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EFFECTIVENESS OF LEARNED REINFORCEMENT AS
A FUNCTION OF PRIMARY REWARD PERCENTAGE.
AND NUMBER OF PRIMARY PAIRINGS.**

**The Ohio State University, Ph.D., 1966
Psychology, experimental**

University Microfilms, Inc., Ann Arbor, Michigan

EFFECTIVENESS OF LEARNED REINFORCEMENT AS A FUNCTION OF
PRIMARY REWARD PERCENTAGE AND NUMBER OF
PRIMARY PAIRINGS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the
Degree Doctor of Philosophy in the Graduate School of
The Ohio State University

By

James Pence James, B.A., M.S.

* * * * *

The Ohio State University
1966

Approved by

Adviser
Department of Psychology

ACKNOWLEDGMENTS

The writer expresses his sincere appreciation to Dr. Raymond C. Miles, his adviser, for guidance and encouragement. Thanks are also due to the other members of the dissertation committee, Drs. Delos D. Wickens and Reed Lawson. For financial assistance, he expresses his gratitude to the National Institute of Mental Health. And to his wife, Margit, he expresses his sincere thanks for her encouragement and faith.

The research reported here was supported in part by NIMH Grant MH-08016.

VITA

June 2, 1937 Born, Chicago, Illinois

1961 B.A., Northern Illinois University,
DeKalb, Illinois

1961-1962 Graduate Assistant, Northern Illinois
University, DeKalb, Illinois

1962-1963 Teaching Assistant, Oklahoma State
University, Stillwater, Oklahoma

1963 M.S., Oklahoma State University,
Stillwater, Oklahoma

1963-1964 Graduate Assistant, The Ohio State
University, Columbus, Ohio

1964-1965 Teaching Assistant, The Ohio State
University, Columbus, Ohio

1965-1966 Predoctoral Fellow, NIH Training Grant,
The Ohio State University, Columbus, Ohio

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INTRODUCTION

When a neutral stimulus is repeatedly paired with the occurrence of primary reinforcement, the neutral stimulus will acquire reinforcing properties of its own. Typically, the acquisition of reinforcing properties by a neutral stimulus is demonstrated in a two-stage experiment. During the first (training) stage, the neutral stimulus and primary reinforcer are presented to Ss in a specific temporal sequence. During the second (testing) stage, the strength of the previously neutral stimulus, the derived or secondary reinforcer as it is now called, is measured in one of three ways by making its appearance contingent upon a particular response. One common test procedure has been to measure extinction strength of the instrumental response which preceded the neutral-stimulus, primary-reinforcement complex during training; in the test situation, some Ss experience secondary reinforcement following the instrumental response and some do not. According to the second test procedures, Ss are required to make a choice between the secondary reinforcer and a neutral stimulus. The choice response is usually identical with that which preceded neutral-stimulus, primary-reinforcement pairings during the training stage. A third procedure is designed to require Ss to learn a new response (one not required during training) when secondary reinforcement is contingent upon that response in the test phase of the experiment.

Many excellent reviews of secondary reinforcement experiments are available. The first review (by Miller) appeared in the Handbook of Experimental Psychology (1951) and was followed by Myers' (1958) review. Kimble (1961) devoted a chapter to the secondary reinforcement literature in his revision of Hilgard & Marquis' Conditioning and Learning, and Kelleher and Gollub (1962) reviewed the work done by the Skinner group using chained schedules to investigate what they refer to as conditioned reinforcement (i.e., secondary reinforcement). Very recently, Wike (1966) edited a book of readings on the subject and, based upon his review of the literature, listed 15 principles regarding secondary rewards.

Several studies have shown that strength of a secondary reinforcer is functionally related to the following variables: (1) number of pairings of neutral stimulus with primary reinforcement (Bersh, 1951; Miles, 1956); (2) length of interstimulus interval (Bersh, 1951; Jenkins, 1950); (3) amount of primary reward (Butter & Thomas, 1958; D'Amato, 1955); (4) effortfulness of response (Lewis, 1965); and (5) schedule of primary reinforcement (D'Amato, Lackman, & Kivy, 1958; Fox & King, 1961; Klein, 1959; Saltzman, 1949; Zimmerman, 1957). On the basis of these and similar studies, psychologists apparently are in a position to make a fairly definitive statement concerning the optimal conditions for producing a secondary reinforcer. The reader is cautioned, however, that the literature also contains a number of studies whose findings indicate no significant effect of these variables on the subsequent strength of the secondary reinforcer during testing (Myers, Craig, & Myers, 1961; Fort, 1961, Hopkins, 1955, Lawson, 1953, 1957; Longstreth, 1966).

In addition to these studies concerned with identifying and quantifying parameters necessary to the formation of a secondary reinforcer, certain experiments have been conducted to test particular theories. For example, Miles and Wickens (1953) tested a portion of Hull's theory and found that a secondary reinforcer acquired under a specific drive did not reduce consummatory behavior when later presented while Ss were eating. To test the hypothesis (Keller and Schoenfeld, 1950) that a necessary condition for the acquisition of a secondary reinforcer is that it serve as a discriminative stimulus for an instrumental response during training, Stein (1958) obviated instrumental responding by using brain stimulation as primary reinforcement. Secondary reinforcement effects were shown under these conditions.

