

*BLOCKING, UNBLOCKING, AND OVEREXPECTATION IN  
AUTOSHAPING WITH PIGEONS*

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Three experiments used pigeons in an autoshaping procedure and a single-subject design to examine compound stimulus control in classical conditioning. Experiment 1 examined the blocking effect, and Experiment 2 examined the unblocking effect. In both experiments, response-independent food was first delivered intermittently in the presence of one distinctively colored houselight but not another. Then, conventional autoshaping trials were carried out in the presence of each houselight. In Experiment 1, the keylight readily elicited responding in the presence of the houselight that had been negatively correlated with food, but not in the presence of the houselight that had been positively correlated with food. In Experiment 2, the keylight readily elicited responding in the presence of the houselight positively correlated with food, but only when the amount of food used on the autoshaping trials was either greater or less than that previously delivered in the presence of the houselight. Experiment 3 examined the overexpectation effect. Conventional autoshaping trials were first carried out by presenting each of two keylights individually. Then, additional autoshaping trials were carried out by presenting the two keylights as a compound, with either the same amount of food or a greater amount of food per trial. Finally, the keylights were retested by again presenting them individually. The number of responses per trial elicited by the keylights decreased when the amount of food used in compound trials was the same as that used in individual trials. However, the number of responses per trial remained approximately the same when the amount of food used in compound trials was greater than that used in individual trials. Taken together, the results of the three experiments demonstrate (a) the generality of the blocking, unblocking, and overexpectation effects by virtue of their extension to appetitive unconditioned stimuli; (b) the suitability of pigeons as subjects and autoshaping as a procedure for studying classical conditioning; and (c) the appropriateness of single-subject designs.

*Key words:* blocking, unblocking, overexpectation, Rescorla-Wagner model, autoshaping, key peck, pigeons

Blocking (Kamin, 1968, 1969), unblocking (Holland, 1984, 1985b), and overexpectation (Kremer, 1978; see Mazur, 1994, p. 95, for an origin of the term *overexpectation*) are three prominent classical conditioning phenomena. The present research sought to examine the generality of these three phenomena by employing an autoshaping procedure with pigeons as subjects and an appetitive stimulus as the unconditioned stimulus (US) (for general reviews of the autoshaping literature and its application to classical conditioning phe-

nomena, see Locurto, Terrace, & Gibbon, 1981; Miller & Spear, 1985).

The present research also used a single-subject design (Sidman, 1960) to examine the phenomena, in contrast to the previous studies that have used group-statistical designs. The demonstration of these phenomena using a single-subject design would constitute further evidence of their generality and robustness. Although conclusions from group-statistical studies are often used interchangeably with those from single-subject studies in general, a number of behavioral researchers have pointed out that conclusions from the two types of research are not necessarily identical (Baron, 1990; Perone, 1991; Sidman, 1960).

Overall, three experiments were conducted. Experiment 1 investigated blocking, Experiment 2 investigated unblocking, and Experiment 3 investigated overexpectation.

## GENERAL METHOD

### *Subjects*

Eight mixed-breed pigeons, 1 to 2 years old, served as the subjects in the three ex-

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periments. All subjects had 3 to 6 months' previous experience pecking response keys and earning food reinforcers according to various variable-interval schedules. Birds 1, 2, 3, and 4 served in Experiments 1 and 2. Birds 5, 6, 7, and 8 served in Experiment 3. The birds were maintained at 80% of their free-feeding weights and had continuous access to water and grit in their home cages. Experimental sessions were conducted at approximately the same time of day 6 days per week, with the subjects under approximately 23-hr food deprivation for each session.

### *Apparatus*

Four operant conditioning chambers for pigeons were used in the present research. Two chambers were approximately 35 cm high, 35 cm deep, and 47 cm wide. A third chamber was approximately 32 cm high, 35 cm deep, and 35 cm wide, and a fourth chamber was approximately 30 cm high, 30 cm deep, and 30 cm wide. Centered on the intelligence panel in each of the chambers were a rectangular opening (5 cm by 6 cm) through which the bird gained access to an elevated food hopper and a circular response key (2.5 cm diameter). In the first two chambers, the distances from (a) floor to food-hopper opening and (b) floor to response key were 6 cm and 22 cm; in the third and fourth chambers, the distances were 3 cm and 20 cm. In all chambers, the response keys required approximately 0.15 N to operate. Each chamber was housed in its own sound-attenuating shell to minimize interference from outside stimulation.

Two types of conditioned stimuli (CS) were used in the research. One was diffuse green (G) and red (R) houselights. Each color was provided by two 6-W 110-VAC lightbulbs, located at the top rear of the experimental chamber and separated from the subject by a light-diffusing plastic shield. The other was a localized white image of a square (S), a triangle (T), or an X, projected on the response key with a dark background by means of a standard IEEE projector with standard 28-VDC lightbulbs (#1820, 3 W).

The houselights were illuminated for alternating 90-s periods. The keylights were presented in a standard discrete-trials procedure for 10 s. The houselight remained on when a keylight was illuminated. If a 90-s houselight

period ended during the 10-s keylight period, both the houselight and keylight remained on for the full 10-s keylight period. In addition, any event associated with the end of the keylight, such as a food presentation, also occurred. A 10-s period of darkness separated the 90-s houselight periods (Blanchard & Honig, 1976). The US consisted of 3-s access to mixed grain presented in an illuminated food hopper. Houselights and keylights were not illuminated during the food presentations. Events were controlled and data recorded by electromechanical equipment located in an adjoining room.

### *Dependent Measures*

The experiments were derived from conventional three-phase experimental designs, according to which Phase 1 typically consists of pretraining to establish baseline performance, Phase 2 consists of some experimental treatment, and Phase 3 consists of testing the effects of Phase 2 treatments with respect to Phase 1 baseline performance. In conventional designs, control groups that are exposed to variations on these phases of training are also included as necessary.

In the present research, the use of a single-subject design meant that these discrete phases were modified somewhat. The description of each experiment below indicates the specific training conditions for each bird. In any case, in the testing phases of Experiments 1 and 2, the dependent measures of interest were (a) the number of trials that preceded the development of responding and (b) the number of responses per trial to a particular keylight that was illuminated in the presence of a particular houselight (e.g., Blanchard & Honig, 1976). The dependent measure in the testing phases of Experiment 3, which was not specifically concerned with the development of responding, was simply the number of responses per trial elicited by one or more particular keylights after exposure to the sequence of training conditions.

### *Stability Criteria and Behavioral Observations*

During training with the houselights, subjects' behavior was observed through one-way windows (e.g., Jenkins, Barnes, & Barrera, 1981). Differential orientation and general activity with respect to the intelligence panel

and the opening of the food hopper in the presence of the houselight that was positively correlated with food (including, of course, eating from the raised hopper; see also Rescorla, Durlach, & Grau, 1985) were taken as appropriate evidence of excitatory conditioning to the positive stimulus. Training involving compound houselight-keylight stimuli began only when subjects had exhibited excitatory conditioning in the presence of the positive houselight for four consecutive sessions. With the exception of the test-trial conditions, the termination of one condition involving keylight stimuli and the introduction of the next was based on a stability criterion. This criterion required that the number of autoshaped responses per trial show (a) no increasing or decreasing trends during at least the last 4 of a minimum of 10 sessions of training and (b) no greater than a 10% fluctuation during those sessions.

