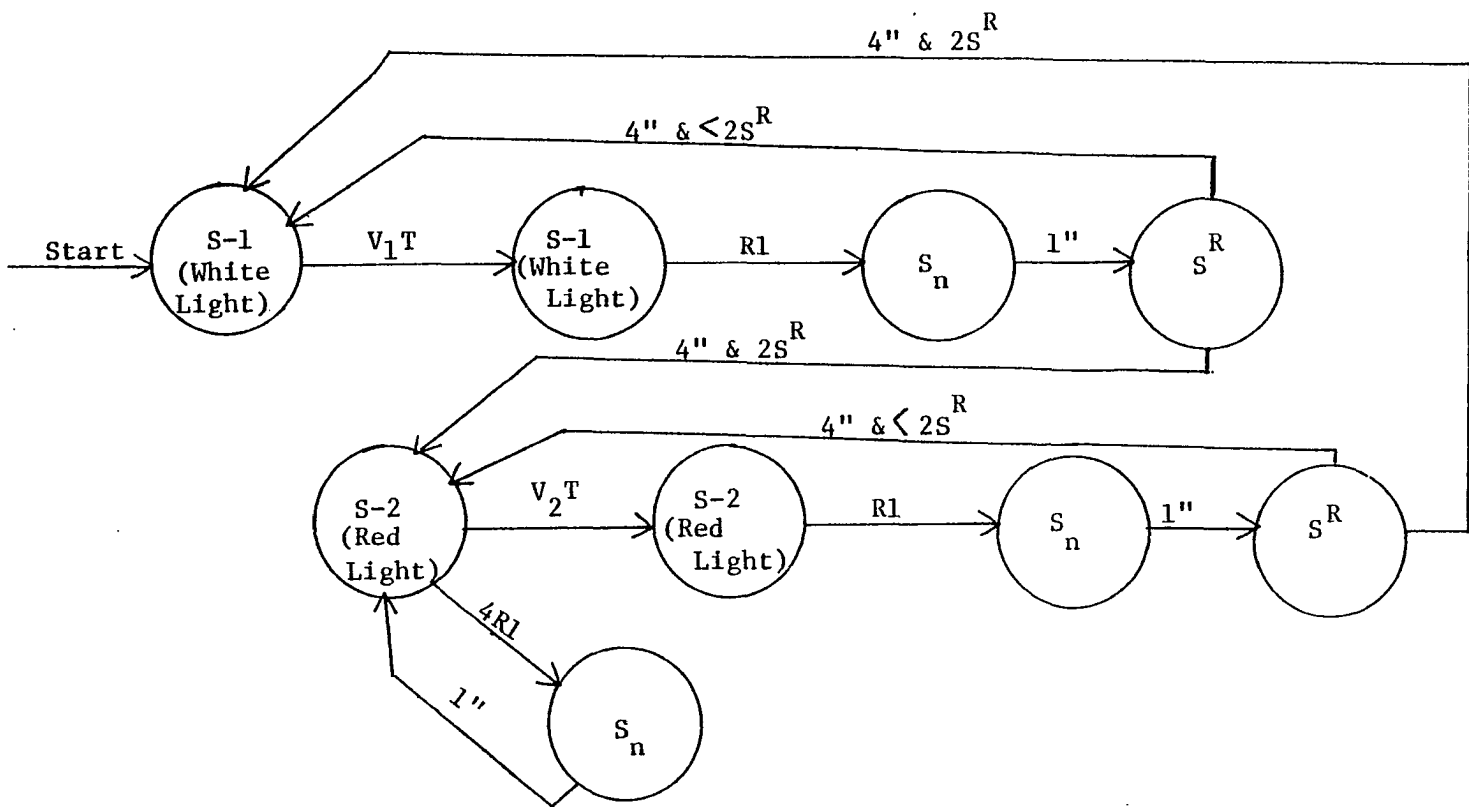


Diagram 8. Simplified state diagram of Experiment V, Condition 2: added presentations of the previously neutral stimulus every 4th lever press during the Red component. Schuster did not report whether the V_1T timer ran when S-2 was in effect (which would have frequently arranged for the delivery of a consequence following the first response after transition into S-1). The timers were not continuously running in this experiment.

Figure 10: The relative response rate of Subject 1 across sessions of Experiment V. A relative rate was calculated for each sessions by dividing the response rate during the Houselight (HL) component by the response rate during the Red (R) component.

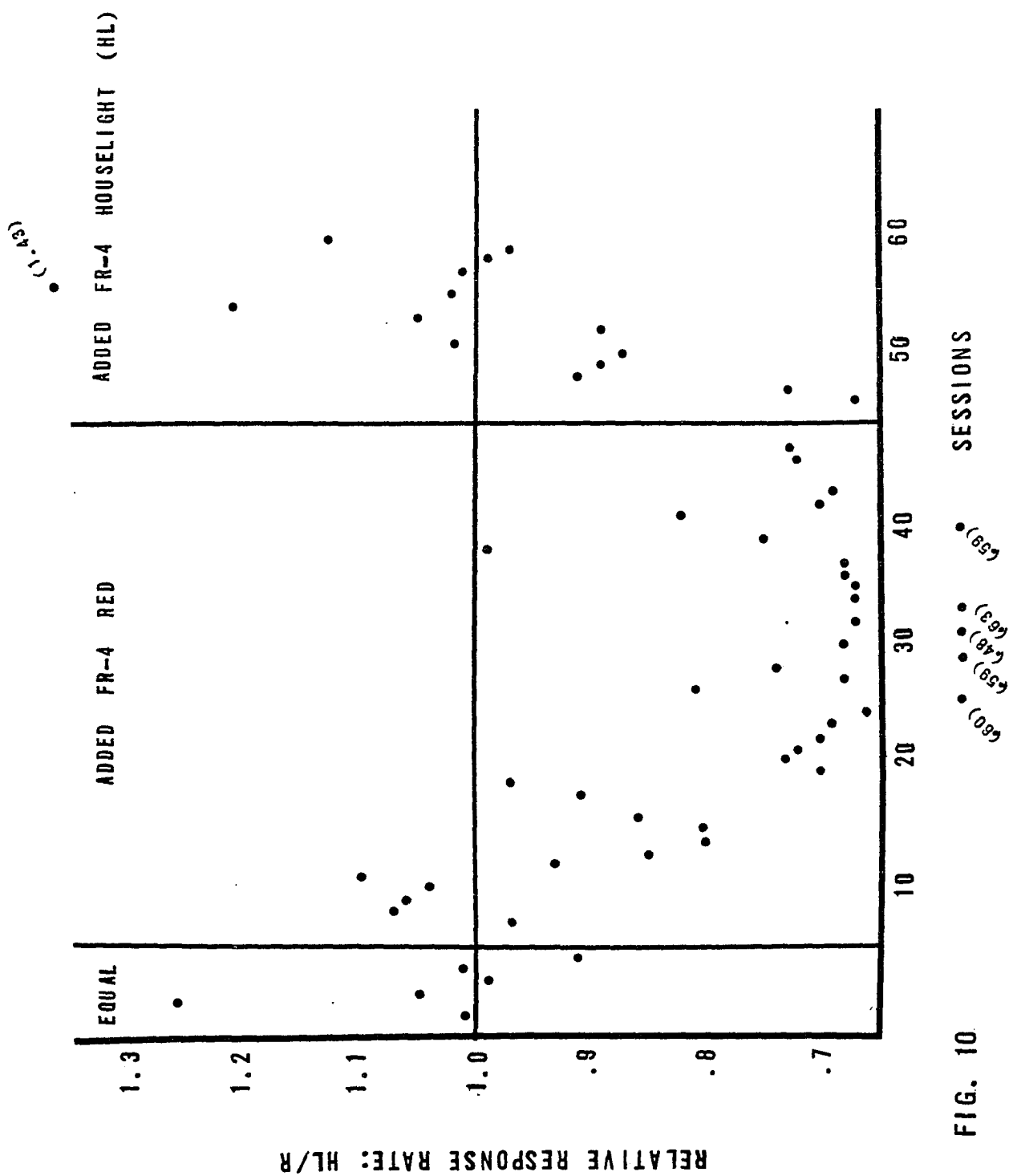


FIG. 10

those in the EQUAL condition, with rates in Red showing the larger increase, as is seen in Table VIII.

When the superimposed additional stimuli were programmed to occur following every fourth response during the HL component, S-1's relative rate returned to approximately 1.0, indicating that rates during the two components were similar. This change in relative rate occurred due to a joint increase in the response rate during HL and a decrease in the response rate during Red. Table VIII provides component rate data for the last five days of each condition. It should be noted that the experiment terminated as the relative response rate was increasing.

Relative rates for S-2, pictured in Figure 11, do not show such consistent changes. Widely varying relative rates occurred in both conditions in which the added stimuli were programmed. The superimposition of the added stimuli in the Red component was associated with an initial increase in relative rate--higher rates in the HL component--followed by a gradual decline, marked by considerable day-to-day variability, to a relative rate below 1.0. Shifting the superimposed added stimulus schedule to the HL component did not affect relative rate in any consistent manner. Table VIII presents a similar view. The rate increase in the Red component was slightly greater in Condition 2, but further increase in rates in Condition 3 did not favor the HL component when the added stimuli were switched to HL.