From the preceding discussion it becomes evident that much experimental and theoretical effort has been expended in the area of learned rewards. It is also obvious that we remain uninformed about many of its aspects. For instance, no investigator has addressed himself specifically to the question of how secondary reward value is acquired, i.e., whether it is learned through a process bearing more similarity to classical conditioning or to instrumental conditioning. This question would be meaningful only to a two-process theorist. Skinner (1938, pp. 18-21) strongly emphasized this distinction. He assumed that when behavior is elicited by a stimulus, learning occurs by means of a Pavlovian (respondent) conditioning process. Thorndikian learning, not correlated with a specific eliciting stimulus, involves a different process which he named operant conditioning. In 1940, Hilgard and Marquis referred to these two processes as classical conditioning and

instrumental conditioning, respectively. Mowrer (1960) distinguished between the two processes by suggesting that classically conditioned responses are autonomic and instrumentally conditioned responses are skeletal. Kimble (1961), however, has listed 15 phenomena common to both instrumental and classical conditioning (e.g. acquisition, extinction, spontaneous recovery, stimulus generalization, and discrimination). Empirical data, however, reveal only one reliable difference between the two kinds of learning. During either acquisition or asymptotic performance, a conditioned response (CR) exhibits weaker properties when it has been partially reinforced than when every conditioned stimulus (CS) presentation is followed by the unconditioned stimulus (UCS). Although this decremental effect also occurs during early acquisition of partially reinforced instrumental responses, strength of these partially reinforced instrumental responses later surpasses that of continuously reinforced instrumental responses.

Several experiments have been designed to reveal the effects of partial reinforcement during classical conditioning. Pavlov (1927) reported that conditioning suffered immensely when meat powder (UCS) was omitted on certain trials. Grant and Schipper (1952) demonstrated the decremental effect which partial reinforcement has upon a conditioned eyelid response. Using a light CS and a corneal air-puff as UCS, they conditioned five groups of 14 Ss each under light-adapted conditions where percentage reinforcement was either 0, 25, 50, 75, or 100%. The findings indicated essentially that percentage CR's was a positive function of percentage of reinforcement. Reynolds (1958) used a 50% reinforcement

schedule wherein the partial group's "nonreinforcement" consisted of a trial in which the CS-UCS interstimulus interval was 2500 msec. On reinforced trials the intertrial interval was 500 msec. Reynolds' results confirmed those of Grant and Schipper. Ross (1959) used a similar schedule of reinforcement in an eyeblink conditioning situation, but added two groups which were switched, one from 100% to 50% and the other from 50% to 100% reinforcement. Again, his results showed the decremental effect of partial reinforcement. Furthermore, the groups switched from continuous to partial reinforcement showed a sudden decrease in performance while the Ss switched from partial to continuous reward gradually approached the performance level of the continuous group. More recently, an experiment by Fitzgerald (1963), with dogs as Ss and salivation as the unconditioned response (UCR) to acetic acid, produced results consonant with those of the eyeblink studies, i.e., the magnitude of the CR in drops of saliva was a positive function of percentage of reinforcement (25, 50, or 100%). The decremental effect of partial reinforcement upon the eyelid CR of the rabbit was recently demonstrated by Thomas and Wagner (1964).

Let us now turn to investigations concerning the effect of partial reinforcement upon instrumental responses. Weinstock (1958) gave rats one trial per day under either 16.7, 33.3, 50, 66.7, 83.3, or 100% reinforcement in an enclosed runway. Time-dependent response measures of latency and speed of running indicated that partially reinforced animals were initially slower than continuously reinforced Ss, but that the performance of Ss under partial reinforcement surpassed that of the 100% group by the 40th trial. Goodrich (1959) confirmed Weinstock's (1958) results for

starting and running speeds; however, goal box speeds were either superior for the 100% group (Experiment I) or did not differ for the 100% and 50% groups (Experiment II). Wagner (1961) has recently confirmed Goodrich's (1959) results concerning starting, running, and goal box (Experiment I) speed measures.

To return to the question of how a secondary reinforcer is learned, attention is called to a point stressed by Kimble (1961, pp. 97, 169-170) that the operations required to experimentally produce a secondary reinforcer are identical to those of classical conditioning, i.e., the neutral stimulus is associated with primary reinforcement in the same way that the CS is associated with the UCS during classical conditioning. Frolov's investigations of higher order conditioning as reported by Pavlov (1927) point to a pure instance of a learned reward established through classical conditioning. In summary, it appears that learned rewards can be classically conditioned, that the experimental operations of imbuing a stimulus with rewarding properties in an instrumental learning situation are identical with classical conditioning, and that a method for separating classical conditioning from instrumental conditioning is available through the empirically demonstrated differential effect which partial reinforcement has upon the two processes of learning. Accordingly, a survey of secondary reinforcement experiments in which schedule of primary reinforcement was varied during training may provide an answer to the question of how a secondary reward is learned.