#### EXPERIMENT 1: BLOCKING

The typical preparation for investigating blocking employs rats in a conditioned suppression procedure (Dickinson, Hall, & Mackintosh, 1976; Kamin, 1968), although blocking has also been demonstrated with rats in appetitive conditioning (Holland, 1985b), and with rabbits in aversive conditioning of the nictitating membrane response (Stickney & Donahoe, 1983). Interestingly, the demonstration of blocking with pigeons in an autoshaping procedure has proved to be problematic. Blanchard and Honig (1976), Schreurs and Westbrook (1982), Straub and Gibbon (1983), Tomie (1976), and Williams (1981) were successful, whereas Tomie (1981) and Jenkins et al. (1981) were unsuccessful in demonstrating blocking (or at least blocking-like effects) with pigeons in the autoshaping procedure. The reason why experimenters have often had difficulty demonstrating blocking in the autoshaping procedure is not altogether clear. According to Tomie (1981), "Whether this difficulty is attributable to the selection of inappropriate parameters, the 'preparedness' of the autoshaping response, or the intrusion of instrumental factors that mask blocking in autoshaping is left to conjecture" (p. 205). According to Williams (1981), the failure of

blocking in some autoshaping experiments may be related to the type of stimuli used. For example, when two localized stimuli are juxtaposed on the same response key, a new type of stimulus may be created, causing the previously conditioned element to possibly lose its salience along with its conditioning significance. Diffuse or nonlocalized stimuli, according to Williams, may be superior to discrete stimuli in this case.

In fact, most of the autoshaping experiments that have reported evidence consistent with blocking have utilized one form or another of diffuse stimuli (Blanchard & Honig, 1976; Straub & Gibbon, 1983; Tomie, 1976). For example, Blanchard and Honig first paired a diffuse colored houselight (CS1+) with food (US) during pretraining (Phase 1). They found that conditioning to a white keylight (CS2+) was retarded when the keylight was introduced in the presence of the houselight during compound training (Phase 2). In contrast, conditioning to CS2+ was facilitated when this stimulus was introduced in the presence of another diffuse houselight (CS1-) that was correlated with the absence of the US in Phase 1. Tomie (1976) also obtained similar results in an autoshaping experiment utilizing diffuse auditory stimuli.

The present Experiment 1 had two aims. The first was to confirm that delivering food in the presence of a diffuse houselight during pretraining would interfere with the development of autoshaped responding to a keylight in the presence of that houselight, in a replication of Blanchard and Honig's (1976) study. The second was to determine whether a single-subject design was suitable for the demonstration of this effect, a methodological question that has not been previously addressed using any preparation.

#### METHOD

##### *Procedure*

Table 1 presents specific details about the nature and order of conditions for each bird. In general, Birds 1 and 2 were trained on a sequence of conditions counterbalanced for stimuli and order one way, and Birds 3 and 4 were trained on a sequence of conditions counterbalanced for stimuli and order another way, although the exact training conditions were unique for each bird.

Table 1

Design of Experiment 1. Listed for each of the 4 birds are the stimuli employed in each condition, the trials per session, and the number of sessions. Each bird was trained in the order indicated.

Bird	Condition	Trials per session	Sessions
1	1: G+, R-	20	18
	2: GT+, RX+	10, 10	3
	3: GT-, RX-	10, 10	6
	4: GT+, R-	20	11
	5: GT-	20	4
	6: T+	20	10
2	1: G+, R-	20	17
	2: GX+, RT+	10, 10	3
	3: GX-, RT-	10, 10	7
	4: RT+, G-	20	10
	5: RT-	20	4
	6: T+	20	10
3	1: T+	20	10
	2: T-	20	8
	3: GT+, R-	20	10
	4: GT-	20	4
	5: R+, G-	20	16
	6: RT+, GX+	10, 10	3
4	1: T+	20	10
	2: T-	20	8
	3: RT+, G-	20	10
	4: RT-	20	4
	5: R+, G-	20	15
	6: RX+, GT+	10, 10	3

*Note.* G = a diffuse green houselight; R = a diffuse red houselight; T = a white image of a triangle on the key; X = a white image of an X on the key; + = a single 3-s food (US) presentation; - = no food.

In Condition 1, Birds 1 and 2 received training with the green (G) and red (R) houselights. During G+ periods, response-independent food was delivered at irregular intervals averaging 60 s. During R- periods, no food was delivered. Sessions were terminated after 20 food presentations.

In Condition 2, the birds received conventional autoshaping trials with keylights in the presence of both houselights. For example, Bird 1 received autoshaping trials with a triangle when the houselight was green (designated as the compound GT+) and with the X when the houselight was red (designated as the compound RX+). These conditions were derived from Blanchard and Honig's (1976) procedure. The keylights appeared at irregular intervals averaging 60 s. Bird 2 received analogous training with GX+ and RT+ compounds. Sessions were terminated after 20 food presentations were obtained via

the two types of trials (e.g., 10 with each keylight, 11 with one and 9 with the other, 12 with one and 8 with the other, etc.).

In Condition 3, the birds received extinction trials with the keylight-houselight compounds used in the previous condition. For example, Bird 1 received trials with the triangle when the houselight was green and with the X when the houselight was red, but no food followed either keylight. These compounds are designated as GT- and RX-, respectively. The keylights appeared at irregular intervals averaging 60 s. Bird 2 received analogous training with GX- and RT- compounds. These extinction sessions were conducted until responding had completely ceased to both keylights, in preparation for the introduction of the next condition. Sessions were terminated after 20 extinction trials (e.g., 10 with each keylight) were conducted.

In Condition 4, the birds received standard autoshaping trials in the presence of one houselight but not the other. For example, Bird 1 received autoshaping trials with a triangle when the houselight was green (designated as the compound GT+), but no keylight was illuminated and no food was delivered when the houselight was red (R-). The keylight appeared at irregular intervals averaging 60 s. Bird 2 received analogous training with the T when the houselight was red (RT+) and with the green houselight (G-). Sessions for both birds were terminated after 20 food presentations.

In Condition 5, the birds received extinction trials with the appropriate keylight in the presence of the appropriate houselight. For example, Bird 1 received trials with the triangle when the houselight was green, but no food followed the keylight. This compound is designated as GT-. The keylight appeared at irregular intervals averaging 60 s. No other houselight or keylight was used. Bird 2 received analogous training with the RT- compound. These extinction sessions were conducted until responding to the keylight had completely ceased, in preparation for the introduction of the next condition. As in Condition 3, sessions for both birds were terminated after 20 trials.