For comparison purposes, Schuster (1969) obtained an average doubling of keypeck rates in the component in which the added FR-11 schedule of the potential conditioned reinforcer was superimposed.

TABLE VIII: Response rates averaged over the last five days of each condition in each component of the multiple schedule for each subject, Experiment V.

TABLE VIII

RESPONSE RATES AVERAGED OVER THE LAST FIVE DAYS OF
EACH CONDITION IN EACH COMPONENT
OF THE MULTIPLE SCHEDULE FOR EACH SUBJECT

<u>Condition</u>	<u>S1</u>		<u>S2</u>	
	<u>Houselight</u>	<u>Red Light</u>	<u>Houselight</u>	<u>Red Light</u>
Condition 1	5.57	5.50	16.28	15.83
Condition 2	10.15	14.67	34.21	38.92
Condition 3	14.31	13.09	39.38	46.88

Figure 11: The relative response rate of Subject 2 in Experiment V.

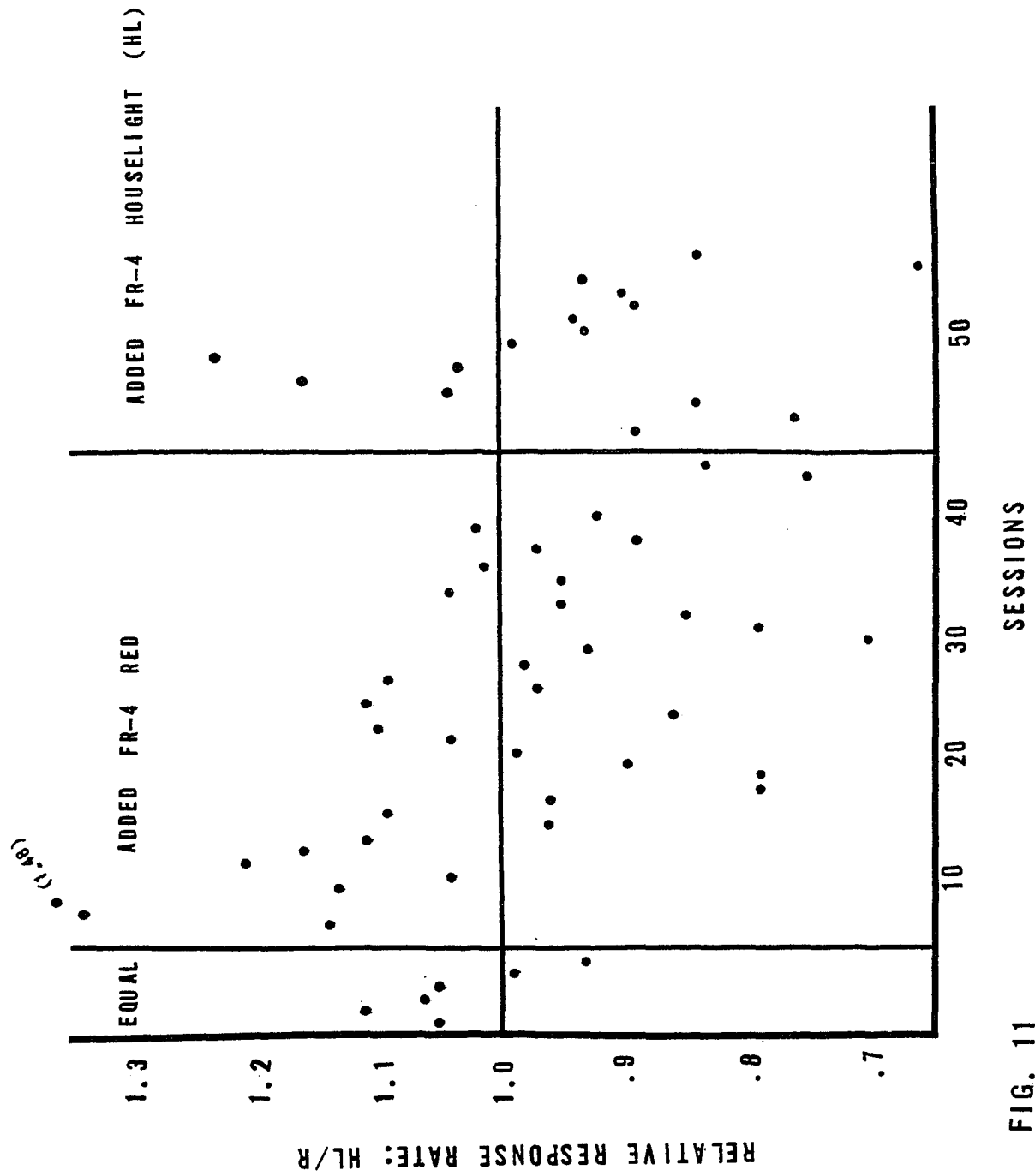


FIG. 11

Average rates before addition were approximately 35 rpm for the seven birds studied; they increased to an average of approximately 65 rpm after superimposition of the FR-11 schedule of "added" stimuli. Rates in the unchanged component increased from 35 to 45 rpm. This increase when the FR-11 schedule was superimposed occurred only when the stimulus which was presented as the consequence was also paired with each presentation of the unconditioned reinforcer (Schuster, 1969, Figure 8.4, p. 207).

Discussion

In Schuster's (1969) experiment, all pigeons showed increased pecking on both keys and a marked relative rate increase when the added stimulus contingency was superimposed on one of two otherwise equivalent components. Such a systematic relative rate change favoring the added stimulus manipulandum occurred only for S-1 in the present experiment, and it reversed readily. For S-2, wide relative rate variations occurred from one session to the next but showed no definite trend. Thus the performance of one of two rats was consistent with that reported by Schuster. Differences between this experiment and Schuster's included choice of subject and of the added stimuli which were also paired with food. Pigeons are generally recognized as being visually acute, and as such their perception of a buzzer, house-light dimming and keylight color change may have been greater than the rats' perception of light flashes. In addition, Brown and Jenkins (1968) have shown that pigeons peck salient stimuli predictive of food. The change in the keylight from its normal color to white in the

Schuster experiment was predictive of food in the sense that food never occurred without such a change. The extra brief stimulus changes functioning as predictive cues could have generated autopecking, irrespective of their other possible functions.

Finally, when the subject was in the added stimulus component of the present experiment, tone-on time was more closely related to food than tone-off time because food only arrived following the tone. A contingency relating responding to the brief change from tone-off to tone-on seems to have been responsible for the higher relative rates generated here in S-1. Of course rate is not necessarily related to preference and the reinforcing properties of stimuli in choice situations, as Schuster (1969) pointed out. In addition, the failure of relative rate changes to develop with S-2 is unexplained.

EXPERIMENT VI

Method

The purpose of this experiment was to determine the preference behavior of rats in a two-option choice situation in which both options were equal with respect to primary reinforcement but one option also provided "extra" brief stimulus presentations. The procedure permitted the preference response by presenting two retractable levers until one was pressed, at which time both were withdrawn and identical schedules of food presentation, plus "extra" brief stimulus presentations correlated with only one lever, were presented. In this way the effects on preference of "extra" stimuli which were also paired with all food presentations could be assessed in a situation which eliminated the response rate differences present in the Schuster (1969) procedure while retaining its other advantages.

Subjects

Two naive male albino rats, randomly selected from an original group of 20 obtained from The Upjohn Company colony in Kalamazoo, Michigan, and 90-120 days old at the start of the experiment, served as subjects. They were individually housed, provided free water except in the experimental chamber, and were maintained at 80% of their free feeding weights by restricting Purina Laboratory Chow intake.

Apparatus

The plexiglas experimental chamber measured 25 x 25 x 18 cm, and

was housed in a sound attenuated trunk equipped with an exhaust fan. Two retractable levers (LVE/BRS Model No. 123-07) were mounted 8 cm above the floor and 10 cm apart. Six cm above each lever was an amber stimulus light. A white houselight and a tone generator (Sonalert Model SC628) were centered in the ceiling. A food dish into which 45 mg Noyes food pellets could be delivered was positioned on the tubular grid floor and centered on the wall opposite the two levers. All programming and recording of experimental events were accomplished by a PDP-8e computer manufactured by Digital Equipment Corporation of Maynard, Massachusetts, and located in a nearby room. Experimental event scheduling and data recording were coordinated by a SKED process-control system available through State Systems, Inc. of Kalamazoo, Michigan (Snapper et al., 1976).

Procedure

Once subjects were trained to press either lever when present, a choice paradigm was arranged. The houselight remained on at all times except during reinforcement, when it was turned off for 0.5 sec; as it reappeared one 45 mg Noyes pellet dropped into the food dish. Upon session start both levers were fully extended 1.5 cm into the chamber. A press to either lever of more than 20 grams of force was immediately followed by both levers withdrawing and both lever lights being turned off. After 3 sec the reinforcement sequence of houselight flash and pellet delivery occurred, and 1 sec later the two levers reappeared as the lever lights were reilluminated. If the rat pressed either lever on five consecutive trials only the other lever with its associated lever

light reappeared following the reinforcement sequence. This forced choice insured contact with contingencies associated with both levers at least occasionally, and was in effect throughout the experiment. Two sessions were conducted daily for each subject, separated by approximately 30 minutes. Each session terminated after 60 pellet deliveries.

