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Autoshaping, hand-shaping, and errorless learning

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Eighteen food-deprived pigeons were divided into three groups and either hand-shaped or autoshaped to peck a response key illuminated with red or green light. Group 1 was autoshaped using a procedure that employed a 30-sec intertrial interval (ITI); the other two groups were hand shaped by the method of successive approximations, one (Group 2) with a 30-sec ITI, the other (Group 3) without. In subsequent discrimination training, the subjects in Groups 1 and 2 emitted significantly fewer errors than those in Group 3. The role of the ITI was explained with reference to the Rescorla-Wagner model of associative learning, modified to account for stimulus generalization. Implications of the data for the study of errorless learning and the comparison between hand shaping and autoshaping are discussed.

Since its discovery by Brown and Jenkins (1968), there have been efforts to contrast autoshaping with the traditional acquisition procedure of hand-shaping. Often this contrast has focused on the greater economy of the autoshaping procedure (e.g., Bilbrey & Winokur, 1973; Brown & Jenkins, 1968; Smith, Borgen, Davis, & Pace, 1971). There has also been considerable interest in the possibility that autoshaping and hand-shaping derive from two different underlying processes of learning: classical and operant conditioning, respectively (Gamzu & Williams, 1971a, 1971b; Skinner, 1971; Wasserman, Franklin, & Hearst, 1974). Other investigators have suggested that the responses engendered by the two experimental procedures may be traced to the single process of classical conditioning; that is, stimulus-reinforcer correlation (Hearst & Jenkins, 1974; Moore, 1973). Jenkins (1973), with experimental support for the latter view, showed that hand-shaped subjects' responding could be manipulated by stimulus-reinforcer correlations after response acquisition; that is, it was affected in the same way as responding that had been autoshaped. However, Jenkins' study lacked a specific comparison with autoshaped controls.

To the present, there have been only two studies that have attempted to directly compare the products of the different shaping procedures. Schwartz and Williams (1972) were interested in the possibility of distinctive response topographies following application of the two methods. They found that the duration of pigeon's keypecks varied as a function of the procedures used to maintain the keypeck (i.e., classical or operant conditioning). Their focus, however, was on the maintenance of responding rather than on the acquisition phase. Wilkie and Ramer (1974) also trained two groups of pigeons; one by autoshaping, the other by the standard hand-shaping method of successive approximations. Their basis of comparison was the number of errors emitted by the two groups during subsequent discrimination training involving different key-light colors. They found that the autoshaped group learned the discrimination errorlessly (the number of errors ranged from zero to four), while the hand-shaped group made substantially more errors (range: 16-36). It was apparently not their purpose to study and compare the two procedures in terms of specific temporal configurations of stimuli. Their conclusion was simply that "the manner in which pecking the key on S+ trials is established is an important determinant of whether or not errors occur on S– trials" (Wilkie & Ramer, 1974, p. 336).

One obvious major procedural difference between the two keypeck training procedures as they are traditionally employed is the presence or absence of an intertrial interval (ITI) between stimulus presentations. Autoshaping relies on an ITI (Brown & Jenkins, 1968; Perkins, Beavers, Hancock, Hemmendinger, Hemmindinger, & Ricci, 1975), whereas in hand-shaping, an explicit ITI is traditionally absent. Perhaps this difference between the two procedures could account for the differential results found by Wilkie and Ramer (1974). Stated alternately, perhaps the presence of an ITI is an essential factor in the demonstration of subsequent errorless discrimination learning. It was the purpose of the present study to partially replicate the Wilkie and Ramer (1974) study and to investigate the implications of the use of an ITI during training for the subsequent acquisition of a color discrimination. Subjects were trained using both the autoshaping and hand-shaping procedures.

METHOD

Subjects

Eighteen experimentally naive White Carneaux pigeons were maintained at 80% of their free-feeding weights throughout the experiment. Grit and water were freely available in the home cages.