In Condition 6, no houselights were involved. Both birds received standard autoshaping trials with the triangle at irregular in-

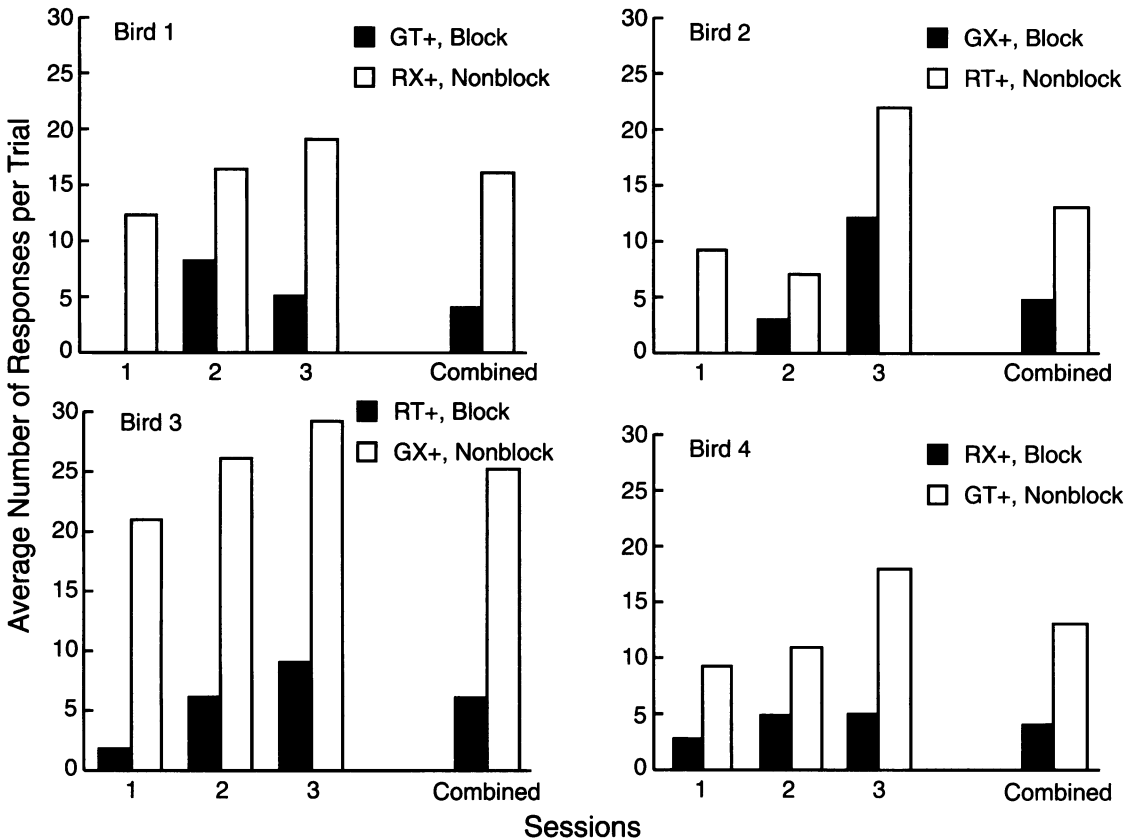


Fig. 1. Average number of key-peck responses per trial to keylight autoshaping stimuli (T, X) during compound CS Sessions 1, 2, and 3, as well as during the three sessions combined (far right) for each bird in Experiment 1. The filled bars are data from blocking manipulations, and the open bars are data from unblocking manipulations. The data are from Condition 2 for Birds 1 and 2 and from Condition 6 for Birds 3 and 4.

tervals averaging 60 s in an otherwise dark chamber. Sessions were terminated after 20 food presentations.

These conditions were designed to permit the appropriate comparisons to be made. For example, slower acquisition or lower frequencies of responding in Condition 2 than in Conditions 4 and 6 would suggest that the reduced levels of responding were due to the pretraining of the houselight and not to the inability of the pigeon to come under the control of more than one stimulus at a time.

As indicated above, Birds 3 and 4 were trained on a similar but essentially counter-balanced sequence of conditions (see Table 1). This counterbalancing controlled for any bias as a function of order of training and stimulus characteristics, and thus enhanced the internal validity of the various comparisons (Perone, 1991). Note that Condition 1

for Birds 3 and 4 involved autoshaping trials with the triangle and no houselights. This condition was equivalent to Condition 6 for Birds 1 and 2. Condition 2 for Birds 3 and 4 involved extinction trials with the triangle before the birds were exposed to further conditions.

## RESULTS AND DISCUSSION

The results of Experiment 1 are shown in Figures 1, 2, and 3. Figure 1 shows that the average number of responses per trial for all 4 birds was substantially larger on autoshaping trials carried out in the presence of a houselight that was negatively correlated with food than on trials carried out in the presence of a houselight that was positively correlated with food.

Figure 2 shows the number of responses on a trial-by-trial basis to keylight stimuli during

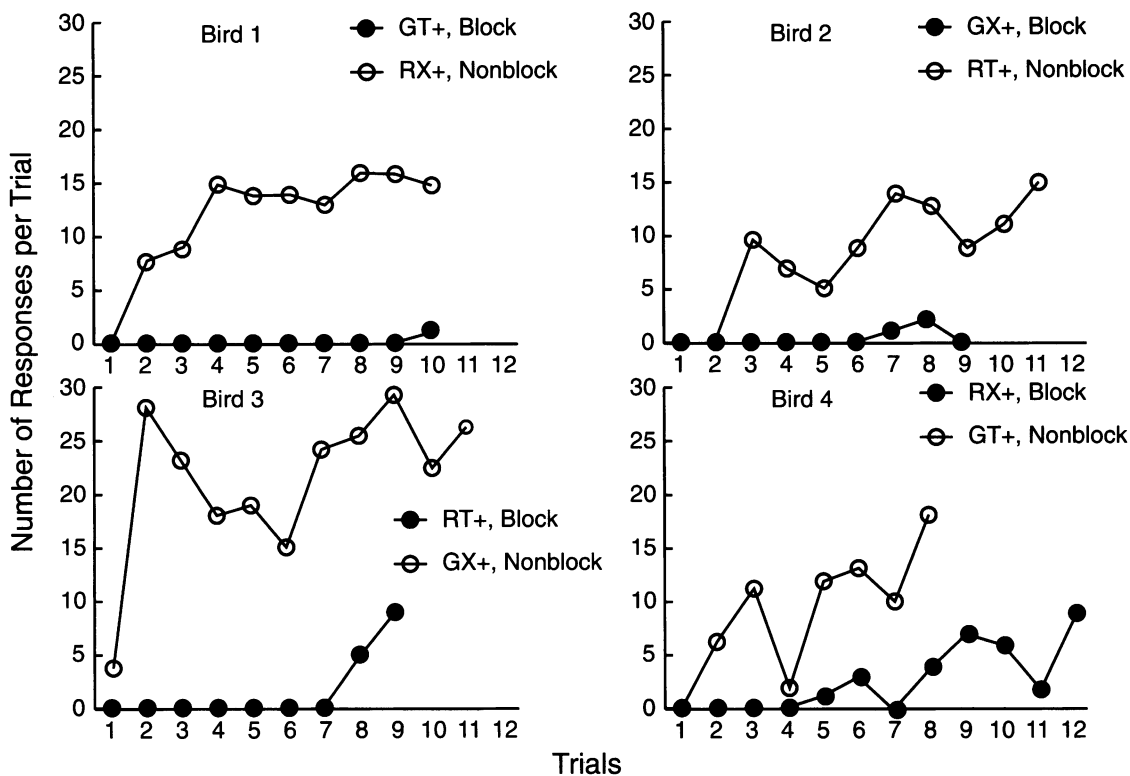


Fig. 2. Number of key-peck responses on a trial-by-trial basis to keylight autoshaping stimuli (T, X) during Session 1 of compound CS training for each bird in Experiment 1. The filled circles are data from blocking manipulations, and the open circles are data from unblocking manipulations.