Three days of this condition were followed by three days of an identical schedule except that the delay between a lever press and the reinforcement sequence was lengthened to 6 sec and the period between pellet delivery and reappearance of lever(s) and lever light(s) was 2 sec. A third condition changed the two time values to 10 sec and 5 sec, respectively, and was considered the beginning of the experiment; the number of presses of each lever provided measures of preference when consequences associated with the two levers were identical.

After nine days the schedule of reinforcer presentation associated with the left lever changed such that the reinforcement sequence included the houselight flashing off for 0.5 sec and then three food pellets were delivered with 1 sec separating each pellet delivery. The purpose of this manipulation was to determine whether different magnitudes of food associated with the two levers would influence preference. A preference for the lever associated with the larger unconditioned reinforcer would demonstrate that the procedure was sensitive enough to detect this different in consequences. Sessions terminated after 40 reinforcement sequences, each sequence composed of either one pellet (right lever) or three pellets (left lever). The

forced trial procedure of presenting only one lever if the other had been chosen on five consecutive trials was in effect in this condition, and remained in effect throughout the experiment.

After 12 days the delivery of three pellets was then associated with presses to the right lever to test the sensitivity of the procedure with respect to reversals; left lever presses yielded one pellet. This condition remained in effect for eight days.

Conditions were then switched back to the presentation of one pellet for presses to either lever, with the following modification of the reinforcement sequence: a tone initiated the sequence; after 0.5 sec of the tone-on condition, the houselight was turned off; 0.5 sec later the tone was turned off, the houselight was reilluminated, and a pellet was delivered to the food dish. Diagram 9 illustrates this reinforcement sequence.

A major change in the consequences associated with right lever presses for Subject 1 (S-1) and with left lever presses for S-2 was then initiated. In addition, the fixed delay of 10 sec between a lever press and the initiation of the reinforcement sequence was changed to a variable delay of 15 sec, with values of 8 sec, 9 sec, 10 sec, ...22 sec being equally possible following a lever press. The computer was programmed to select a value randomly from the set of possible values without replacement until all values were used, at which time the complete set of values was again available. This 15 sec variable delay remained in effect for the duration of the experiment. The change in consequences associated with right lever choices for S-1 was: although the food reinforcement sequence remained

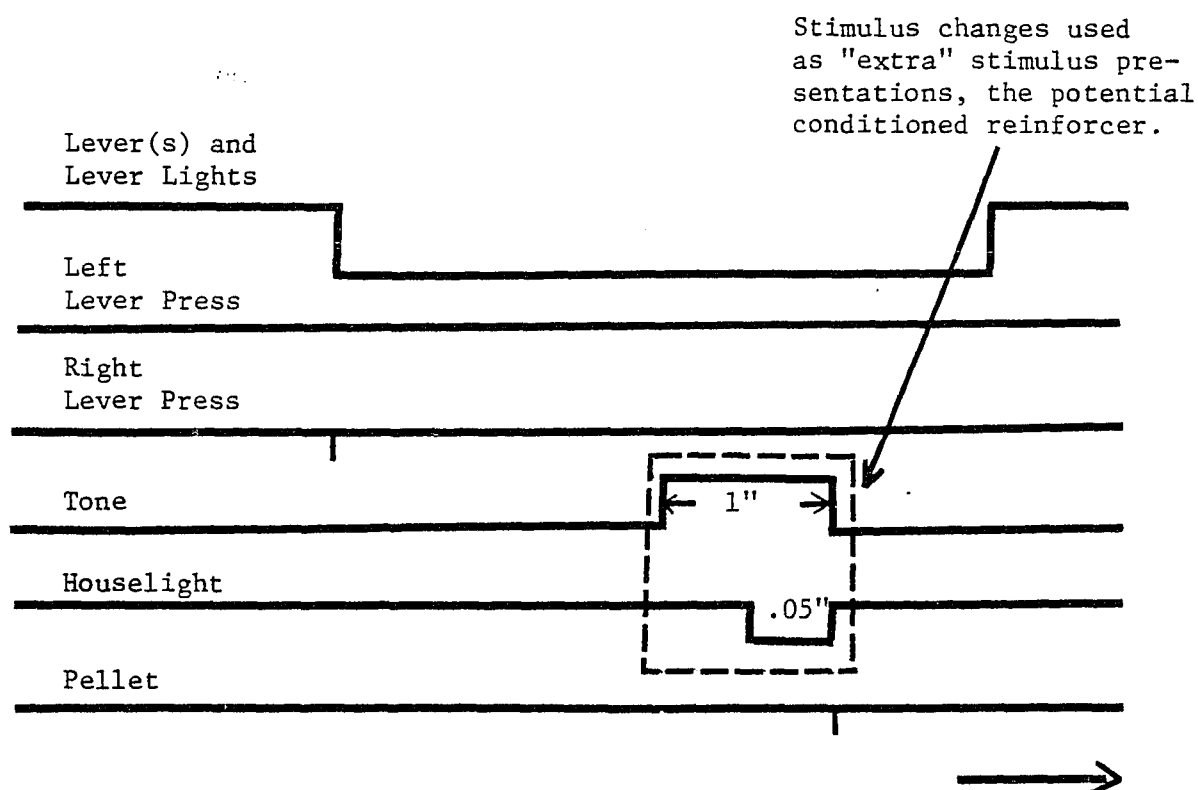


Diagram 9. An illustration of a lever press resulting in the retraction of lever(s), turning off of lever light(s), and initiation of a delay terminated by the tone-houselight-pellet reinforcement sequence, after which a shorter delay was followed by reintroduction of lever(s) and re-illumination of lever light(s).

the same for each lever in this and all future conditions, "extra" stimuli, potential conditioned reinforcers, were "added" during the variable delay associated with the right lever only. These "extra" stimuli were always identical to the stimulus changes in the reinforcement sequence prior to actual pellet deliver. In other words, an "extra" stimulus presentation consisted of the tone appearing, after 0.5 sec of which the houselight went off for 0.5 sec, and when it was reilluminated the tone ceased. Diagram 9 illustrates the portion of the reinforcement sequence employed as "extra" stimuli. During the variable 15 sec delay between a right lever press and the reinforcement sequence, the following occurred: from 1 sec after the lever press to 2 sec before the food reinforcement sequence, an "added" stimulus could occur each second with a probability of 0.167. At least one second was required to elapse between the end of one "added" stimulus presentation and the beginning of another. The variable delays before the unconditioned reinforcer and the random presentations of potential conditioned reinforcers were designed to eliminate any possible contingent relationship between the neutral stimulus and the unconditioned reinforcer. Diagram 10 displays the sequence of events which could occur during each trial. For S-2, the added stimuli were programmed during the delays following presses to the left lever. In Diagram 11, a simplified state diagram of this condition is presented.

Table IX presents the number of days and description of each condition of the experiment for each of the two subjects. Changes in conditions represent a reversing of the levers with which the "added" stimuli were associated. Two exceptions are noted. Beginning with

