Combined autoshaping-operant (AO) training: CS-UCS interval effects in rats*

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The time between lever presentation (CS) and free delivery of food (UCS) was varied in an autoshaping procedure which also contained the operant contingency of immediate food reinforcement for leverpressing. Without prior magazine training or adaptation to the apparatus, naive rats readily acquired leverpressing when the CS-UCS interval was 30 sec. In contrast, rats trained under a 5-sec interval showed no development of leverpressing and displayed typical "freeloading" behavior. Subsequent work, which confirmed and extended these findings, is summarized.

The efficacy with which Pavlovian-type autoshaping procedures can induce keypecking in pigeons (e.g., Brown & Jenkins, 1968) and lever responses in rats (Peterson, Ackil, Frommer, & Hearst, 1972) suggests a handy way of getting conventional operant conditioning studies off to a quick start. Instead of giving separate sessions of magazine training and operant shaping, why not convert the initial magazine training period into an autoshaping session (with distinctive manipulandum presentations signaling free reward deliveries) and institute the usual operant contingency (immediate reward for manipulandum response) from the outset as well? Such combined autoshaping-operant (AO) training, which may also be viewed as combined classical-instrumental conditioning, is of interest in its own right as a paradigm that is distinguishable from "pure" autoshaping (no operant contingency) and "pure" operant training (no signaled, free reward presentations).

Although some autoshaping demonstrations have employed procedures representing a mixture of Pavlovian and the usual operant contingencies (e.g., Brown & Jenkins, 1968, Experiments 1-3; Sidman & Fletcher, 1969), only one study seems to have instituted these dual contingencies at the outset of magazine training. A technical note by Smith, Borgen, Davis, and Page (1971) indicates that leverpressing in rats can be conditioned readily in a single AO session when 45-mg pellet presentations are preceded by 30-sec illumination of a translucent (nonretractable) lever in discrete trials separated by 40 sec. Under these conditions, Smith et al found that five Long-Evans female rats showed short-latency magazine-approach responses within 12 trials, and in four of the five cases began pressing consistently within 34 trials.

The present study agreed in finding rapid conditioning in nearly all Ss with a 30-sec CS-UCS interval in AO

training and provided a context in terms of sharply differing performance in groups of rats trained at shorter intervals.

METHOD

The Ss were 38 naive male albino rats purchased from the Holtzmann Company, Madison, Wisconsin, at the age of 72 days. Within an hour after (across-town) delivery, ad lib weights were obtained, the rats were handled for approximately 2 min, and a 48-h food-deprivation period began. Two days later, each rat was given 30 45-mg Noyes pellets in a glass dish in its home cage and thereafter fed 6 to 10 g daily; on the third through sixth days following delivery, weights averaged 90%, 89%, 87%, and 86% of ad lib, respectively.

Two identical rat test chambers, controlled by conventional electromechanical programming devices, were used. Each chamber was equipped with a modified Lehigh Valley retractable lever, a lever cue light, a recessed food receptacle, a Davis PD-104 pellet dispenser, and a ceiling-mounted houselight. The lever was wired to a contact relay to permit measurement of contacts as well as presses. The leverlight was built into the retractable lever unit and consisted of a GE Type 313 bulb behind a frosted Plexiglas window (3 cm wide x 2 cm high), the bottom of which was nearly flush with the top of the lever paddle; the bulb was illuminated by 10/sec pulses of 28-V dc current. The houselight was a bare GE Type 1819 bulb continuously illuminated (20-V ac) both during trials and intertrial intervals. No magazine light was used.

On the fourth day following delivery, AO training was given without prior magazine training in the apparatus in two 50-trial sessions (termed Days 1 and 2). The Ss were randomly assigned to CS-UCS intervals of 5, 10, 20, or 30 sec which represent intervals between trial onset and reward presentation on nonpress trials. On such trials, events consisted of the presentation of the lever and its flashing light for a predetermined duration (the CS-UCS interval), followed by reward delivery (one 45-mg pellet) which coincided with lever retraction and termination of the leverlight. If a press response was made by the rat during the CS-UCS interval, however, the reward delivery and trial offset occurred immediately. Thus, all trials ended with the one-pellet delivery, at the end of the CS-UCS interval on nonpress trials or whenever the rat pressed the lever. Contact responses were recorded but did not produce reward or shortening of the trial. The intertrial interval (ITI) was 10 sec. Only one S failed to consume all the rewards presented on Day 1 of training, and all 38 rats displayed prompt consummatory responses on Day 2.

On Day 3, 50 discrete operant trials were administered. The procedure was the same as in AO training except that the

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Fig. 1. Leverpressing performance of four groups receiving AO training under varying CS-UCS intervals.

duration of nonpress trials was 30 sec for all rats and reward was delivered only on press trials.

RESULTS

The development of consistent leverpressing clearly depended upon the CS-UCS interval. As may be seen in Fig. 1, the 30-sec group was the only one of the four to display evidence of learning on Day 1; 9 of the 10 30-sec rats attained a criterion of 10 successive press trials before the middle of Day 2. The individual learners in this group completed this criterion in 40, 43, 47, 55, 63, 63, 64, and 72 trials. At the other extreme, all 10 rats in the 5-sec group and the nonlearners in the 10- and 20-sec groups showed a trend toward consistent nonresponding on the latter half of Day 2.