the first test session in Condition 2 for Birds 1 and 2 and in Condition 6 for Birds 3 and 4. Autoshaped responding developed readily to a keylight when the autoshaping trials were carried out in the presence of a houselight that was negatively correlated with food. Responding did not develop readily, however, when the autoshaping trials were carried out in the presence of a houselight that was positively correlated with food. For example, Bird 1 did not make its first response to GT+ (Condition 2) until the 10th trial, whereas its first response to RX+ during the same condition occurred on the second trial. Similar results were obtained for the remaining 3 birds.

Figure 3 shows the average number of responses per trial for Birds 1 and 2 during Conditions 4 and 6 and for Birds 3 and 4 during Conditions 1 and 3, which are control conditions. The data are presented for comparison with those in Figure 1. The number of responses per trial elicited by the triangle

when it was presented in a compound with the houselight was similar to the number of responses per trial elicited by the triangle when it was presented individually. In addition, the number of responses per trial was substantially larger in the control conditions (Figure 3) than in the blocking conditions (solid bars in Figure 1). This result suggests that the lower levels of responding during the compound training shown in Figure 2 are not simply artifacts of the pigeon's inability to come under the control of more than one stimulus at a time.

Overall, the results of this experiment replicate those of Blanchard and Honig (1976), and suggest that autoshaped responding does not readily develop to a keylight that is illuminated in the presence of a diffuse houselight that has been positively correlated with food. In addition, these results were obtained in a single-subject design rather than in a more traditional group-statistical design.

Although the results of both Blanchard

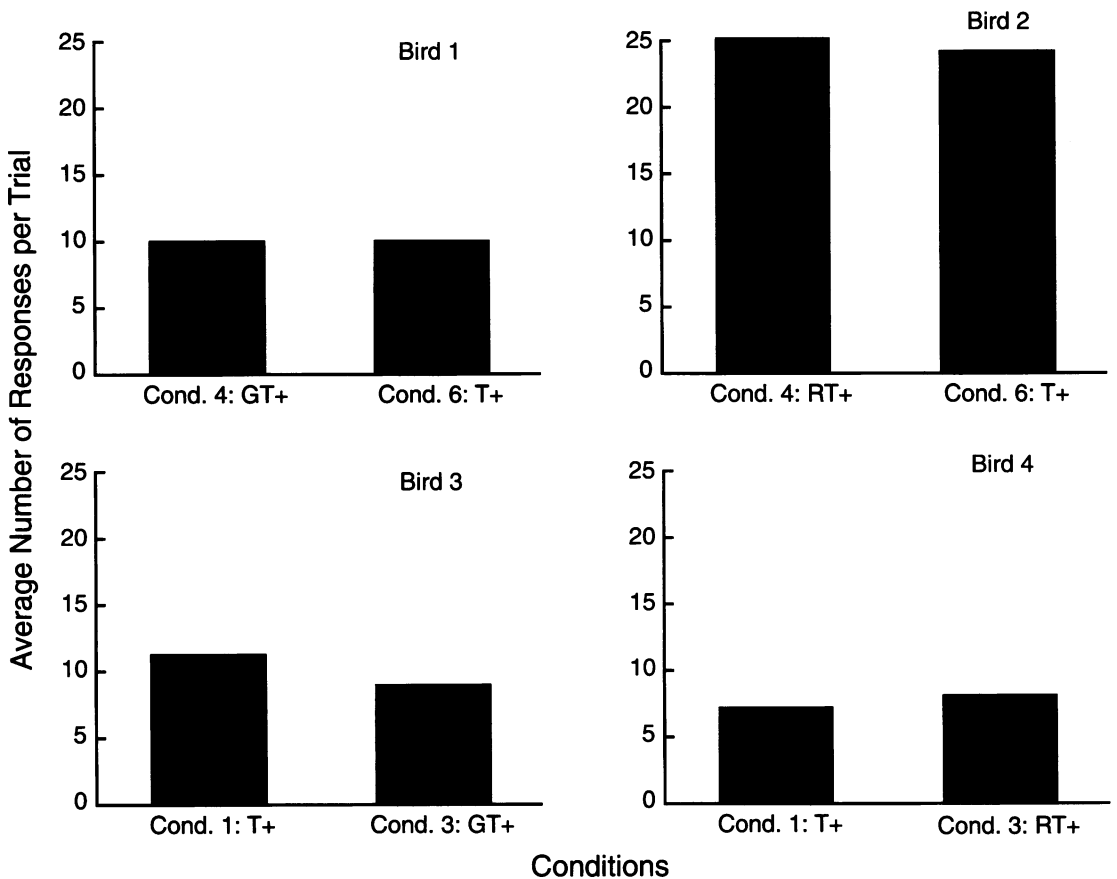


Fig. 3. Average number of key-peck responses per trial to the keylight autoshaping stimulus (T) during control conditions for each bird in Experiment 1. The data are averages over all three test sessions in these conditions.

and Honig's (1976) study and the present research suggest that blocking occurred, an alternative interpretation is that overshadowing rather than blocking was demonstrated. For example, neither Blanchard and Honig (1976) nor the present research included training wherein (a) the houselight was associated with food, (b) a few autoshaping trials were conducted in the presence of the houselight, and then (c) the keylight was presented alone, in the absence of the houselights. Given training of this sort, blocking could be directly implicated if responding occurred readily to the keylight-alone in the third phase of training. A keylight alone condition was included in the present training, but as a control at the end of training for Birds 1 and 2 and at the beginning of training for Birds 3 and 4. The testing of the keylight alone was not carried out after the three ses-

sions of compound training because the birds had already begun to respond to the keylight, and the data would not be informative.

#### EXPERIMENT 2: UNBLOCKING

In the reference work on unblocking, Kamin (1969) showed that blocking of the newly added CS was attenuated when the US was modified in some way on the compound trials (e.g., by adding another shock). Over the years, unblocking has been demonstrated using (a) increases and decreases in the intensity of an aversive US, such as shock (Wagner, Mazur, Donegan, & Pfautz, 1980); (b) the addition of a new or omission of a second anticipated shock (Dickinson et al., 1976); (c) changes in the locus of the US (Stickney & Donahoe, 1983); (d) increases and decreases

in the CS-US interval (Schreurs & Westbrook, 1982); and (e) increases and decreases in the magnitude of an appetitive US (Holland, 1984, 1985b).