Wike (1966, pp. 427-431) considers 19 experiments meeting the requirement of partial primary reinforcement during training and continuous

secondary reinforcement in the test situation. A recent experiment (Knott & Clayton, 1966) also meets these requirements. Basing his conclusion upon five experiments, Wike (1966) makes the generalization for within-Ss designs, that a stimulus paired with partial reinforcement will be a more effective secondary reinforcer than a stimulus paired with continuous reinforcement. However, the concern here is not with experiments employing the differential method since the disparity between classical and instrumental conditioning was demonstrated with the absolute method, a between-Ss design. A possible exception is the study of Ross (1959) in which the groups were switched from one reinforcement schedule to another. But strictly speaking, the switching procedure is not in the spirit of the differential method as delineated by Lawson (1957) for amount of reward, since Ss did not simultaneously experience two stimuli each associated with a different reinforcement schedule. The results of some of the remaining studies, with between-Ss designs, have been questioned by Wike (1966, p. 429). Generalizing from the results of the remainder of between-Ss experiments, Wike concludes that a secondary reinforcer established in a between-Ss experiment will manifest stronger effects when paired with partial primary reinforcement during the training stage than when the neutral stimulus acquires reinforcing properties under a continuous schedule of primary reinforcement. However, the results of the studies from which Wike draws his conclusion can also be questioned. They all required the same response during the testing stage as that required in the training stage. Therefore, any conclusion concerning the strength of the secondary reinforcer, as measured by resistance to

extinction of the instrumental response, is likely to be confused with the partial reinforcement effect reflected by these responses during the test phase. Kimble (1961, p. 187) has leveled this criticism against such experiments. Knott and Clayton (1966) circumvented this methodological weakness by employing brain stimulation as primary reinforcement and requiring no instrumental response during training. The group administered partial primary reinforcement showed performance superior to the group given continuous reinforcement during training. Their results appear to confirm Wike's statement of the superiority of partial reinforcement over continuous reinforcement for acquiring a secondary reinforcer.

In view of the foregoing discussion, it seemed fruitful to conduct an experiment wherein different instrumental responses were required during training and testing in order to more clearly delineate the effect of schedules of primary reinforcement upon the later effectiveness of a secondary reward. Since there is some inconsistency among results of experiments concerning the effect of number of primary reinforcements upon strength of secondary reward (Bersh, 1951; Hall, 1951; Miles, 1956; Myers, Craig, & Myers, 1961; Kass & Wilson, 1966), it seemed desirable to also manipulate number of training trials.

In summary, one purpose of the present investigation was to provide parametric data on the shape of the acquisition function of a secondary reinforcer as a result of both different schedules of primary reinforcement and number of pairings of neutral stimulus with primary reinforcement. Second, an attempt was made to determine the relative position of asymptotes. A third aim was to provide evidence bearing on the issue of

how secondary reinforcing properties are acquired, whether through a process showing greater similarity to instrumental conditioning or to classical conditioning.

METHOD

Subjects: The Ss were 136 male albino rats, 90-120 days old at the beginning of each replication.

Apparatus: The equipment used during the pretraining stage consisted of two operant chambers (9 in. wide x 12 1/2 in. high x 13 in. long) constructed of clear Plexiglas. These chambers were placed in a sound insulated box which was ventilated by a single exhaust blower mounted on the outside. A retractable lever (1 1/8 in. wide x 3/8 in. thick), 3 1/2 in. above the floor, protruded 5/8 in. from the center of the front wall. Located 2 1/2 in. to the right of the lever was a .01-ml. water dipper which was 1 1/2 in. above the floor and protruded 3/8 in. into the chamber. Continuous illumination was provided by an incandescent, 1.12-w. lamp located at the front of the chamber.

The Plexiglas chambers (9 in. wide x 12 in. high x 12 in. long) used for secondary reinforcement training and testing dispensed 45-mg. Noyes pellets. The center of the retractable lever was located 2 3/4 in. from the right wall. The center of the food cup was located 2 3/4 in. from the left wall, and its edge was 1 1/4 in. from the floor. Water was continuously available from a water bottle attached to the outside of the front wall. The metal drinking tube was located 3/4 in. from the right wall. An incandescent 30-v. lamp located at the rear of each chamber provided continuous illumination. A 6-v. step-down transformer provided power for, and dimmed the lamps. A 28-v. lamp located directly above the

food cup, 4 1/4 in. above the floor, served as the initially neutral stimulus (the potential secondary reinforcer). Each of these light sources derived their power from separate 25.2-v. transformers. Programming and recording equipment were located in an adjacent room.

Experimental design: The experiment consisted of five replications of 26 Ss, accounting for two Ss per treatment combination. Different groups were given 40, 80, 160, or 320 pairings of neutral stimuli (light and click) and food, while the probability that primary reinforcement would follow the neutral stimuli was .25, .50, or 1.00, again for different groups. The experiment was thus a between-Ss 3 x 4 factorial. In addition, one O-pairings control group (N = 10) received neither neutral stimulus nor primary reinforcement, and, during the final replication, a second O-pairings group (N = 6) experienced 80 presentations of the light-click compound with no primary reinforcement.