Mean percentages of press trials for the 5- through 30-sec groups, respectively, were 10.2, 14.8, 21.6, 43.4 on Day 1 and 15.2, 27.8, 48.0, and 87.6 on Day 2. In an analysis of variance of the percentage press trials measure, significant ($p < .001$) effects of CS-UCS interval ($F = 13.62$, $df = 3,34$), trial blocks ($F = 54.81$, $df = 9,306$), and the Interval by Trial Blocks interaction ($F = 3.29$, $df = 27,306$) were found. On Day 2, the 30-sec group exceeded the other three groups ($p < .001$), and the 20-sec group was significantly ($p < .02$) above the 5-sec group, by *t* tests. Similar findings were obtained for lever contacts.

Contacts and presses occurred very early in training in all four groups. Mean ordinal trial numbers of the first lever contact were 7.6, 2.7, 2.2, and 1.5 for the 5- through 30-sec groups, respectively ($p < .05$). These initial lever responses are better regarded as investigative responses than as products of the autoshaping contingency, since many of them occurred prior to

consistent magazine approach; indeed, 21 rats contacted and 10 rats pressed the lever on the first trial of Day 1.

The groups quickly converged to a common high level of leverpressing on Day 3. Acquisition under the more conventional operant procedures of this stage was so rapid for Ss which had been low responders in AO training that no significant group difference in number of press trials was found over the 50 trials or even in the first 10 trials of the session.

DISCUSSION

The duration of the CS-UCS interval in AO training in rats appears to make all the difference between learning and not learning to press a lever. With a 30-sec interval, both the present study and that reported by Smith et al (1971) indicate that naive laboratory rats will readily learn leverpressing in a session of 60 to 100 AO trials without prior magazine training or even prior exposure to the apparatus. A comparable success rate (i.e., at least 80% of the rats pressing consistently within 100 trials) has been found in our subsequent work with 13 naive male Holtzman rats and an additional 20 male Holtzman rats which had received prior testing in a complex maze. Where failures have occurred under the 30-sec AO condition, the rats have promptly shown consistent pressing in the first session of conventional operant trials after AO training in all instances. It should be noted, however, that our success rate has dropped to below 30% whenever we have administered the 30-sec AO procedure to relatively untamed Holtzman rats that we have reared from birth with a minimum of handling.

None of the rats in the 5-sec group of the present study displayed consistent leverpressing during the AO phase, and their behavior by the end of Day 2 was directed almost entirely to the food magazine rather than the lever. Again, subsequent work has been confirmatory, showing no leverpressing acquisition, and almost total fixation to the foodcup after 320 trials, in 24 5-sec rats trained with ITIs of 10 or 35 sec. The suggestion that this "freeloading" would be manifested in the form of a negative transfer effect in later training, as in the "learned laziness" (Engberg, Hansen, Welker, & Thomas, 1972) and "learned indolence" (Hulse, 1973) studies, was not borne out by the present results on Day 3, but our subsequent work has shown some impairment of discrete pure-operant acquisition of leverpressing by more extensive AO training.

There are two fairly obvious reasons why leverpressing acquisition in AO training should improve as the CS-UCS interval is lengthened. One is the opportunity factor: with longer intervals, the probability is increased that on a given trial a press response will occur, whether its occurrence be viewed as "random," a natural part of investigative behavior, or directed by Pavlovian conditioning. Secondly, since the rat can get the reward sooner by pressing than by waiting for a free delivery, the relative advantage of lever responding over freeloading increases with the duration of the CS-UCS interval.

An interesting question remains as to whether the contribution of the autoshaping component in AO training is merely that of guaranteeing magazine training or inducing lever responses as well. Obviously needed are studies in which pure autoshaping, pure operant training, and AO training are directly compared with respect to the effects of both the CS-UCS interval (trial duration in the case of pure-operant training) and manipulations of prior magazine training. In one comparison along these lines which we have already run, a surprising result has emerged: 9 newly purchased male Holtzman rats readily acquired leverpressing in pure-operant trials having a 30-sec time limit with no prior magazine training, and the acquisition rate

was essentially equal to that shown by 13 AO-trained rats (tested concurrently, also without prior magazine training) with a 30-sec CS-UCS interval and the 30-sec rats of the present study. This would seem to indicate little or no positive contribution of the autoshaping component in successful instances of AO-trained leverpressing, and from a practical standpoint, little advantage of AO over conventional operant procedures as a training technique, at least with relatively tame rats.

AO training may have more important uses as a criterion task than as a training method in any event. In studies concerned with the effects of prior exposure to stimulus and/or reward presentations on the initial acquisition of operant leverpressing (e.g., experiments on learned indolence, latent inhibition, incentive contrast, and classical-to-instrumental transfer), the use of a 30-sec AO procedure seems worth considering as a criterion task which is readily learnable and provides the additional control, unlike pure-operant procedures, of guaranteeing equal experience with the reinforcing stimulus at each stage of acquisition.

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Does imagery enhance long-term retention*

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In a recent series of experiments, Begg and Robertson (1973) found a direct relationship between the concreteness-imagery value of words and long-term retention. It is suggested that the procedures used to equate degree of learning for concrete and abstract words were faulty, and the conclusion that imagery facilitates retention is questioned.

Is long-term retention, as well as speed of acquisition, related directly to the concreteness-imagery (C-I) value of words? The available empirical evidence appears to provide contradictory answers to this question. In a

recent study, Begg and Robertson (1973) reported a series of experiments in each of which long-term retention was found to be substantially higher for concrete (C) than for abstract (A) nouns. This difference was observed under conditions of both free-recall and paired-associate learning. The latter result contrasts

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