Experiment 2 had three aims. The first was to confirm that unblocking occurs with both increases and decreases in the magnitude of an appetitive US. As noted above, Holland (1984, 1985b) appears to be the only researcher who has systematically examined this question. The second aim was to determine whether unblocking is general enough to be demonstrated in a hitherto unexamined preparation, with pigeons as subjects in an autoshaping procedure. The third aim was to determine whether a single-subject design was suitable for the investigation of unblocking, as it had been for the effects noted in Experiment 1.

#### METHOD

##### *Procedure*

Table 2 presents specific details about the nature and order of conditions for each subject. As in Experiment 1, Birds 1 and 2 were trained on a sequence of conditions in one order, and Birds 3 and 4 were trained in a similar but essentially counterbalanced order. The results of Experiment 1 had shown that exhaustive counterbalancing of stimuli was not necessary, in that all keylights and all houselights produced equivalent effects.

In Condition 1, Birds 1 and 2 received the same kind of initial training as they had in Experiment 1, involving diffuse green (G) and red (R) houselights. During G+ periods, response-independent food was delivered at irregular intervals averaging 60 s. During R- periods, no food was presented. Sessions were terminated after 20 food presentations. This condition established the basis for comparison with Condition 2, and whether unblocking occurred with an *increase* in the magnitude of the US.

In Condition 2, the birds received six compound GT++ (test) trials in one session. In this condition, the triangle was presented at irregular intervals averaging 60 s when the houselight was green. Each triangle was followed by two 3-s food presentations that were separated by a 1-s interval.

In Condition 3, the birds received GT- extinction trials. In this condition, the triangle

Table 2

Design of Experiment 2. Listed for each of the 4 birds are the stimuli employed in each condition, the trials per session, and the number of sessions. Each bird was trained in the order indicated.

Bird	Condition	Trials per session	Sessions
1	1: G+, R-	20	11
	2: GT++	6	1
	3: GT-	40	5
	4: G+, R-	20	10
	5: GT+	6	1
	6: GT-	20	7
	7: G++, R-	20	10
	8: GT+	6	1
2	1: G+, R-	20	11
	2: GT++	6	1
	3: GT-	40	5
	4: G+, R-	20	10
	5: GT+	6	1
	6: GT-	20	7
	7: G++, R-	20	10
	8: GT+	6	1
3	1: G++, R-	20	12
	2: GT+	6	1
	3: GT-	40	5
	4: G+, R-	20	10
	5: GT++	6	1
	6: GT-	20	8
	7: G+, R-	20	11
	8: GT+	6	1
4	1: G++, R-	20	11
	2: GT+	6	1
	3: GT-	40	5
	4: G+, R-	20	10
	5: GT++	6	1
	6: GT-	20	5
	7: G+, R-	20	10
	8: GT+	6	1

*Note.* G = a diffuse green houselight; R = a diffuse red houselight; T = a white image of a triangle on the key; + = a single 3-s food (US) presentation; ++ = two 3-s food presentations separated by a 1-s interval; - = no food.

was presented at irregular intervals averaging 60 s when the houselight was green, but no food was delivered on these trials. The red houselight and other keylights were not used. These sessions were intended to extinguish responding from the previous condition in preparation for the next condition. Sessions were terminated after 40 trials.

In Condition 4, the birds received new G+ and R- training. As in Condition 1, response-independent food was delivered at irregular intervals averaging 60 s when the houselight was green, but not when the houselight was red. Sessions were terminated after 20 food



presentations. This condition established the basis for comparison with Condition 5, as a control condition not involving any change in the magnitude of the US.

In Condition 5, the birds received one session of six compound GT+ trials. On these trials, the triangle was presented at irregular intervals averaging 60 s when the houselight was green, and each presentation of the triangle was followed by a single 3-s food presentation. The red houselight and other keylights were not used.

In Condition 6, the birds again received GT- extinction trials in preparation for the next condition. As in Condition 3, when the houselight was green, the triangle was presented at irregular intervals averaging 60 s, but no food was delivered. Sessions were terminated after 20 trials.

In Condition 7, the birds received G++ and R- training. This training was similar to that of Condition 1, except that two food presentations, separated by 1 s, occurred when the houselight was green. The food presentations occurred at irregular intervals averaging 60 s. No keylights were illuminated in conjunction with the food presentations, and no food was presented when the houselight was red. Sessions were terminated after 20 instances of food presentation. This condition established the basis for comparison with Condition 8, and for determining whether unblocking occurred with a *decrease* in the magnitude of the US.

In Condition 8, the birds received six compound GT+ test trials for one session in order to assess responding to the triangle. In this condition, when the houselight was green, the triangle and a single food presentation occurred at irregular intervals averaging 60 s, in a standard autoshaping procedure.

In summary, unblocking with increases in the magnitude of the US was examined by first giving pretraining with G+ and then giving compound GT++ trials (e.g., Conditions 1 and 2 for Birds 1 and 2). The results were then compared with those from when G+ pretraining preceded compound GT+ trials (e.g., Conditions 4 and 5 for Birds 1 and 2).

Unblocking with decreases in the magnitude of the US was examined by first giving pretraining with G++ and then giving compound GT+ trials (e.g., Conditions 7 and 8

for Birds 1 and 2). As before, the results were then compared with those from when G+ pretraining preceded compound GT+ trials (e.g., Conditions 4 and 5 for Birds 1 and 2).

In both cases, at issue was whether the responding to the triangle took fewer trials to develop, and whether the number of responses per trial was larger, when the magnitude of the US was either increased (from the G+ to the GT++ conditions) or decreased (from the G++ to the GT+ conditions) than when the magnitude of the US remained constant (from the G+ to the GT+ conditions).

#### RESULTS AND DISCUSSION

The results of Experiment 2 are shown in Figures 4 and 5. Figure 4 shows that the average number of responses per trial to the triangle for all birds was quite low when the magnitude of the US remained constant during compound training. These data replicate the effect noted in Experiment 1. In contrast, the number of responses per trial to the triangle for all birds was greater when the magnitude of the US was either increased or decreased during compound training (the two unblock conditions). (Note that the counterbalanced order of training means that the bars for Birds 1 and 2 are in a different order than those for Birds 3 and 4.)

Figure 5 shows the number of responses on a trial-by-trial basis when the magnitude of the US increased, decreased, or remained constant during compound test trials for each bird. Responding was slow to develop and unstable when US magnitude remained constant. In contrast, responding developed on an earlier trial and occurred at high frequency when the magnitude of the US either increased or decreased during compound training.