Pretraining: On the day of their arrival in the laboratory, Ss were placed on an ad lib schedule of food and water. On the second day a 23-hr. schedule of water deprivation was instigated, consisting of 1 hr. of water availability and 23 hr. of water deprivation. For the remainder of the pretraining stage Ss were maintained on ad lib food and a 23-hr. water deprivation schedule. On the 4th day each S was adapted to the pretraining chamber for a 15-min. period while under approximately 22-hr. water deprivation. Dipper training, occurring on the 5th and 6th days, consisted of 25-min. sessions wherein the dipper was programmed to function at variable intervals on the average of once every 30 sec. Subjects were conditioned to press the lever to operate the dipper on the 7th and 8th days. In the

first replication Ss were under 22-48 hr. water deprivation at the time of lever training. These conditions of deprivation were unsatisfactory so on subsequent replications Ss were deprived for 44-72 hr. On the day of conditioning each S was allowed 20 lever responses. On the 9th day all Ss were allowed 40 reinforced bar presses and were subsequently given free access to water and placed on a food deprivation schedule consisting of 12 gm. of Purina rat chow per day.

Secondary reinforcement training: On Days 10-14 Ss were adapted to the food deprivation schedule and to the training chambers during daily 15-min. periods. Two food pellets were available in the food cup upon each S's initial placement into the experimental chamber during this adaptation stage. Subjects were then randomly assigned to experimental conditions. Thereafter, each S was run in a specific experimental chamber; the response lever was retracted during training sessions. Beginning on the 15th day, each S received 40 primary reinforcements per day until the assigned number of pairings had been experienced. Thus, the number of daily trials was 40 for the 100% group, 80 for the 50% group, and 160 for the 25% group. Light onset occurred on the average of every 20 sec. and successive light presentations did not follow one another by less than 5 sec. or more than 35 sec. A food pellet was dispensed into the food cup 1 sec. after the onset of the light. After pellet delivery the light remained on for another 1 sec., making its total duration 2 sec. On nonreinforced trials the light onset, feeder solenoid firing, and light offset, all occurred in the usual temporal order except, of course, no food pellet was dispensed. These nonreinforced presentations were programmed to occur according to a predetermined quasi-random schedule.

Secondary reinforcement test: Testing began on the day after the assigned number of pairings had been experienced by each S. The lever was inserted and the secondary reinforcement complex was programmed to occur after each lever press. Responses were summarized in 1-min. periods for 4 daily sessions. If S emitted less than 10 responses during any session, testing was discontinued after 4 daily sessions. Those Ss not meeting this criterion were tested until either the daily response frequency was less than 10 or until 10 days of testing were completed.

RESULTS

Since there was no significant difference ($t = .914$, $df = 14$, $p = .50$) between the control group consisting of 10 Ss receiving no light-click presentation and the Ss receiving 80 light-click presentations, these groups were combined.

The mean number of responses for the groups differing in percentage of reinforcement are presented in Figure 1. Figure 2 shows the mean number of responses for the groups differing in the number of neutral-stimulus, primary-reinforcement presentations. Each of the four data points within a group, represents a daily test session. Inspection of both Figure 1 and Figure 2 reveals that on the 1st day the groups are fairly well differentiated with respect to the independent variables. By the 2nd day the differential effects due to percentage of reinforcement and number of pairings have diminished considerably. Similarly, no differences are apparent on the 3rd and 4th days. The overall effectiveness of secondary reinforcement does appear to continue over the 4 days since the experimental groups remain at a slightly higher response level than the control group.

Since the purpose of the present experiment was to investigate the effects of the main variables rather than to demonstrate secondary reinforcement as a phenomenon, an analysis of variance was performed on the 1st day's data only. It included as factors: percentage of primary

Fig. 1.--Mean Number of Responses For Each Percentage Primary Reinforcement Condition as a Function of Days of Testing.

Fig. 2.--Mean Number of Responses For Each Number of Pairings Condition as a Function of Days of Testing.

reinforcement, number of pairings of the neutral stimulus complex with primary reinforcement, and replications. In an analysis of this sort, in which two observations constitute the basis upon which within-cell variance is estimated, homogeneity of variance cannot usually be assumed. In respect to this issue, Hays (1963) instructs the psychologist who is interested in direct comparisons of means that, ". . . modern opinion holds that the analysis of variance can and should be carried on without a preliminary test of variances, especially in situations where the number of cases in the various samples can be made equal" (p. 381). Returning to the present analysis, its outcome showed none of the interactions to be significant. With the exception of replications, all main effects were significant (percentage of reinforcement: $F = 4.49$, $df = 2/60$, $p < .05$; number of pairings: $F = 3.01$, $df = 3/60$, $p < .05$).