Apparatus

Two soundproofed operant conditioning chambers were employed. The chambers measured 48 cm long, 50 cm high, and 33 cm wide. A translucent response key, 2.5 cm in diameter, was located 25 cm above the floor, and 14 cm above the aperture of a grain feeder. The aperture was directly in the center of the front wall of the chamber. Mounted behind the response key was a nine-stimulus cell. The key was transilluminated with either a green or a red light. One 7-W lamp illuminated the feeder tray during reinforcement while another served as the houselight. Experimental conditions and data collection were arranged by a Digital PDP-8/e computer located in an adjacent room. The SKED programming system was used.

Procedure

Magazine training was standardized as much as possible for all subjects and consisted of one 20-sec food presentation period followed by four 8-sec presentations, and, finally, 15 4-sec presentations. Each food presentation was followed by a 30-sec interval. All subjects were eating from the hopper consistently at the end of magazine training trials and were then divided into three groups of six birds each.

The subjects in Group 1 were introduced to a procedure that can be described as typical autoshaping. For half the subjects, it consisted of the presentation of a green positive stimulus (CS+) for an 8-sec duration following a 30-sec ITI. A red key light was the CS+ for the remaining subjects. The CS+ was followed immediately by a 4-sec presentation of mixed grain. Group 2 received a procedure identical to that of Group 1 except that the experimenter reinforced successive approximations to a keypeck (i.e., hand-shaped the keypeck) only when the CS+ was present. Group 3 was also hand-shaped to peck the key; however, the 30-sec ITI was eliminated. Thus, for this group, the key light was illuminated constantly except during reinforcement. The latter technique typifies the standard acquisition method of most operant research where fast and dependable acquisition is desired. For all subjects, pecks on the lighted response key turned off the key light and resulted in immediate access to food. Reinforcement rate during CS+ was approximately equal for all groups, although no data were recorded to substantiate that fact. Following 300 CS+ food pairings, the training phase of the study was terminated.

After training with CS+, all 18 subjects were then introduced to discrimination training sessions consisting of 25 CS+ trials randomly interspersed with 25 CS– trials per session. The CS– was the alternative key-light color to that used in acquisition (CS+). The same sequence was repeated across all subjects and sessions. Reinforcement was still contingent upon a keypeck during a CS+ trial. Also, a 30-sec ITI, in which only the houselight illuminated the chamber, separated all trials. The CS– trials lasted 8 sec if no error (response to CS–) occurred, or longer, since an error would reset the CS– timer and the 8-sec trial would start again. This correction procedure was utilized to prevent adventitious reinforcement of responding to CS– by its offset. Discrimination training lasted six sessions.

RESULTS

Figure 1 shows the number of errors (total responses to CS–) for each subject in each group during discrimination training. As is evident, the subjects in Group 1 were almost entirely without errors (range: 0-4; mean = 1.17), while the subjects in Group 3 emitted, on the average, almost 30 times as many errors (range: 7-57; mean = 30.33). This finding replicates almost exactly the data of Wilkie and Ramer (1974) for similar groups. The errors emitted by the hand-shaped ITI group (Group 2) were at a level comparable to those of Group 1 (range: 0-12; mean = 5.33) and could also be considered errorless, at least by the criterion of total number of errors (see Terrace, 1972). A one-way analysis of variance was computed for the data and it revealed a significant overall effect of training method [$F(2,15) = 13.27$, $p < .001$]. A Scheffé multigroup comparison test showed that Groups 1 and 2 did not differ significantly [$F_{1,2}(2,15) = .46$, $p > .25$]; however, it did indicate significant differences between Group 3 and the other two groups [$F_{2,3}(2,15) = 16.77$, $p < .01$; $F_{1,3}(2,15) = 22.81$, $p < .01$]. In summary, these data demonstrate the substantial effects of the experimental manipulation of the ITI.