An unexpected feature of the data shown in Figure 5 is the occurrence of a substantial number of responses on the first test trial of the *first* unblocking manipulation to which the birds were exposed (i.e., from G+ to GT++ for Birds 1 and 2 and from G++ to GT+ for Birds 3 and 4, see Conditions 1 and 2 in Table 2). Ordinarily, one would have expected a small number of responses on this first trial, because there was no difference between blocking and unblocking conditions until after the CS had terminated,

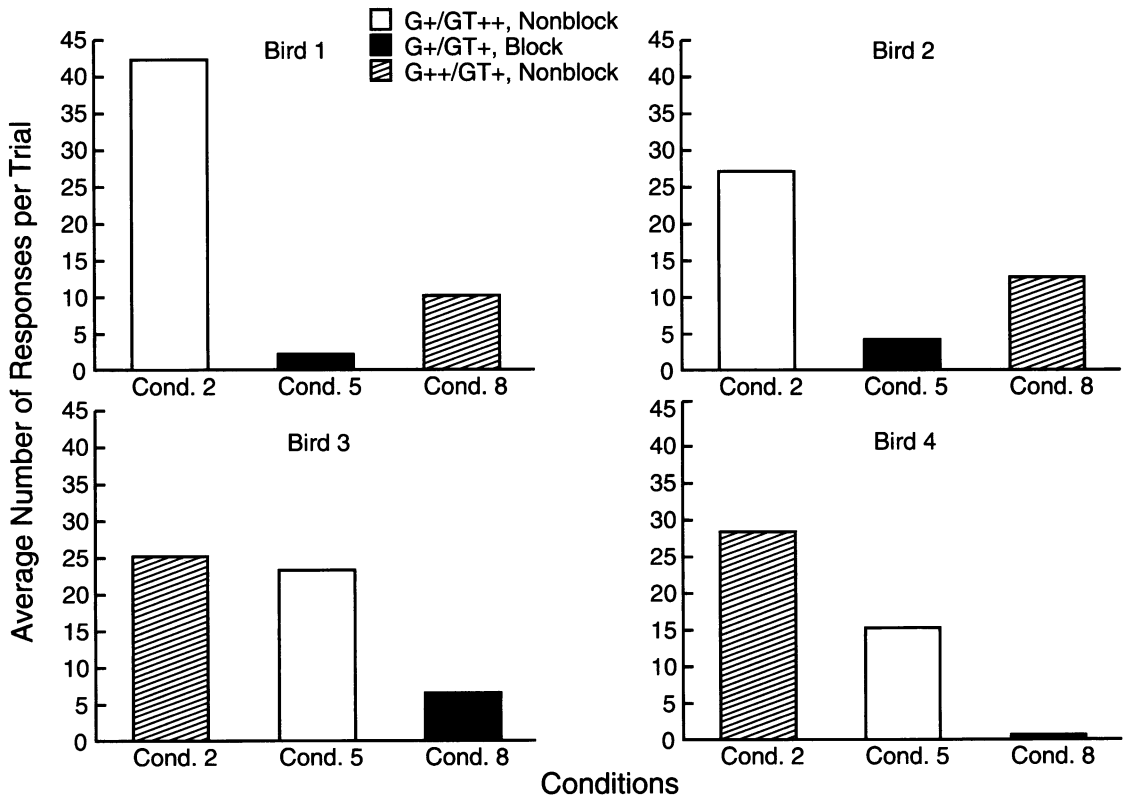


Fig. 4. Average number of key-peck responses per trial to the keylight autoshaping stimulus (T) when US size was increased (open bars), decreased (hashed bars), or held constant (filled bars) during compound test trials for each bird in Experiment 2. These data are averages over the six test trials during each of Conditions 2, 5, and 8.

when the bird experienced the change in the magnitude of the US. Interestingly, this unexpectedly large number of responses did not occur on the first test trial of the *second* unblocking manipulation to which the birds were exposed (i.e., from G++ to GT+ for Birds 1 and 2, Conditions 7 and 8 in Table 2; from G+ to GT++ for Birds 3 and 4, Conditions 4 and 5 in Table 2). On the second unblocking manipulation, the number of responses on the first test trial was as low as in the blocking condition, as would be expected.

The large number of responses during the first unblocking manipulation may be attributable to the generalized tendency of pigeons to peck at keylights after multiple presentations of the food hopper, an effect noted by Hitzing and Safar (1970) and Steinhauer, Davol, and Lee (1976). Although this possibility is post hoc, the birds in the pres-

ent experiment may have been sensitized by the particular sequence of conditions (e.g., the multiple food presentations in the presence of the houselights coming early in the training) and were thereby predisposed to peck at a lighted key. In any case, the data do not compromise the unblocking that occurred later in the training, for both birds, with both increases and decreases in US magnitude.

Overall, the results of this experiment replicate those of Holland (1984, 1985b) as well as those of other unblocking experiments, and confirm that unblocking does indeed occur with decreases and not just increases in the magnitude of an appetitive US. In addition, the results extend unblocking to pigeons and the autoshaping procedure. Finally, the results demonstrate that a single-subject design is suitable for examining unblocking.

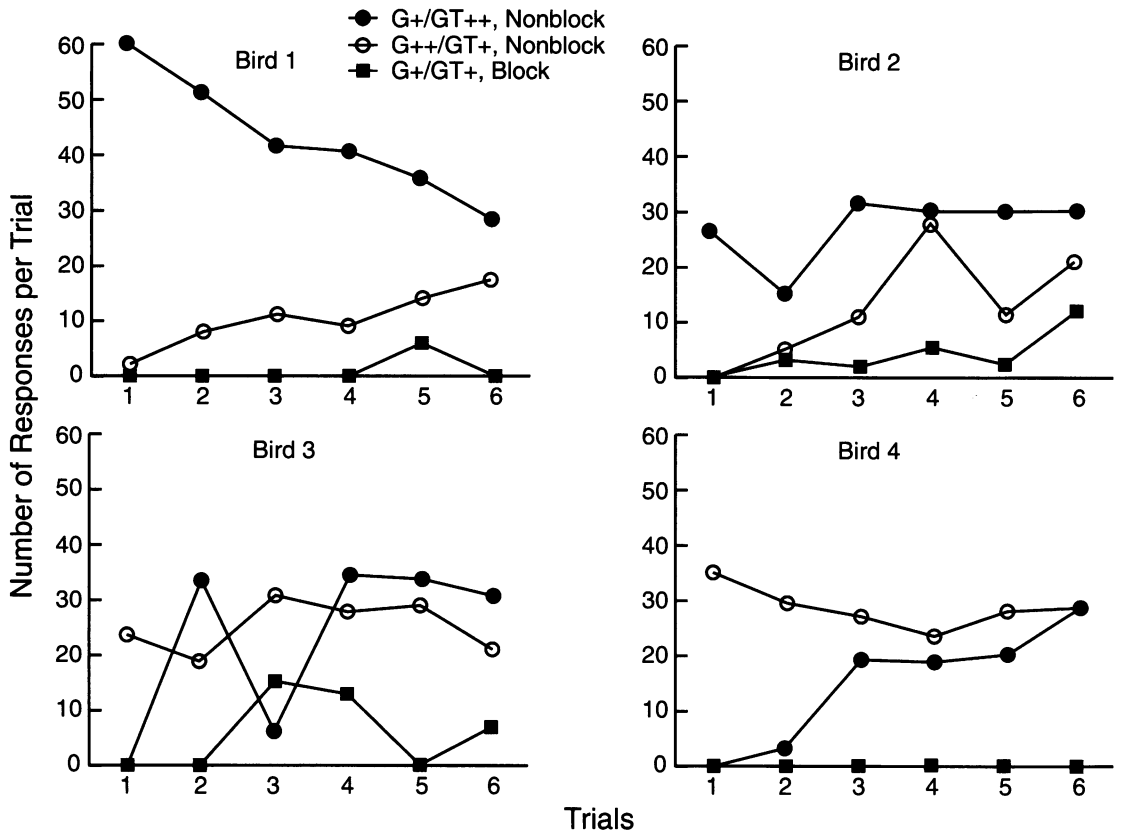


Fig. 5. Number of key-peck responses on a trial-by-trial basis to the keylight autoshaping stimulus (T) when US size was increased (G+/GT++; filled circles), decreased (G++/GT+; open circles), or held constant (G+/GT+; filled squares) during compound test trials for each bird in Experiment 2. These data are taken from the single test session in each of Conditions 2, 5, and 8.