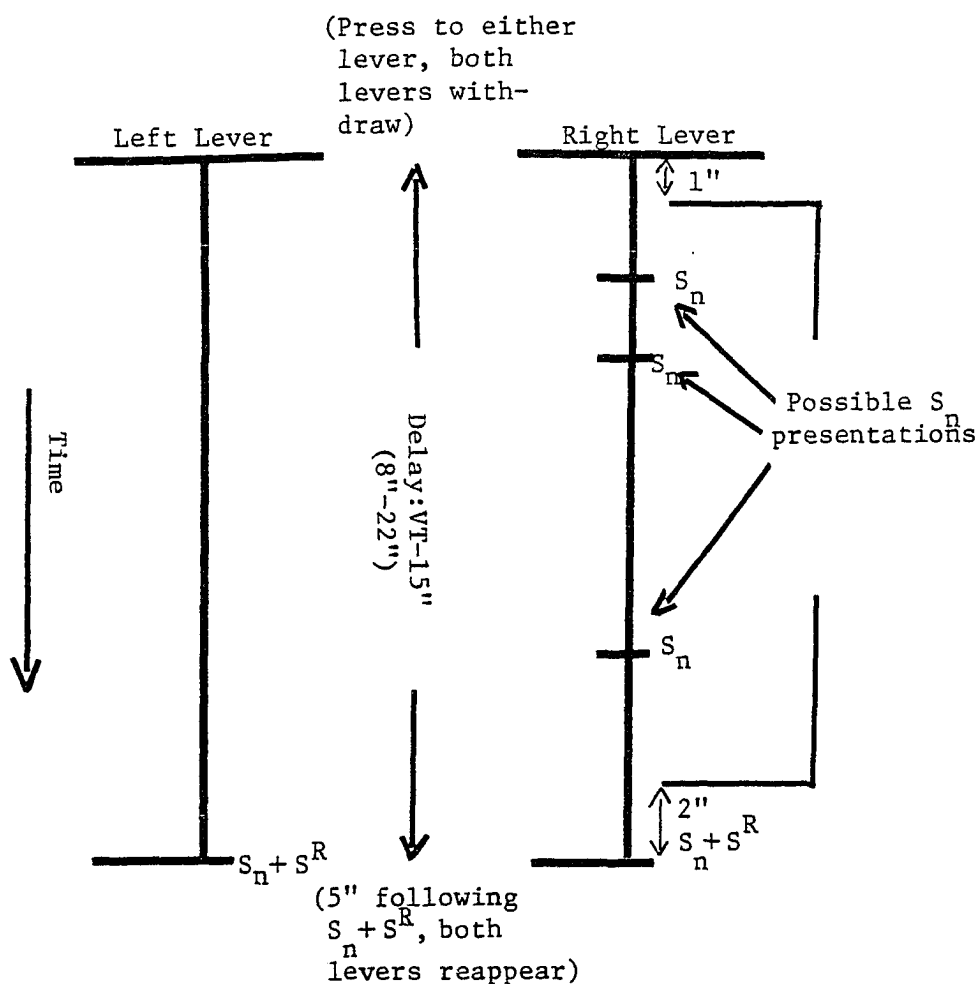


Diagram 10. Display of the sequence of events which could occur during each trial. The potential conditioned reinforcer is indicated by S_n and the food pellet by S^R . S_n 's were possible on a probability per second basis from 1 sec after a lever press to 2 sec before $S + S^R$ if the right lever were pressed. A minimum of 1" separated offset of one S_n from initiation of another.

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TABLE IX: Duration and description of experimental conditions of Experiment VI.

DURATION AND DESCRIPTION OF EXPERIMENTAL
CONDITIONS OF EXPERIMENT VI

Condition	<u>Subject 1</u>		<u>Subject 2</u>	
	<u>Days</u>	<u>Description</u>	<u>Days</u>	<u>Description</u>
1	9	1 pellet each lever	10	Same as S1
2	12	3 pellets left lever	11	Same as S1
3	8	3 pellets right lever	8	Same as S1
4	7	1 pellet each lever	7	Same as S1
5	16	1 pellet each lever "Added" on right (.167) ("Added" = Tone+Light Flashes)	42	1 pellet each lever "Added" on left (.167) ("Added" = Tone+Light Flashes)
6	24	1 pellet each lever "Added" on left (.167)	8	1 pellet each lever "Added" on left (.334)
7	8	1 pellet each lever "Added" on left (.334)	38	1 pellet each lever "Added" on right (.334)
8	9	1 pellet each lever "Added" on right (.334)	43	1 pellet each lever "Added" on left (.334)
9	32	1 pellet each lever "Added" on left (.334)	15	1 pellet each lever "Added" on left (.334) ("Added" = 1"series Light Flashes)
10	21	1 pellet each lever "Added" on right (.334)		
11	22	1 pellet each lever "Added" on left (.334) ("Added" = 1"series Light Flashes)		
12	14	1 pellet each lever "Added" on right (.334)		
13	8	1 pellet each lever "Added" on left (.334)		

Condition 6 for S-2 and Condition 7 for S-1 the probability of an "added" stimulus was increased from 0.167 to 0.334. Secondly, beginning with Condition 9 for S-2 and Condition 11 for S-1 the reinforcement sequence and the "added" stimulus sequence were changed. For reinforcement, the houselight flashed off and back on each 0.2 sec for 1 sec, at which time a pellet was delivered. The added stimulus sequence involved only the series of 0.2 sec houselight flashes for 1 sec. This change was made to reduce the possibility that a lack of preference for the added stimulus lever could be attributed to the aversive characteristics of the added stimulus itself, a (loud) tone.

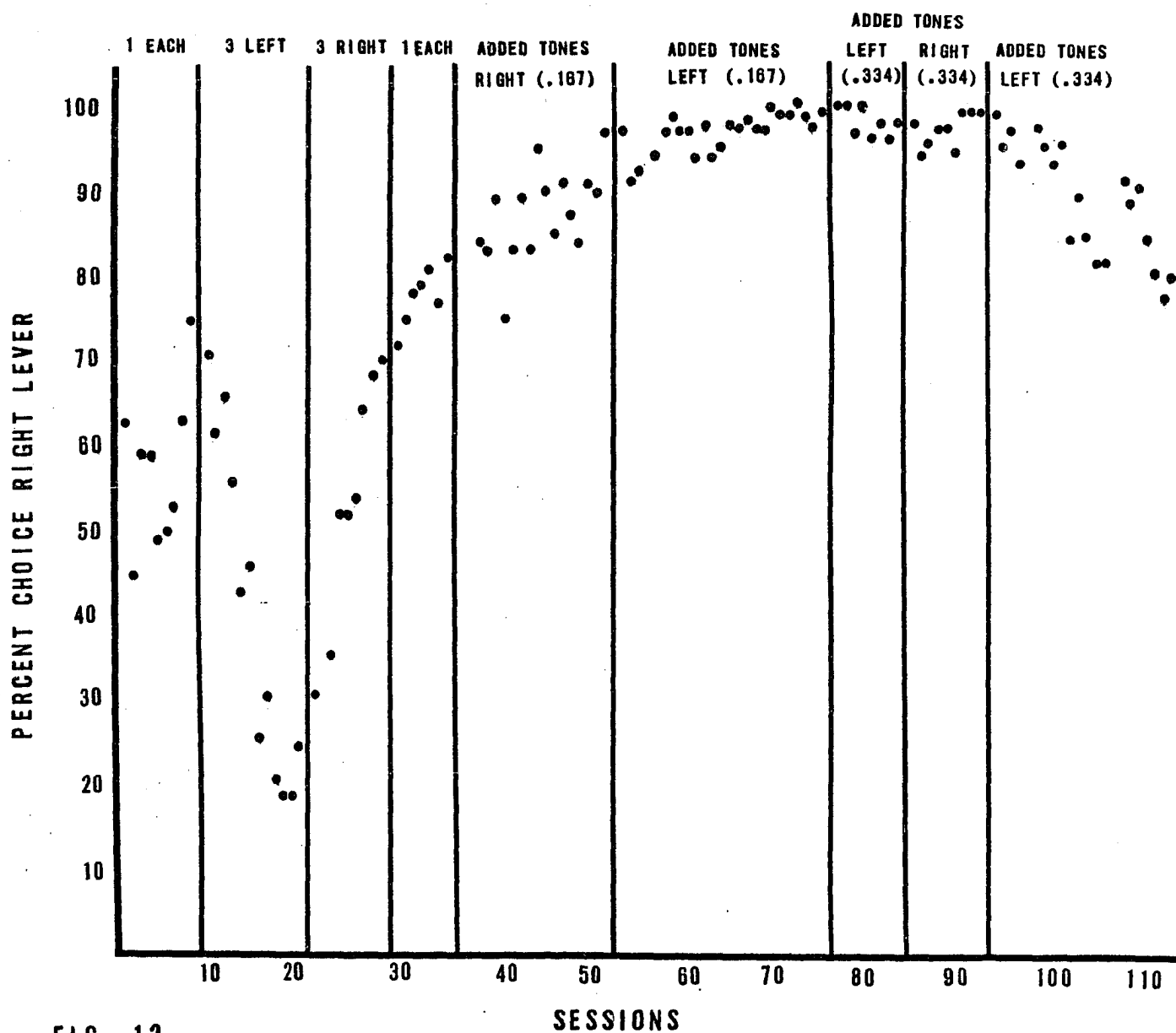
Results

The percentage of responses to or choices of the right lever when both levers were present is plotted in Figure 12 and Figure 13 for S-1 and S-2, respectively. Each datum point was calculated after first summing the data from the two daily sessions unless otherwise indicated. Conditions are abbreviated across the top of each figure within condition boundary lines.

When the consequence of choosing either lever was the delivery of one pellet 10 sec following the choice (and the correlated withdrawal of both levers), S-1 showed a small preference for the right lever, approximately 60 percent at the end of the condition. Only lever presses when both levers were presented were included in the percentage calculations; forced-trials were excluded.

When three pellets followed choice of the left lever, the choice of the right lever dropped to near 20 percent, while a switch to three

Figure 12: Daily percentage of responses to or choice of the right lever by Subject 1 across the several experimental conditions. Forced choice data were excluded from choice percentage calculations.