Since the differential treatment effect is manifest only on the 1st day, these data were further analyzed. Due to the experimental procedure employed, a print-out counter was started after Ss were placed into the experimental chambers on their 1st day of testing. Since the latency of the first bar press varied from animal to animal, it is believed that the 3-min. blocks (taken directly from the print-out counter starting with the first 1-min. block in which S responded) provide a more accurate estimate of S's response strength.

Figures 3 and 4 present mean data from the first three 3-min. blocks of the 1st day. Inspection shows that most of the secondary reward effect is present only during the first two blocks. A repeated measures analysis of variance was performed on the data presented in

Fig. 3.--Mean Number of Responses For Each Percentage Primary Reinforcement Condition on Each of Three 3-Min. Blocks of Test Day 1.

Fig. 4.--Mean Number of Responses For Each Number of Pairings Condition For Each of Three 3-Min. Blocks of Test Day 1.

Figures 3 and where the factors of the analysis were percentage of reinforcement, number of pairings, and replications taken over the three 3-min. blocks. The results of the within-Ss portion of the analysis indicates that blocks were highly significant ($F = 60.53$, $df = 2/120$, $p < .01$). However, the F-ratios of all the interactions with blocks were less than unity. From the between-Ss part of the analysis two sources of variance were significant: percentage of reinforcement ($F = 4.15$, $df = 2/60$, $p < .05$) and number of pairings ($F = 3.79$, $df = 3/60$, $p < .05$). These main effects are illustrated in Figures 5 and 6. A trend analysis was performed on the two significant main effects and the results indicated that a quadratic function accounted for a major portion of the variance within the percentage of reinforcement variable as is indicated in Figure 5 ($F = 6.86$, $df = 1/60$, $p < .05$), while the number of pairings factor was defined significantly by the linear component ($F = 7.72$, $df = 1/60$, $p < .05$). The Newman-Keuls Sequential Range Test (Winer, 1962) was employed to test all differences between means within all levels of percentage of reinforcement and number of pairings. The following group means were significantly different ($p < .05$): percentage of reinforcement, 50% vs. 25%, 25% vs. 100%, and 50% vs. 100%; number of pairings, 320 vs. 80, 160 vs. 80, 320 vs. 40. Figure 7 presents the responses of the three 3-min. blocks for the three percentage of reinforcement groups plotted over number of pairings. Since the percentage of reinforcement X number of pairings interaction term did not attain significance, no individual comparisons were made between the data points. However, to show that secondary reinforcement was obtained, a t-test was run on the difference

Fig. 5.—Mean Responses For Each Percentage Primary Reinforcement Condition.

Fig. 6.--Mean Number of Responses For Each Number of Pairings Condition.

Fig. 7.--Mean Number of Responses For Each Percentage Primary Reinforcement Condition as a Function of Number of Pairings.

between the 100% group mean and the control group mean. The results indicated a reliable difference between the two groups ($t = 2.05$, $df = 54$, $p < .05$).

DISCUSSION

The present results strongly suggest that a partial primary reinforcement schedule, rather than a continuous schedule, was more effective in the development of a secondary reinforcer. The data of Figure 1 show the ephemeral nature of this differential effect, i.e., by the 2nd day there appears to be no difference at all. The fact that differential response strength attributable to number of pairings (Figure 2) also was found only on the 1st day may suggest the generally weak nature of secondary reinforcement per se.

A few words concerning the design of the present experiment may be apropos at this time. To reiterate, Ss were not required to make the same response during both training and testing. Furthermore, the design did not require learning a new response during the test stage. Instead, all Ss began the test phase with equal bar-press response strength acquired prior to secondary reinforcement training under a deprivation state different from that in effect during training and testing. It is recognized that transfer habits from one drive to another can occur but this effect should have been minimal, since water deprivation was zero during testing and previous water deprivation, reinforcement conditions were the same for all Ss. Consequently, differences in the maintenance of bar-press response rate during testing can be attributed to differential secondary reward strength. The design of this experiment also eliminated

two factors which may have influenced the results of secondary reinforcement experiments where the same response was required during training and test phases. First, partially reinforced Ss in these experiments showed a higher response rate during training, and this higher response rate could have transferred to the test situation. Second, strength of the response learned during training could have revealed a strong partial reinforcement effect which masked the relatively weak effect of the secondary reward. Finally, the present method may prove to be a more adequate technique than the new-learning method, since, with the present design, the likelihood of "no responders" is considerably lessened.

Returning to the results, it is clear that the ordered strength of secondary reinforcement, from low to high, as a function of percentage of primary reward, was 100%, 25%, 50%. As Figure 5 indicates, the function is of the inverted-U variety, and when the group which experienced no pairings of primary reward with neutral stimulus is added at the zero percentage point, the emergence of a quadratic function is quite clear. These results generally are in agreement with results of studies which investigated resistance to extinction as a function of percentage of reinforcement during training. An inverted-U function is a typical finding in that area (Lewis, 1960). Moreover, the present study afforded a direct test of Grant and Schipper's (1953) conjecture that the inverted-U function represents the operation of two processes, one due to increased response strength because of reinforced trials, and the other process as a result of the hypothetical positive relation between percentage of reinforcement in training and the ease of discriminating the training sessions from

extinction. As stated by Lewis (1960), greater training would move the point of inflection toward the lower end of the percentage scale. Since in the present experiment the percentage of primary reinforcement by number of pairings interaction was not significant, no support was found for the hypothesis of Grant and Schipper (1953). The findings that primary reinforcement schedules produce similar functions (inverted U) for response strength and secondary reinforcement has important implications. Various reinforcement schedules may produce differential response strength indirectly through the conditioning of different amounts of secondary reinforcement.