### EXPERIMENT 3: OVEREXPECTATION

Overexpectation has received considerably less empirical attention than blocking and unblocking. Overexpectation is said to occur when responding to individual stimuli decreases after these stimuli have first been conditioned individually with the US, then presented in a compound with a US of the same magnitude, and then retested individually. Paradoxically, the elements of the compound CS lose conditioning strength even though they continue to be positively correlated with the US.

The reference work on overexpectation is a series of experiments by Kremer (1978) involving conditioned suppression in rats. In Kremer's Experiment 1, for example, subjects were presented with four light-CS+ trials followed by four noise-CS+ trials during

each of four sessions in Phase 1. In Phase 2 the light and noise stimuli were presented as a compound CS+ for four more sessions. In Phase 3 the light and noise CSs were retested separately. The results showed less suppression to each of the two stimuli than after Phase 1.

Experiment 3 had three aims. The first was to determine whether overexpectation occurs with an appetitive US. As noted above, previous research on this phenomenon has employed aversive USs. The second aim was to determine whether overexpectation is general enough to be demonstrated in a hitherto unexamined preparation, with pigeons as subjects in an autoshaping procedure. The third aim was to determine whether a single-subject design was suitable for the investigation of overexpectation, as it had been for the effects noted in Experiments 1 and 2.

Table 3

Design of Experiment 3. Listed for each of the 4 birds are the stimuli employed in each condition, the trials per session, and the number of sessions. Each bird was trained in the order indicated.

Bird	Condition	Trials per session	Sessions
5	1: (G)S+, (G)X+, (R)S-, (R)X-	20, 20 20, 20	10
	2: (G)SX+, (R)SX-	40, 40	11
	3: (G)S+, (G)X+	6, 6	1
	4: (G)S-, (G)X-	20, 20	5
	5: (G)S+, (G)X+ (R)S-, (R)X-	20, 20 20, 20	10
	6: (G)SX++, (R)SX-	20, 20	11
	7: (G)S+, (G)X+	6, 6	1
6	1: (G)S+, (G)X+, (R)S-, (R)X-	20, 20 20, 20	10
	2: (G)SX+, (R)SX-	40, 40	11
	3: (G)S+, (G)X+	6, 6	1
	4: (G)S-, (G)X-	20, 20	4
	5: (G)S+, (G)X+ (R)S-, (R)X-	20, 20 20, 20	11
	6: (G)SX++, (R)SX-	20, 20	11
	7: (G)S+, (G)X+	6, 6	1
7	1: (G)S+, (G)X+, (R)S-, (R)X-	20, 20 20, 20	11
	2: (G)SX++, (R)SX-	40, 40	12
	3: (G)S+, (G)X+	6, 6	1
	4: (G)S-, (G)X-	20, 20	3
	5: (G)S+, (G)X+, (R)S-, (R)X-	20, 20 20, 20	10
	6: (G)SX+, (R)SX-	20, 20	11
	7: (G)S+, (G)X+	6, 6	1
8	1: (G)S+, (G)X+, (R)S-, (R)X-	20, 20 20, 20	10
	2: (G)SX++, (R)SX-	40, 40	10
	3: (G)S+, (G)X+	6, 6	1
	4: (G)S-, (G)X-	20, 20	4
	5: (G)S+, (G)X+, (R)S-, (R)X-	20, 20 20, 20	10
	6: (G)SX+, (R)SX-	20, 20	11
	7: (G)S+, (G)X+	6, 6	1

*Note.* S = a white image of a square on the key; X = a white image of an X on the key; + = a single 3-s food (US) presentation; ++ = two 3-s food presentations separated by a 1-s interval; - = no food. The letters in parentheses designate diffuse green (G) and red (R) houselights that were illuminated during autoshaping trials involving the keylights. The letters are in parentheses to indicate that the function of the houselights was different from that in Experiments 1 and 2 (see text for rationale).

## METHOD

### Procedure

Table 3 presents specific details about the nature and order of conditions for each of the 4 subjects. As in Experiments 1 and 2, Birds 5 and 6 were trained on a sequence of conditions in one order, and Birds 7 and 8

were trained in a similar but essentially counterbalanced order.

In Condition 1, Birds 5 and 6 received individual stimulus training consisting of (G)S+, (G)X+, (R)S-, and (R)X- trials. Individual stimulus training involved presentations of the square (S) alternating with presentations of the X on the response key when the houselight was green (G). The keylights appeared at irregular intervals averaging 30 s. Each of these keylights was followed by response-independent food, in a standard autoshaping procedure. These sorts of trials are designated as (G)S+ and (G)X+. Sessions were terminated after 40 food presentations.

Individual stimulus training in this condition also involved presentations of the square alternating with presentations of the X on the response key when the houselight was red (R). As before, the keylights appeared at irregular intervals averaging 30 s. In this case, however, the keylights were not followed by food. These sorts of trials are designated as (R)S- and (R)X-.

The addition of the diffuse green and red houselights during individual stimulus training constituted a modification of the original overexpectation paradigm (e.g., Kremer, 1978), in which only the two target stimuli were used. This modification of the original procedure was designed to reduce the salience of the two localized keylights when they are presented on the response key, and thereby minimize the tendency of the pigeon to peck at a lighted key, a problem noted by several previous investigators (e.g., Jenkins et al., 1981; Tomie, 1981). The houselights are put in parentheses to distinguish their function from that of Experiments 1 and 2.

In Condition 2, the birds received compound (G)SX+ and (R)SX- trials. In this condition, the two keylight stimuli (S and X) were superimposed on the response key to make a compound CS. These trials occurred at irregular intervals averaging 30 s. Food was delivered on these compound CS trials when the houselight was green but not when the houselight was red. The compound training was designed to determine whether stimuli lose some of their associative strength when given further training as a compound with a US of the same magnitude, as noted by Kremer (1978). Sessions were terminated after 40 food presentations.

In Condition 3, the birds received six (G)S+ and (G)X+ test trials in one session. These test trials involved presentations of the square alternating with presentations of the X on the response key when the houselight was green, at irregular intervals averaging 30 s. Each of these keylights was followed by food, in a standard autoshaping procedure. At issue in this test condition was whether the square and X elicited fewer responses per trial than they had during Condition 1.