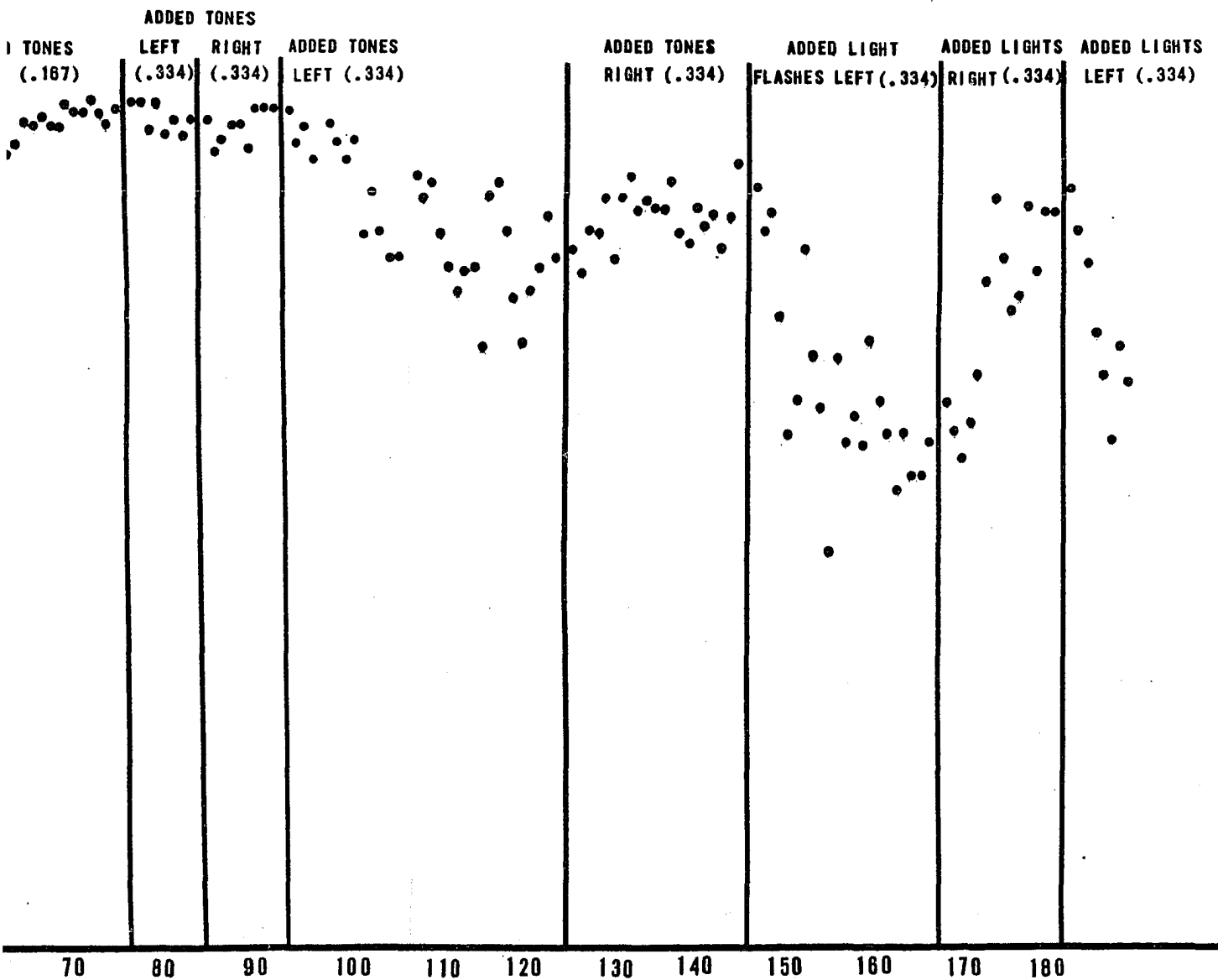


Figure 13: Daily percentage of responses to or choice of the right lever by Subject 2 in Experiment VI.

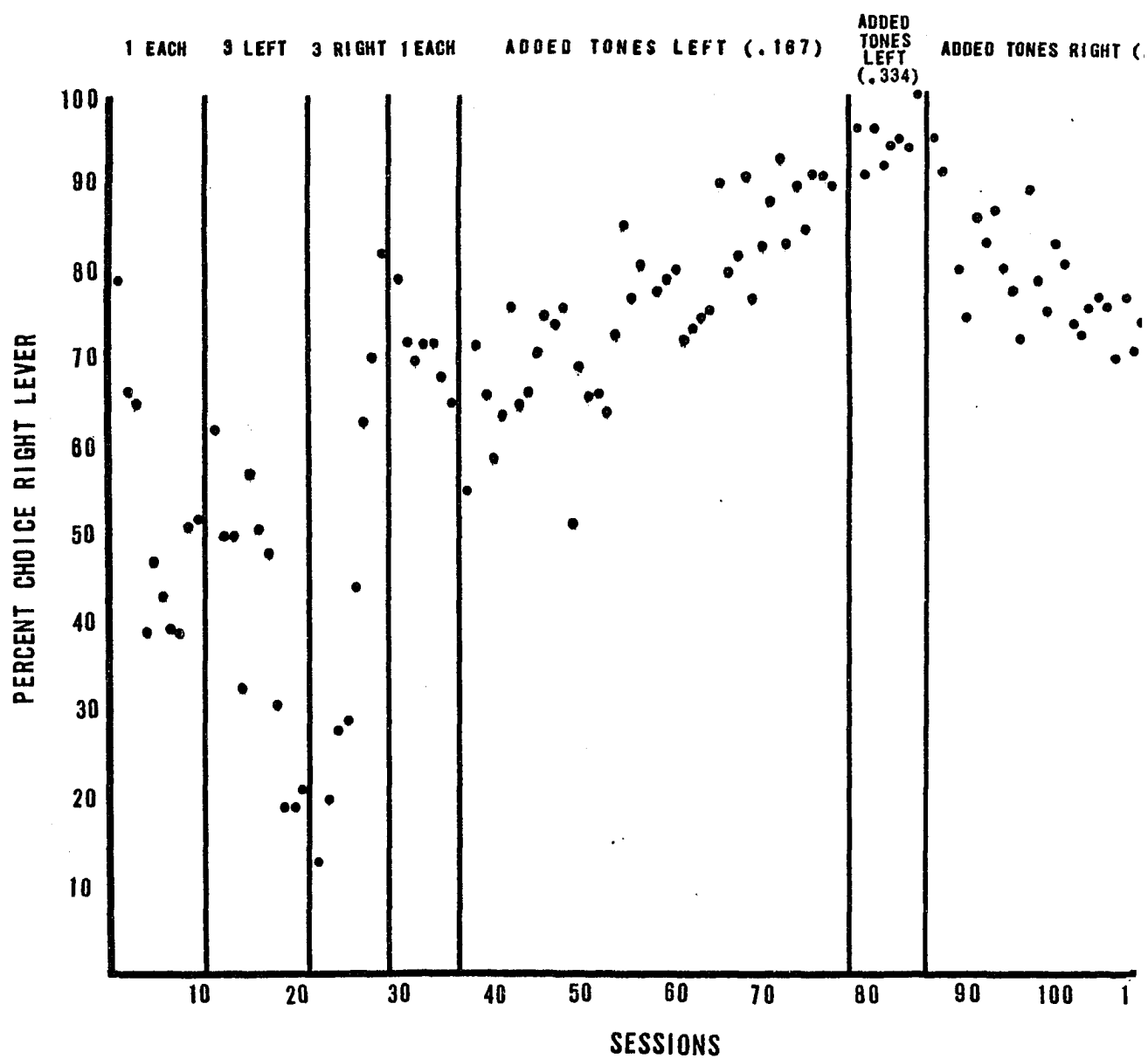
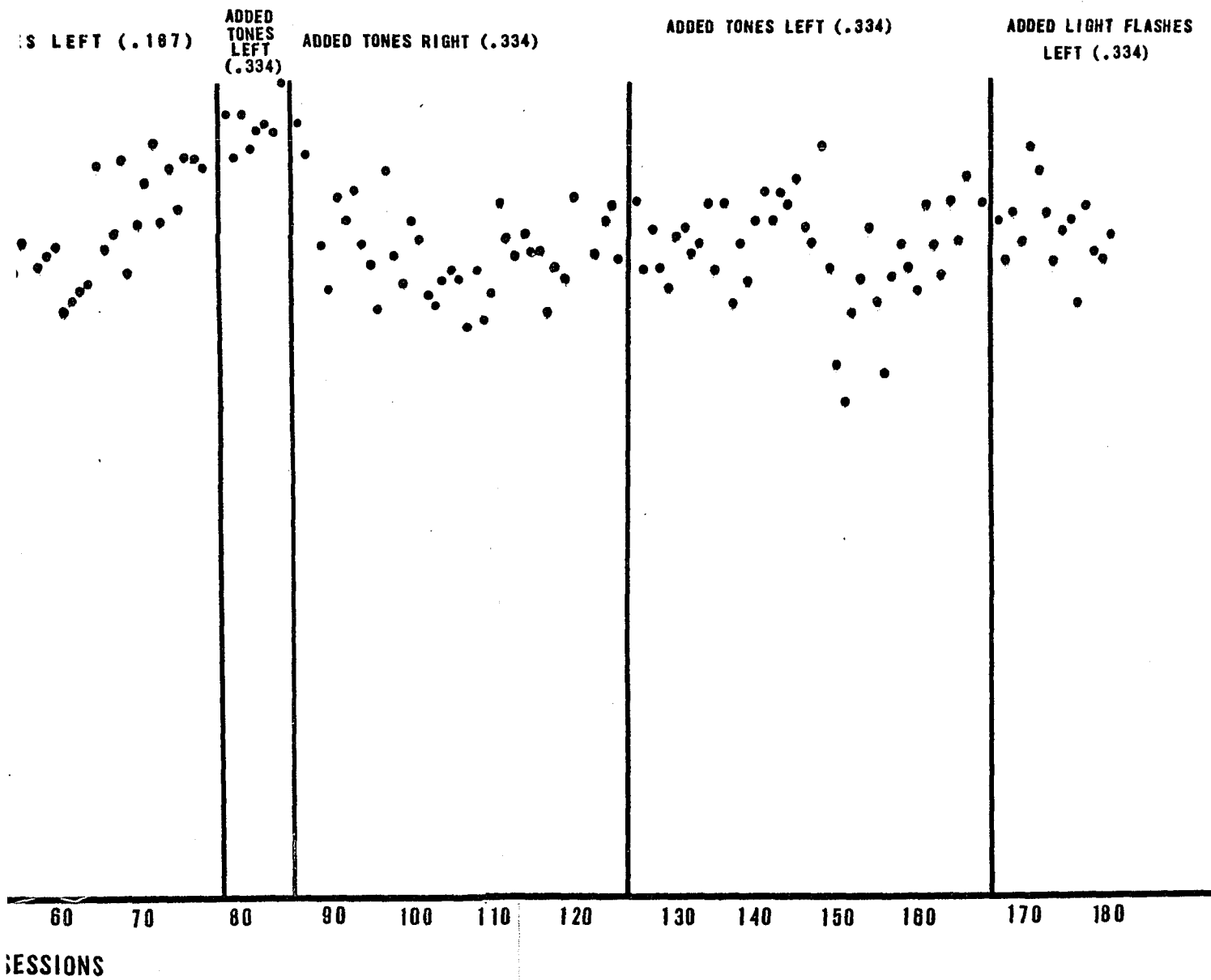