The data reported here are consistent with results of other between-Ss secondary reinforcement studies in which the same parameters were manipulated. The data support Wike's (1966) generalization that with between-Ss designs, partial primary reinforcement yields stronger reinforcing effects than continuous reinforcement. However, the present results take issue with certain other hypotheses. For instance, Wike (1966, p. 430) states that "three studies . . . suggest an hypothesis regarding partial reinforcement: the more nonreinforced trials that are administered in training, the greater the secondary reinforcing value of the stimulus." The finding of the present experiment indicated that the 25% group, which was administered twice as many nonreinforced trials as the 50% group, performed reliably poorer during testing than the 50% animals.

Fox and King (1961) suggested that a necessary condition for demonstrating the effect of scheduling in the development of secondary reinforcement was partial presentation of primary reward during training

followed by partial presentation of secondary reinforcement during testing. This supposition was not supported by the present experiment, since a reliable secondary reinforcement effect was found for all percentage groups when a continuous schedule of secondary reinforcement was in effect during testing.

The other major finding of the present study is that number of pairings of neutral stimulus with primary reward reliably determines the effectiveness of learned rewards (refer to Figure 6). Specifically, it was found that the number of pairings alone, regardless of schedule, determined the strength of a secondary reinforcer. Number of pairings was also found to be a significant variable in the studies of Bersh (1951), Hall (1951), and Miles (1956), all of which used rats as Ss. Conversely, in studies using children as Ss (Myers, 1960; Myers, Craig, & Myers, 1961; Kass & Wilson, 1966), number of pairings had no effect on strength of secondary reinforcement. In fact, in the study of Kass & Wilson (1966) resistance to extinction in the presence of the secondary reinforcer was a negative function of number of pairings administered during training. It may be found that in the case of human Ss the departure from the traditional effect of number of reinforcements could be attributed to the operation of a cognitive element which tends to obscure basic learning processes. Because of verbal mediational abilities, the task becomes better defined for human Ss as trials progress, and a discrimination between acquisition and extinction is thereby facilitated. The discrimination hypothesis has recently fallen into ill-repute with animal work (see Theios, 1962; Jenkins, 1962; Sutherland, Mackintosh, & Wolfe, 1965). An experiment investigating the relation

between number of pairings and secondary reinforcement in pre-verbal children is badly needed.

Turning now to the issue of how a secondary reinforcer is learned, the present results suggest that a neutral stimulus acquires rewarding properties through an instrumental learning process. It can be argued that during training, Ss learned the instrumental response of approaching the food tray in the presence of the neutral stimulus. The neutral stimulus could, in this case, be called a discriminative stimulus (S^D). When primary reinforcement was eliminated during testing, it is possible that the reinforcement for bar pressing consisted of the elicitation of the approach response in the presence of the light-click complex. This approach response would be more resistant to extinction if it were acquired under partial reinforcement. However, a more adequate explanation must incorporate a mechanism to account for this partial reinforcement effect.

A point of departure to explain the partial reinforcement effect is to examine a statement made by Hull (1943). In reference to how a secondary reinforcer is learned, he stated that a ". . . secondary reinforcing stimulus acquires its power of reinforcement by virtue of having conditioned to it some fractional component . . . of the goal situation . . ." (p. 100). Differential secondary reinforcing strength of a stimulus is directly related to its ability to elicit r_g (Hull, 1943, p. 101). Thus, according to Hull, the potential secondary reinforcer gains in associative strength concomitantly with r_g through the process of classical conditioning. The stronger the r_g , the stronger will be the stimulus consequence, s_g , which produces the overt response.

It follows that the most strongly conditioned r_g 's, and, therefore, the strongest secondary reward, should be acquired under 100% primary reinforcement. This prediction is not borne out by the present data.

Amsel's extension of Hullian theory (1962), which explicitly deals with effects of frustrative nonreward (i.e., nonreward of a previously rewarded response), can be applied to the present findings. During training the neutral stimulus comes to elicit fractional anticipatory components of the overt consummatory response, which are themselves elicited by the food pellet. These are similar to Hull's r_g and are conditioned to the neutral stimulus by the same mechanism. In the case of the partially reinforced $\underline{S}$ s, a different response is elicited in the vicinity of the food cup as a result of nonreinforced trials. This reaction to nonreward is termed frustration and, as is the case with consummatory responses, fractional components of it, r_f , can be conditioned to the potential secondary reinforcer. The frustrative response is thought to be an avoidance response with associated emotional overtones. Conditioned frustration (r_f) possesses the same attributes.