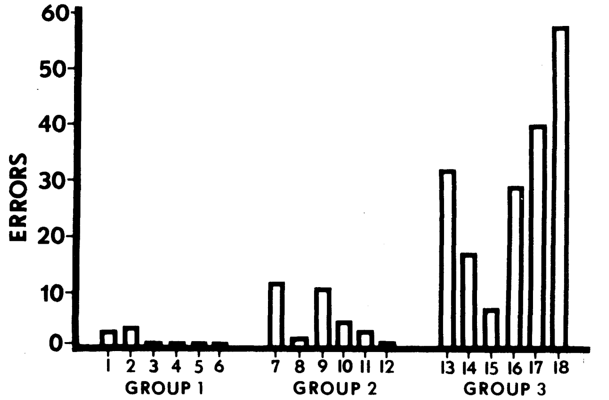

Figure 1. Total number of errors emitted during a color discrimination task by the subjects of Group 1 (autoshaping), Group 2 (hand-shaping with ITI), and Group 3 (hand-shaping without ITI).

Other data of interest are the number of trials to the first keypeck and the number to the criterion of consistent responding. These are displayed in Table 1. For purposes of this analysis, a trial was defined simply as a CS+ food pairing; thus, subjects in Group 3 can be conceived of as having a number of specified trials (i.e., reinforcements) prior to the first keypeck. The criterion for consistent responding was met when five consecutive reinforcements were response produced. The subjects of Group 3 acquired the keypeck response

Table 1
Acquisition Data for All Subjects

Group 1			Group 2			Group 3		
Subject	First Peck	Criterion	Subject	First Peck	Criterion	Subject	First Peck	Criterion
1	31	36	7	108	118	13	2	7
2	29	45	8	20	25	14	8	21
3	54	66	9	10	17	15	2	7
4	63	68	10	7	12	16	29	34
5	13	37	11	15	22	17	2	17
6	26	31	12	5	10	18	6	11
Mean	36.00	47.17		27.50	34.00		8.17	16.17

in fewer trials on the average than Groups 1 or 2. However, subjects in Group 2 differed only slightly from those of Group 3, in terms of acquisition, except for Subject 7. A relatively higher number of trials was necessary for subjects in the autoshaped group.

DISCUSSION

It is apparent that performance in a discrete trial discrimination task employing an ITI is affected by the presence or absence of an ITI in keypeck training (cf. Wilkie & Ramer, 1974). Training and maintaining a keypeck response under a schedule that allows continuous opportunity for reinforcement hinders the subject's subsequent discrimination performance. Alternatively, hand-shaping a subject to keypeck with an ITI (as per autoshaping) will result in fewer errors.

Rescorla and Wagner (1972) have recently proposed a model to account for the formation of associations between stimuli in classical conditioning. In order to apply their model to the outcome of the operant discrimination experiment reported here, two assumptions are required: (1) The number of responses made to CS– (errors) is a direct function of the discriminative or associative strength of that stimulus; and (2) any associative strength that the CS– has on its first few presentations must be a result of stimulus generalization from the previously reinforced CS+ (i.e., there must be conditioned stimulus elements that the CS– shares with the CS+ in order for the CS– to have associative strength initially). The absence of this mutuality would mean that the CS– had no associative strength and would therefore occasion no responses.

Rescorla (1976) has explained stimulus generalization with a "combined-elements" adaptation of the Rescorla-Wagner model. In order to be consistent with Rescorla's terminology, it is necessary to modify the symbols previously used in this paper. A and B symbolize the separate elements (e.g., hues) of CS+ and CS–, respectively. X is defined as the shared elements of the stimuli (e.g., brightness) plus the shared "background" stimulus elements or "context" stimuli (e.g., houselight, chamber walls, response key, etc.) that are uniformly present when either CS+ or CS– occurs. Since stimuli A and B can never be presented without their shared elements, they are denoted as stimulus compounds: AX and BX.

To review, after 300 pairings of key light (AX) with food, all subjects were introduced to a new stimulus (BX), and Group 3 (no ITI) made significantly more errors to the new stimulus than did either Group 1 or Group 2. Since B is defined as a stimulus element completely different from A, and since X consists of the shared elements between AX and BX, then it may be assumed that X constitutes the factor representing different levels of conditioning between Groups 1 and 2 and Group 3. Since more errors were made by the last group, it follows that the associative strength of X (V_X) was stronger for that group.