FIG. 13



pellets for a right lever choice raised choice of that lever to 70 percent. These choice patterns indicate that the procedure was sensitive with respect to the different consequence magnitudes. Choice of the right lever continued to rise to 80 percent by the end of Condition 4 when each lever was again associated with the delivery of one pellet.

In Condition 5, choice of either lever resulted in a 1 sec tone plus food pellet after a variable 15 sec delay following the choice, plus additional 1 sec tones with a probability of 0.167 each second during the delay following only a press to the right lever. This condition coincided with a continued gradual increase in right lever choice to 90 percent. When these additional tones were switched to the left lever, the rise in choice of the right lever continued, reaching almost 100 percent by the end of Condition 6.

An increase in the probability of tone presentation during the delay to 0.334 for choices of the left lever did not markedly effect choice behavior, although a slight drop in right lever choice possibly occurred at the end of Condition 7. Shifting the increased number of added tone presentations to the right lever had no major effect on choice, although at the end of Condition 8 a slightly increased preference for the right lever may have developed.

Switching the added tones back again to the left lever in Condition 9 coincided with a decrease in choice of the right lever from 100 to 80 percent (or an increase from 0 to 20 percent in selection of the left lever) over the 32 days of the condition. Added tones occurred following selections of the right lever in Condition 10, and was associated with a slight rise to approximately 85 percent in right

lever choice.

At this point the tones were replaced with 1 sec series of light flashes, with the added light flashes now occurring when the left lever was selected. Choice of the right lever declined from 85 to 60 percent by the end of the 22nd day of Condition 11. When the added light flashes occurred following right lever choices in Condition 12, right lever choice increased to 85 percent, and then decreased to below 70 percent in the final condition of the experiment when the added light flashes were programmed in association with presses to the left lever.

Subject 2's choice behavior was similar to S-1's through the first four identical conditions, with the exception that S-2 did not show a preference for either lever in Condition 1 or Condition 4. A very gradual rise from 60 to 90 percent choice for the right lever occurred during Condition 5 when the added tones were associated with the left lever. Increasing the probability of tone occurrence associated with the left lever in Condition 6 was correlated with the continued rise in right lever choice to near 100 percent. When these added tones were switched to the right lever, choice of the right lever decreased to 80 percent. Subject 2 then continued to choose the right lever on approximately 80 percent of the choice opportunities throughout the remainder of the experiment, despite the switching of the added tones to the left lever in Condition 8, and the replacement of tones with light flashes in Condition 9.

Discussion

Subject 2 appeared to be developing a preference for the no-added

tones lever when Condition 7 replaced Condition 6. However, no confirmation of such a preference was evidenced during the remainder of the experiment. For this subject, then, conditions associated with either lever were equally reinforcing.

In contrast, S-1 did display a preference for the lever with the added stimuli in the part of the experiment in which a brief series of light flashes replaced the tones. There was an indication that a preference for the lever with the added stimuli had begun at the end of Condition 7, even before light flashes replaced the tones.

It would be instructive to determine whether rats which prefer the added stimulus lever would respond more in extinction with levers always available and only brief stimulus presentations scheduled to follow responding than rats which did not prefer the added stimuli. If a relationship between preference for added stimuli and more responding in extinction should exist, this would further implicate a reinforcing function of the added stimuli.

The preference for the added stimulus lever by S-1 provides support for the pairing hypothesis. The fact that S-2 remained unaffected by the same programmed contingencies, however, suggests that pairing may not be the procedure responsible for the preference of S-1. Three factors may have been responsible for the differing performances of the two subjects. First, once an animal has begun to press one lever more than another, the immediate past history of reinforcement with that lever may be the predominant control of his responding, preference for added stimuli or no-added stimuli notwithstanding. If this were the case, only reversals of lever preference when contingencies on the levers

were switched would provide relevant data concerning immediate preference. A sustained lever reversal would not necessarily indicate sustained preference, however, because of the confounding reinforcement history. In the current study, a forced choice of the opposite lever was scheduled following five consecutive responses on one lever. Whether the control was adequate to compete with reinforcement history is not known. A procedure which randomly switched contingencies on the two levers and offered the subject an observing lever which, if pressed, would present stimuli consistently associated with the two contingencies would provide a more sensitive measure of both immediate and sustained preference (Reference Note 4). Another method of measuring immediate and sustained preference would employ the van Haaren (1977) procedure; two signaled components with consequences similar to those of the two levers in the present experiment would alternate every 3 minutes after component start, with a lever press serving to produce an immediate change from one component to the other.

The second factor to be considered is the manner in which "intruded stimuli" were programmed for non-contingent presentation into the "behavior stream" (Farmer and Schoenfeld, 1966). In the Farmer and Schoenfeld study, responding was maintained by a fixed interval schedule of food presentation. Different stimulus functions and effects appeared to develop depending upon the temporal location of the intruded stimulus with respect to food. In the present experiment, all stimuli following lever withdrawal were presented irrespective of the specific behavior being emitted by the subject at the time of stimulus

delivery. The potential behavioral effects of such stimulus delivery procedures are many, some of which are discussed in the next paragraph.

Finally, aspects of the precise schedules of delayed consequence delivery may have been the most significant factor in determining the different choice patterns. Most important among these are: a) the learning of the predictive relationship between the paired stimulus and food was not required, nor was it essential to the animal in terms of more food, faster food, less effort, etc. In order to approach the food dish to obtain pellets, an approach following the sound of the pellet dispenser would serve the same purpose, and with fewer false alarms. Thus neither discrimination was required, but one of the two would probably be learned. Which one was learned would be a function of the subject's behavior in relation to the independently scheduled stimulus events. b) Complex differences between the schedules on the two levers existed. The added stimulus lever was associated with more stimulus-on time; however, even though food was always preceded by the stimulus, a one-to-one correlation did not exist. The extra uncorrelated signals could give rise to false preparatory responses and thus become aversive (Perkins, 1968). That one subject preferred them and another did not avoid them, however, questions this interpretation to some extent. In general, the tones or light flashes occurred more immediately following an added stimulus selection than did stimulus-food presentations on the other. This could serve to strengthen the choice of the added stimulus lever if the added stimuli were confused with stimulus-plus-food consequences. It should be noted that at the time of presentation, the stimuli preceding food and those occurring

alone were identical. c) The schedules of delayed presentation of the added stimuli and stimulus-plus-food sequences could contribute to difficulty in discriminating the consequences associated with the two levers. Both delays were variable, and both terminated in stimulus-plus-food presentation. As mentioned earlier, extra stimuli were correlated with only one lever, but this was complicated by the fact that the minimum delay of 8 sec before stimulus-plus-food presentation on each lever could result in a relatively rapid terminal consequence after only 8 sec on the no-added stimulus lever. Occasionally, the added stimulus lever would, when selected, result in delivery of only the stimulus-plus-food consequence after a delay longer than 8 sec, and with no extra stimuli occurring during the delay. While infrequent, these occasional occurrences could have hampered the formation of a discrimination between levers and their related consequences. Finally, levers and lever stimuli, lights, were identical.