In regard to the present study, for the partially reinforced $\underline{S}$ s, the stimulus initially elicits both r_g and r_f , and a conflict develops since the stimulus consequences of r_g and r_f (s_g and s_f) elicit incompatible approach and avoidance responses. Since the 50% $\underline{S}$ s are reinforced for approaching in the presence of r_f , the conflict is resolved and s_f comes to be associated with approach responses. During testing the 100% group experiences the nonreward reaction for the first time, avoidance responses are elicited, r_f becomes conditioned to the stimulus,

and the approach responses cease. For the 50% group, r_g is not as strongly conditioned to the stimulus as it is in the 100% group due to the decremental effect of partial reinforcement. But the 50% Ss have been conditioned to approach the food cup in the presence of nonreward so they have gained some in motivation as a result of the conditioning of the r_f mechanism to the neutral stimulus. The 25% group similarly gains in motivation by having the r_f conditioned to the stimulus. This is enough to boost it above the 100% group, but associative strength is less because r_g was reinforced on only a 25% schedule of primary reward and that is why it is below the 50% group.

In summary, the results of the present study suggest that a learned reward is acquired through an instrumental conditioning process. As reviewed previously, this follows from the differential effects of partial reinforcement upon classically and instrumentally conditioned responses. On the other hand, it is an established empirical fact that learned rewards are also acquired through a classical conditioning process as attested by the experiments on higher order conditioning. This observation leads back to the two-process theory as a means of explaining learning. But, rather than accept that now, specific research should be conducted in this area. For instance, would schedule of primary reinforcement, employed during the conditioning of a neutral stimulus as a CS, facilitate or hinder the later effectiveness of this CS when used as a UCS in a higher order conditioning situation? It is most likely that the partial schedule would hinder the effectiveness of the CS to serve as a learned reward. The position that secondary rewards are learned through a classical conditioning

process cannot be entirely disregarded. When a stimulus, which acquires reward value through partial reinforcement in an instrumental conditioning situation, is tested in a classical conditioning situation, the decremental effect of partial reinforcement on classically conditioned responses may obtain. The present results indicated that when this secondary reinforcer was tested in a situation requiring instrumental responses, a possible motivational factor obtrudes and response facilitation occurs. It is suggested that the kind of situation (instrumental or classical conditioning) employed during testing may determine whether a secondary reinforcer acquired under partial primary reinforcement will be more or less effective than a learned reward acquired under 100% primary reinforcement. A test of this could be easily conducted. One group would acquire a learned reward in a classical conditioning situation, half the Ss under 50% and half under 100% primary reinforcement. They would all be tested in an instrumental conditioning situation. Similarly, Ss in another group would receive either 50% or 100% primary reinforcement during secondary reinforcement training in an instrumental conditioning situation, and this group would subsequently be tested in a classical conditioning situation.

REFERENCES

- Amsel, A. Frustrative nonreward in partial reinforcement and discrimination learning: Some recent history and a theoretical extension. Psychol. Rev., 1962, 69, 306-328.
- Bersh, P. J. The influence of two variables upon the establishment of a secondary reinforcer for operant responses. J. exp. Psychol., 1951, 41, 62-73.
- Butter, C. M., & Thomas, D. R. Secondary reinforcement as a function of the amount of primary reinforcement. J. comp. physiol. Psychol., 1958, 51, 346-348.
- D'Amato, M. R. Secondary reinforcement and magnitude of primary reinforcement. J. comp. physiol. Psychol., 1955, 48, 378-380.
- D'Amato, M. R., Lackman, R., & Kivy, P. Secondary reinforcement as affected by reward schedule and the testing situation. J. comp. physiol. Psychol., 1958, 51, 737-741.
- Fitzgerald, R. D. Effects of partial reinforcement with acid on the classically conditioned salivary responses in dogs. J. comp. physiol. Psychol., 1963, 56, 1056-1061.
- Fort, J. G. Secondary reinforcement with preschool children. Child Developm., 1961, 32, 755-764.
- Fox, R. E., & King, R. A. The effects of reinforcement scheduling on the strength of a secondary reinforcer. J. comp. physiol. Psychol., 1961, 54, 266-269.
- Goodrich, K. P. Performance in different segments of an instrumental response chain as a function of reinforcement schedule. J. exp. Psychol., 1959, 57, 57-63.
- Grant, D. A., & Schipper, L. M. The acquisition and extinction of conditioned eyelid responses as a function of the percentage of fixed-ratio random reinforcement. J. exp. Psychol., 1952, 43, 313-320.
- Hall, J. F. Studies in secondary reinforcement: I. Secondary reinforcement as a function of the frequency of primary reinforcement. J. comp. physiol. Psychol., 1951, 44, 246-251.
- Hays, W. L. Statistics for psychologists. New York: Holt, Rinehart & Winston, 1963.