What aspect of the experimental manipulation of the ITI affected the differential associative strengths of X? One answer to this question assumes two conditions: First, that $V_{AX} = V_A + V_X$ for all groups, and second, that V_{AX} is approximately equal for all groups at the end of the 300 training trials. For Groups 1 and 2, as training began and an ITI was alternated with the key light, very little difference in associative strength existed between A and X. However, since AX was always followed by reinforcement and since it alternated with X alone (the ITI), V_A increased while V_X was reduced (perhaps eventually to a near-zero level). Figure 2 contains a theoretical picture of this process. When subsequently introduced together with B, X conferred very little or perhaps no associative strength on the compound and the result was that BX produced very little (errorless) responding.

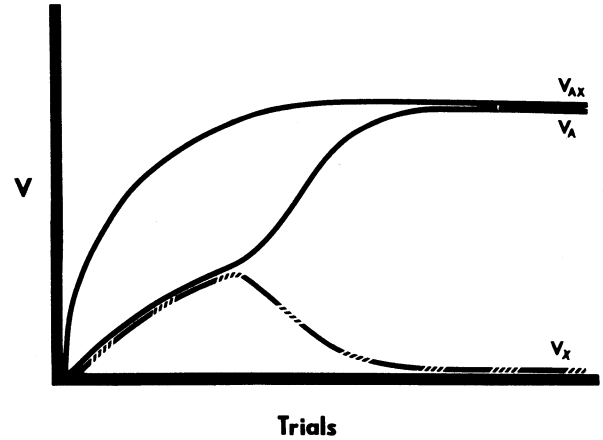

Figure 2. Theoretical representation for Groups 1 and 2 of learning curves for the associative strengths (V) of the compound AX and its separable elements, A and X.

With Group 3, however, it is proposed that the strength of X did not decrease during training as with Groups 1 and 2 (see Figure 3). There was no substantive difference in the associative strengths of A and X, and, therefore, each contributed essentially equally to V_{AX}. From this analysis, it follows that V_X for Group 3 was greater than V_X for Groups 1 and 2, and that this difference was responsible for the variance in discrimination performances following the introduction of BX.

The results of the present study and the theoretical account offered are pertinent to the investigation of factors responsible for the occurrence of errorless learning. While Terrace (1963) and others (e.g., Robinson, Foster, & Bridges, 1976) have indicated that "fading in" (i.e., gradual introduction) of a CS– is a necessary condition for errorless learning, the present results, as well as those of Wilkie and Ramer (1974), demonstrate errorless learning without a fading procedure. The present analysis also offers an explanation for the efficacy of fading when it is employed. In its initial stages, the fading procedure contains elements similar to the ITI used in the present research. This produces a reduction in the associative strength of elements that the CS+ shares with the CS–, that is, the "contextual" elements. Eventually, when the unique aspects of the CS– appear in compound with the shared elements,

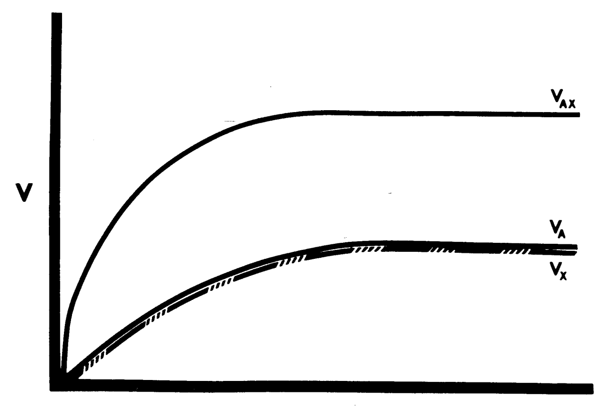

Figure 3. Theoretical representation for Group 3 of the learning curves for the associative strengths (V) of the compound AX and its separable elements, A and X.

the stimulus lacks associative strength and occasions very little, if any, responding.

The present study has shed further light on the process of response acquisition when autoshaping and hand-shaping procedures are employed. In addition, it has accounted for the difference in discrimination acquisition produced by the two kinds of shaping. It also encourages the view (see Hearst & Jenkins, 1974; Jenkins, 1973) that a single associative process serves as the basis for learning.

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