These procedural and schedule variables could combine to determine the different choice patterns seen in the two subjects. For example, primary reinforcement could play a role in development of the stimulus as an S^D ; an approach to the food dish during stimulus presentation could be followed by food more frequently than approaches at other times. Once this discrimination is learned, more and earlier added stimuli could be preferred given the failure of a pronounced discrimination to form between early stimulus-only presentations and the later stimulus-food sequences. The observations of deLonge (1971) and of Squires et al. (1975) provide support for the development and maintenance of such confusion. Thus the present test situation may have controlled for

the rate differences present in Schuster's (1969) experiment, but may not have eliminated the relationship between the added stimuli and food.

In this uncontrolled situation, it is alternatively possible for a subject to press one lever extensively and gradually develop a strong preference for that lever. One possible analysis of such behavior, in addition to some unexplainable side bias, would appeal to Morgan's (1974) principle of recency and also to absolute numbers of reinforcers. The subject may, for trivial reasons, select one lever and return to it because reinforcement was most recently associated with it. After a number of such responses to one lever, the subject may return to one lever because of the absolute number of reinforcers associated with it, even though both levers deliver equal reinforcement per lever press. Subject 2's persistent preference for the right lever after Condition 3 is not inconsistent with this interpretation. The forced trial requirement after every fifth consecutive choice of one lever may not have been sufficient to counter a long history of reinforcement associated with one lever. In addition, the occurrence of early false approaches to the food dish when added stimuli occurred is possible, and extinction of the response during the stimulus could result. A more consistent predictor of food was pellet dispenser noises, and approaches following this noise always resulted in the obtaining of a food pellet. That animals can learn to respond to different components of a complex situation given the conditions of this experiment is not unlikely (Reynolds, 1961b). The testing of control by added stimuli versus dispenser noises could be accomplished by measuring the frequency

of food dish inspection when the added stimulus and the pellet dispenser noises were scheduled to occur independently and randomly during extinction, with photobeam disruptions at food dish entrance being compared.

The different behavioral results of the test situation for the two subjects and the several different processes which could have generated them suggest further modifications of the procedure. The purpose of the variable delays before presentations of unconditioned reinforcers and the variable time presentations of added stimuli were designed to eliminate any relationship between the added stimuli and food. However, this randomness of presentation may have contributed to making the discrimination between added stimuli and food difficult or impossible to learn. In other words, this random scheduling may have actually maintained a relationship between the added stimuli and food due to "confusion" (Reference Note 3).

To minimize the chances of "confusion" developing, a fixed-time delay to stimulus-food presentations could be programmed, with occurrences of the added stimuli also scheduled for fixed-time presentation during the delays. In addition, different stimuli could be associated with the two levers. With these modifications, the probability that a discrimination would form concerning the conditions associated with the two levers is increased, and choice of the added stimulus lever in this case would provide strong evidence for a conditioned reinforcer function independent of both contingency requirements and lack of discrimination.

However, the possibility still remains that the added stimuli could

signal a passage of time or a reduction in delay to unconditioned reinforcer delivery which would be reinforcing as such. This possibility could be tested by presenting added stimuli during the delay which are not paired with food. If the temporal relationship between these added stimuli and food were the crucial variable, they should continue to be preferred by a subject that had preferred the added paired stimuli. If pairing with food is the relevant variable, unpaired added stimuli should not be preferred.

Another question is that of the sensitivity of the procedure for detecting any conditioned reinforcing strength of the added stimuli. An early condition of the experiment showed that the animal would choose the lever consistently associated with three pellets as opposed to one. However, delays were of fixed 10 sec duration rather than variable. One method of assessing sensitivity would be to reduce the magnitude of the difference in amounts of food associated with the two levers, or to establish different variable delay durations associated with the two levers. If a subject would consistently select the lever yielding the greater density of reinforcement with respect to time, confidence in the sensitivity of the procedure would be increased. Another technique would be to utilize the van Haaren (1977) procedure or the observing response procedure (Reference Note 4) mentioned above to determine if different procedures yield similar results.

SUMMARY

A review of the research supportive and critical of the pairing hypothesis led the author to the conclusion that the concurrent schedules study by Zimmerman (1963), and the multiple schedule study by Thomas (1969) were both highly indicative of the effectiveness of pairing. In addition, the Schuster (1969) design, while permitting an uncontrolled variable response effort, seemed to the author to provide another useful method of testing the conditioned reinforcing properties of previously neutral stimuli. Another choice paradigm employing the shuttlebox was also chosen as a test vehicle for whether a stimulus had acquired reinforcing properties through pairing with an effective reinforcer. All procedures delivered the potential conditioned reinforcer in such a way that it was not related to the previously effective reinforcer when its conditioned reinforcing properties were being assessed, and the procedures were such that responding due to "confusion" was a tenuous alternative explanation.

Thus several pairing procedures were identified by the author as being theoretically favorable to the development and detection of conditioned reinforcers based upon previous evidence with pigeons. Rats and children were selected to serve as subjects to ascertain whether the results supportive of pairing obtained by Zimmerman (1963) and by Thomas (1969) were general with respect to species or were limited to the pigeon's key peck. Likewise, rats were selected as subjects for the shuttlebox test. Finally, rats served in the

modification of the Schuster (1969) experiment.

No evidence supportive of the effectiveness of the pairing procedure in establishing conditioned reinforcers was obtained when the Zimmerman and the Thomas procedures were adapted to rats and to children as subjects. A similar statement can be made with respect to the shuttlebox experiment. One rat in the two-lever modification of the Schuster (1969) experiment provided an indication of pairing's success, but two other alternative explanations of this evidence necessitates the further examination of the role of two variables. Specifically, while the two-lever design controlled for mechanically-recorded operant response effort, the supportive results could have occurred due to:

a) the failure of a discrimination to form with respect to the exact nature of the contingencies associated with two levers; and/or b) the added stimuli could have provided signals of reduced time to unconditioned reinforcement. Methods for evaluating the possible effects of these two variables were explained in the Discussion section of Experiment VI.

GENERAL DISCUSSION

The results of experiments by Zimmerman (1963) and Thomas (1969) have been widely cited as examples of research providing major support for the pairing hypothesis. In both experiments, the conditioned reinforcer was presented without its serving any predictive function with respect to the unconditioned reinforcer, and yet sustained response-strengthening effects were observed. Both experiments employed pigeons as subjects, and it was suggested above that the mechanism responsible for the positive results may not be reducible to an S^D versus pairing dichotomy; the autopecking literature referred to earlier is relevant to this subject. In addition, in a feeding situation pigeons may be highly sensitive to environmental cues--their visual acuity is well-known--and the probability of a response occurring in the presence of the neutral stimulus may thus be high. And many animals including man do not have such a uniquely suited food-finding, food-grasping, food-consuming response. Behavioral sequences most useful to or required of technological man are frequently complex, arbitrary chains of discriminated responses which are unrelated to the specific behavior of primary reinforcer consumption.

The Zimmerman (1963) and Thomas (1969) results were not confirmed with either rats or children as subjects in the present series of studies, and while failure may have been due to insensitive procedures and/or poor selection of values of the variables involved, such criticisms seem unlikely to the author, given the several replications

attempted. Further attempts at replication are needed. However, the lack of species generalization observed here suggests that supportive results may pertain only to pigeons in closely restricted spaces when food is being provided occasionally and salient stimuli are available. In addition, support for the pairing procedure deriving from second-order schedules may result at least in part from the failure of a discrimination to form with respect to the neutral stimulus presented alone versus the neutral stimulus-unconditioned reinforcer sequence.

Experiment VI was an attempt to test the pairing hypothesis in a setting containing the controls stipulated by Schuster (1969): complete separation of the potential conditioned reinforcer from any relationship with food, and the use of measures of choice as the indicator of whether a neutral stimulus has acquired conditioned reinforcing properties. However, in this experiment the test situation was uncontrolled with respect to the subject's behavior and its interaction with the delayed consequent stimuli. This may have permitted both preference and non-preference to develop.

With regard to the question of what type of association between a neutral stimulus and an unconditioned reinforcer is necessary for development of a conditioned reinforcer, the predictiveness of the neutral stimulus with respect to the reinforcer is crucial. In both pairing and discriminative stimulus procedures such predictive relations are present, but only the S^D procedure requires such learning. It would seem likely that the organism would have to respond in some way not only in the presence of the unconditioned reinforcer but also to the neutral stimulus if later he is to respond differentially to the

predictive relationship between the two stimuli. When simple pairing occurs, no responding in the presence of the neutral stimulus (attention to the neutral stimulus) is required. If the organism does not so respond, conditions are not established for subsequent responding during the extinction test due to lack of formation of a discrimination of the absence of food. In the S^D procedure, on the other hand, the requirement that the organism attend to the neutral stimulus develops the conditions necessary for later responding due to "confusion" when only the neutral stimulus (without food) is delivered following responses. The amount of "confusion" responding maintained should be related to the strength of discriminative control, as was shown by Notterman (1950). The weakness of the pairing procedure may derive from the fact that no attention to and differential responding in the presence of the neutral stimulus is required, and such responding in the presence of the neutral stimulus may therefore develop only occasionally.