- Hilgard, E. R., & Marquis, D. G. Conditioning and learning. New York: Appleton-Century-Crofts, 1940.
- Hopkins, C. O. Effectiveness of secondary reinforcing stimuli as a function of quantity and quality of food. J. exp. Psychol., 1955, 50, 339-342.
- Hull, C. L. Principles of behavior. New York: Appleton-Century-Crofts, 1943.
- Jenkins, H. M. Resistance to extinction when partial reinforcement is followed by regular reinforcement. J. exp. Psychol., 1962, 64, 441-450.
- Jenkins, W. O. A temporal gradient of derived reinforcement. Amer. J. Psychol., 1950, 63, 237-243.
- Kass, N., & Wilson, H. Resistance to extinction as a function of percentage of reinforcement, number of training trials, and conditioned reinforcement. J. exp. Psychol., 1966, 71, 355-357.
- Kelleher, R. T., & Gollub, L. R. A review of positive conditioned reinforcement. J. exp. Anal. Behav., 1962, 5, 543-597.
- Keller, F. S. & Schoenfeld, W. N. Principles of psychology. New York: Appleton-Century-Crofts, 1950.
- Kimble, G. A. Hilgard and Marquis' conditioning and learning. New York: Appleton-Century-Crofts, 1961.
- Klein, R. M. Intermittent primary reinforcement as a parameter of secondary reinforcement. J. exp. Psychol., 1959, 58, 423-427.
- Knott, P. D., & Clayton, K. N. Durable secondary reinforcement using brain stimulation as the primary reinforcer. J. comp. physiol. Psychol., 1966, 61, 151-153.
- Lawson, R. Amount of primary reward and strength of secondary reward. J. exp. Psychol., 1953, 46, 183-187.
- Lawson, R. Brightness discrimination performance and secondary reward strength as a function of primary reward amount. J. comp. physiol. Psychol., 1957, 50, 35-39.
- Lewis, D. J. Partial reinforcement: A selective review of the literature since 1950. Psychol. Bull., 1960, 57, 1-28.
- Lewis, M. The effect of effort on choice: The value of a secondary reinforcer. Psychol. Reps., 1965, 16, 557-560.

- Longstreth, L. E. Frustration effects rather than Sr effects in children. Psychon. Sci., 1966, 4, 425-426.
- Miles, R. C. The relative effectiveness of secondary reinforcers throughout deprivation and habit strength parameters. J. comp. physiol. Psychol., 1956, 49, 126-130.
- Miles, R. C. & Wickens, D.D. Effect of a secondary reinforcer on the primary hunger drive. J. comp. physiol. Psychol., 1953, 46, 77-79.
- Miller, N. E. Learnable drives and rewards. In S. S. Stevens (Ed.), Handbook of experimental psychology. New York: Wiley, 1951.
- Mowrer, O. H. Learning theory and behavior. New York: Wiley, 1960.
- Myers, J. L. Secondary reinforcement: A review of recent experimentation. Psychol. Bull., 1958, 55, 284-301.
- Myers, N. A. Extinction following partial and continuous primary and secondary reinforcement. J. exp. Psychol., 1960, 60, 172-179.
- Myers, N. A., Craig, G. J., & Myers, J. L. Secondary reinforcement as a function of the number of reinforced trials. Child Developm., 1961, 32, 765-772.
- Pavlov, I. P. Conditioned reflexes. London: Oxford Univ. Press, 1927.
- Reynolds, W. F. Acquisition and extinction of the conditioned eyelid response following partial and continuous reinforcement. J. exp. Psychol., 1958, 55, 335-341.
- Ross, L. E. The decremental effects of partial reinforcement during acquisition of the conditioned eyelid responses. J. exp. Psychol., 1959, 57, 74-82.
- Saltzman, I. J. Maze learning in the absence of primary reinforcement: A study of secondary reinforcement. J. comp. physiol. Psychol., 1949, 42, 161-173.
- Skinner, B. F. The behavior of organisms. New York: Appleton-Century-Crofts, 1938.
- Stein, L. Secondary reinforcement established with subcortical stimulation. Science, 1958, 127, 466-467.
- Sutherland, N. S., Mackintosh, N. J., & Wolfe, J. B. Extinction as a function of the order of partial and constant reinforcement. J. exp. Psychol., 1965, 69, 56-59.

- Theios, J. The partial reinforcement effect sustained through blocks of continuous reinforcement. J. exp. Psychol., 1962, 64, 1-6.
- Thomas, E., & Wagner, A. R. Partial reinforcement of the classical conditioned eyelid response in the rabbit. J. comp. physiol. Psychol., 1964, 58, 157-158.
- Wagner, A. R. Effects of amount and percentage of reinforcement and number of acquisition trials on conditioning and extinction. J. exp. Psychol., 1961, 62, 234-242.
- Weinstock, S. Acquisition and extinction of a partially reinforced running response at a 24-hour intertrial interval. J. exp. Psychol., 1958, 56, 151-158.
- Wike, E. L. Secondary reinforcement: Selected experiments. New York: Harper & Row, 1966.
- Winer, B. J. Statistical principles in experimental design. New York: McGraw-Hill, 1962.
- Zimmerman, D. W. Durable secondary reinforcement. Method and theory. Psychol. Rev., 1957, 64, 373-383.