According to this view, an unconfounded (with discrimination formation) pairing procedure must prevent all operant responding by the organism between neutral stimulus onset and unconditioned stimulus onset. The problem is that techniques for reliably detecting many proprioceptive and internal organismic responses are presently not available. However, Stein (1958) recognized this difficulty and argued that his procedure minimized the likelihood of responses during the brief 0.5 sec between tone onset and brain stimulation. It may be the case, however, that the pairing procedure cannot be conclusively evaluated given current test procedures.²¹ Even the Stein experiment

²¹Although only brief mention has been made in this report of

is open to speculation concerning an operant response during neutral stimulus presentation. If the subject's muscular activity were eliminated through a curarization procedure, one could still hypothesize some central nervous system signal or "tendency to respond" which is blocked by the curarization. Evaluation of such a speculation must await explication of the physiology of such neural activity.

Stein's experiment demonstrated conditioned reinforcing property acquisition by the tone, but the fact that electrical stimulation of a site in the brain rather than an appetitive consequence delivered to a deprived organism served as the unconditioned reinforcer may have been an important determining variable. Maltzman and Raskin (1965) and Sokolov (1963) demonstrated a direct relationship between detectable physiological reaction(s) by the organism to a potential conditioned stimulus and classical conditioning of a response to that stimulus. Certain events may, perhaps for survival purposes, increase an organism's sensitivity to other environmental stimuli. This does not seem unlikely since, for example, attention to aversive events and the circumstances surrounding them, and subsequent escape from these events and circumstances, increases the organism's chances for survival. Several experimental results cited above support this view: Lovaas et al. (1965) succeeded in establishing a neutral stimulus as a

the pairing of neutral and aversive stimuli, a serious questioning of the pairing hypothesis would have direct implications for the two-factor theory of avoidance (Mowrer, 1940). According to this theory, the reinforcer for an avoidance response is the escape from the previously neutral stimulus which has acquired aversive properties as a result of its being paired with the aversive event.

punishing consequence when shock was simply paired with the stimulus, but failed to establish a neutral stimulus as a positive consequence when food was paired with the stimulus (Lovaas et al., 1966). Food-deprived schizophrenic children served as subjects. As previously mentioned, food intake in the study was restricted to the twice daily experimental sessions, with water freely available after 6:00 P.M. Heightened sensitivity to environmental stimuli in the presence of certain events (shock, ESB) may increase the probability of as yet undetectable responses occurring in the presence of these stimuli prior to the onset of the unconditioned stimulus. An extreme S^D view of conditioned reinforcement would state that when pairing is effective, an as yet undetected response is being made in the presence of the previously neutral stimulus even though such a response is not required by the procedure. The research by Hutchinson (1977) was cited earlier in support of this possibility. It should be noted here that any response eventually made in the presence of the neutral stimulus which is useful to the organism with respect to the unconditioned stimulus, and which is capable of operant control, is likely to be maintained by its useful (reinforcing) consequences.

If this were the case, then both the S^D procedure and pairing, a non-contingent discriminative stimulus procedure when effective, create conditions necessary for "confusion", which is manifested later in responding maintained by the production of the stimulus alone. Responding should cease when and if a discrimination is formed with respect to the absence of primary reinforcement. The Schoenfeld, Antonitis and Bersh (1950) experiment perhaps best exemplifies a failure of pairing

to establish a neutral stimulus as discriminative for food; a food-deprived rat was eating a food pellet when the paired stimulus was presented. Not only was there no requirement for a response during the stimulus, but conditions actually minimized the chance of such a response. The result was that the paired stimulus did not function as a reinforcing consequence. However, in the experiment by Skinner (1938) conditions were different. A tone was paired with food pellet delivery, and Skinner reported that after several such pairings the rat reliably approached the food dish only after the tone sounded. Here the tone not only predicted food but the subject responded differentially in its presence--an approach was made to the food dish at the most opportune time, resulting in the rapid and relatively effortless obtaining of the pellet. It is not surprising that this tone later served to strengthen and maintain a new response until it had occurred frequently enough in the absence of food to lose its predictiveness with respect to food. The Squires et al. (1975) analysis of responding in second-order schedules supports the above argument; procedures which maintain the effectiveness of a stimulus as a conditioned reinforcer, according to this S^D view, function essentially to maintain the lack of discriminability between presentations of the potential conditioned reinforcer alone and presentations of the primary reinforcer. Lovaas et al. (1966) stressed the importance of such deception if only the potential conditioned reinforcer is to be presented in certain situations.

If pairing effects exist independently of an eventual S^D explanation, these effects are probably weak, especially when food or other

less powerful positive consequences are used as the unconditioned reinforcer. When food is employed in the human setting, for example, it is rarely to an organism deprived to 80-85 percent of normal body weight.²² The weakness of such a pairing-produced conditioned reinforcer would probably manifest itself in rapid loss of response-strengthening effects as soon as a discrimination was formed concerning the absence of other currently effective reinforcers. The essential point to be made, however, is that the experimenter may not be in control of the amount of discrimination learning which takes place during a pairing procedure. This means that the procedure may or may not prove effective in any given attempt with any given individual.

The previous two statements refer specifically to the possibility that whenever a pairing procedure does produce an effective conditioned reinforcer, the organism had begun to emit a response in the presence of a neutral stimulus capable of being controlled by consequences. To what extent a relation may exist between the conditioned reinforcing effects of a stimulus and the respondent eliciting effects of that stimulus was not investigated. For example, is it the case that a conditioned reinforcer established through an S^D procedure with food as the unconditioned reinforcer would, when presented following a response, serve to strengthen that response only so long as it also produced salivation and/or other respondents reliably occurring with food presentations?

It is of course possible that two distinct effects exist, one

²² Research relating hours of food deprivation and/or body weight reduction to effectiveness of reinforcing consequences with humans is unknown to the author.

deriving from a simple temporal contiguity and the other from S^D training, both of which could contribute to conditioned reinforcer effectiveness; in the S^D procedure both effects could be produced and summate. Both effects could also occur during a pairing procedure, depending upon whether an operant response developed during the neutral stimulus presentation.

If only the respondent conditioning effect developed during pairing, its response-strengthening effect on the previously neutral stimulus may appear only as a transition effect in experiments similar to Schuster's (1969) and the one reported here as Experiment VI. This could be the case if the nature of respondent conditional discrimination as reported by Pavlov (1927) were such that a previously neutral stimulus must be related differentially to an unconditioned stimulus for respondent conditioning effects to develop or be maintained. In fact, one might be led to predict no effects of pairing in Experiment VI: if the neutral stimulus is assumed to be the extra, added stimulus it was not differentially related to (paired with) greater amounts of food. Once a discrimination had formed with respect to which lever was associated with which set of delayed consequences and that both were equivalent with respect to food, the extra stimuli would not be differentially related to food. Such differential relation may be necessary in view of Pavlov's findings concerning respondent conditional discrimination, which he developed when describing conditioned inhibition (Pavlov, 1927, pp. 68-70). Such an analysis would not predict the results obtained by Zimmerman (1963) and Thomas (1969), and would suggest the possibility that (an)other variable(s) may be involved in

the maintenance of responding by stimulus-only consequences.

Miller (1951) and Nevin (1973) have both commented upon the weakness of conditioned reinforcers established through pairing with unconditioned positive consequences. The results of the experiments reported here support this observation. If this is true, the most prudent strategy with human populations at the present time would be the adoption of the chaining procedure for establishing conditioned reinforcers described in the Introduction. The robustness of the chaining procedure is widely recognized, both in the experimental literature and in token economy applications. On the other hand, the present research questions whether pairing is an effective procedure with all subjects and in all settings. Chaining is an S^D procedure, which views each individual component completion both as a conditioned reinforcer which signals component completion and consequently reduced time to primary reinforcement, and as a discriminative stimulus for the required behavior in the next component. Long sequences of component completions can be seen as transitions to more valued situations as each segment is terminated and unconditioned reinforcement is nearer (Baum, 1973), and as reductions in delay to primary reinforcement (Fantino, 1977); each of the successive stimuli in the chain also signal closer temporal nearness to food (Schuster, 1969). The importance of a currently effective reinforcer at chain completion should not be overlooked. Stated in more general terms, contingent presentations of the conditioned reinforcer should be differentially correlated with an improved situation for the organism in terms of increased presentation of currently effective positive events and/or reduced

presentation of currently aversive ones.

This tentative recommendation, however, does not respond to the basic issue of whether the pairing procedure is effective. Other corollary questions are in what situations and with what subjects is pairing effective; what is the strength of the procedure in terms of responses capable of being generated and maintained; and what procedures are required to maintain the reinforcing effectiveness of the stimulus. The experiments proposed in the Discussion section of Experiment VI will hopefully generate useful data in this respect. It was suggested there (see page 157 of this report) that an attempt be made to facilitate the formation of a discrimination concerning the superfluous nature of the added stimuli. Should a preference for the added stimulus lever develop, assessment of the role of pairing as opposed to the temporal nature of the added stimuli would follow.

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- Reference Note 3: van Haaren, Frans; January, 1978; Personal Communication.
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