In Condition 4, the birds received (G)S- and (G)X- extinction trials. These extinction trials involved presentations of the square alternating with presentations of the X on the response key when the houselight was green, at irregular intervals averaging 30 s. However, no food was delivered after the keylights. As in Experiments 1 and 2, manipulations in these sessions were intended to extinguish responding established by the previous condition in preparation for the next condition. Sessions were terminated after 40 extinction trials (e.g., 20 with each keylight) were conducted.

In Condition 5, the birds received individual stimulus training, again consisting of (G)S+, (G)X+, (R)S-, and (R)X- trials. The details of this condition were the same as for Condition 1. As before, sessions were terminated after 40 food presentations.

In Condition 6, the birds received trials with (G)SX++ and (R)SX- compounds. This condition was similar to Condition 3, except that two 3-s food presentations followed each occurrence of the compound keylight when the houselight was green. No food followed the compound keylight when the houselight was red. As before, the keylights were presented at irregular intervals averaging 30 s. Sessions were terminated after 20 (G)SX++ trials.

In Condition 7, the birds received six (G)S+ and (G)X+ test trials in one session. These test trials involved presentations of the square alternating with presentations of the X on the response key when the houselight was green, at irregular intervals averaging 30 s. Each of these keylights was followed by food, in a standard autoshaping procedure. At issue in this test condition was whether the numbers of responses per trial elicited by the keylights would be similar to those of Con-

dition 5, by virtue of the added US in the compound training of Condition 6.

#### RESULTS AND DISCUSSION

The results of Experiment 3 are shown in Figure 6, which shows the average number of responses per trial elicited by the keylights during the three phases of training for each bird. The three phases of training are (a) individual stimulus training with the S (square) and X, (b) compound training with the SX compound, and (c) individual test trials with the S and X. The data are averages of the respective trials in Conditions 1, 2, 3, 5, 6, and 7, as identified in Table 3. All birds responded readily to the S and X during initial training with the individual stimuli. Responding to the SX compound was similarly frequent, and no systematic differences were apparent between the responding generated by one or two food presentations during the compound training.

The important comparison concerns the third set of bars in each panel of Figure 6. The left panels for Birds 5 and 6 and the right panels for Birds 7 and 8 (with one exception for Bird 7) show that when the magnitude of food remained constant during compound training, the birds responded less frequently to the S and X than they had previously. The one exception was the relatively constant number of responses made by Bird 7 to the S on retesting when the magnitude of food remained constant. However, its less frequent responding to the X on retesting is clearly consistent with that of the other 3 birds. The right panels for Birds 5 and 6 and the left panels for Birds 7 and 8 show that when the magnitude of food increased to two 3-s food presentations during compound training, the birds responded about the same to the S and X as they had previously.

Taken together, then, the data from the 4 birds replicate the overexpectation effect previously reported by Kremer (1978). In addition, the results extend the effect to pigeons in an autoshaping procedure with an appetitive US. Finally, as with Experiments 1 and 2, the results show that a single-subject design is suitable to investigate the effect.

#### GENERAL DISCUSSION

The present experiments examined three prominent classical conditioning phenome-

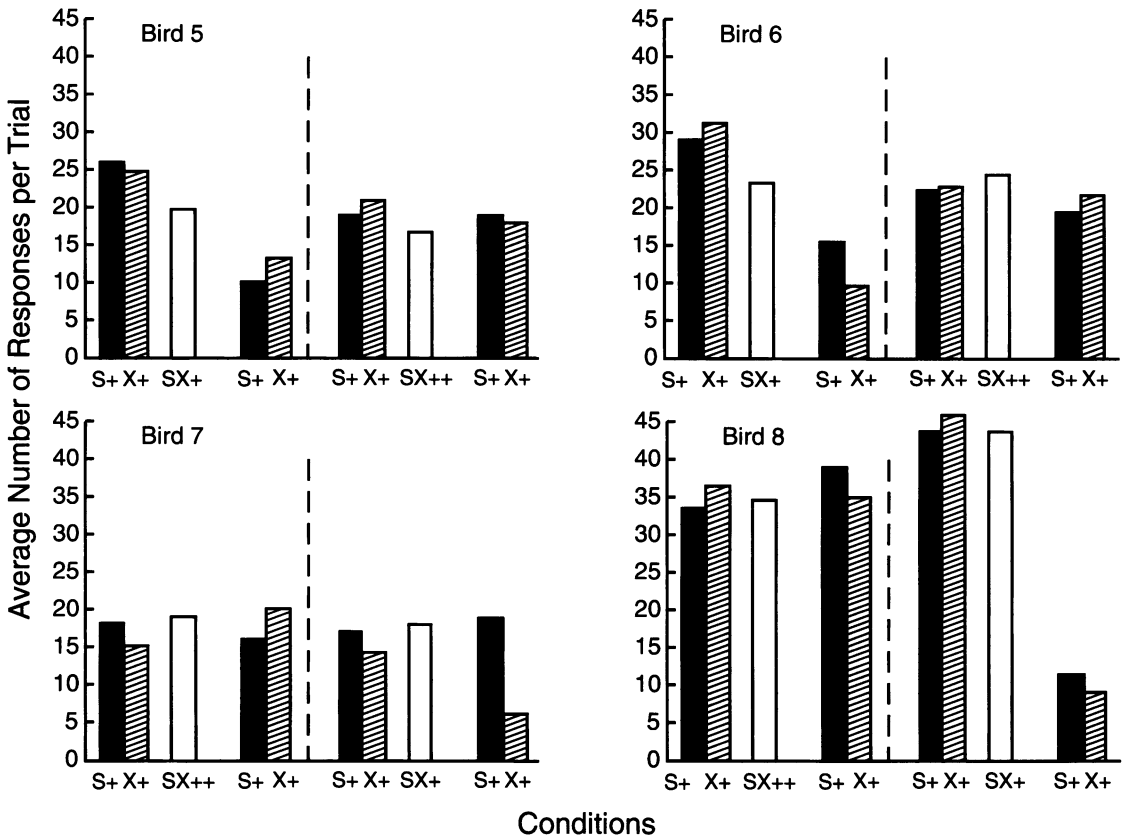


Fig. 6. Average number of key-peck responses per trial to keylight autoshaping stimuli during individual stimulus training (S+, filled bars; X+, hatched bars), compound CS training (SX+, SX++; open bars), and test trials (S+, filled bars; X+, hatched bars) for each bird in Experiment 3. For Birds 5 and 6, the left panels show the data from conditions in which the magnitude of food remained constant during compound training (Conditions 1, 2, and 3), and the right panels show the data from conditions in which the magnitude of food increased (Conditions 5, 6, and 7). For Birds 7 and 8, which were exposed to the training conditions in a counterbalanced order, the left panels show the data from conditions in which the magnitude of food increased during compound training (Conditions 1, 2, and 3), and the right panels show the data from conditions in which the magnitude of food remained constant (Conditions 5, 6, and 7).

na: blocking, unblocking, and overexpectation. Taken together, the results of the three experiments replicate and extend prior research on these phenomena. Experiment 1 replicated Blanchard and Honig's (1976) findings on blocking using pigeons and the autoshaping procedure by showing that conditioning to one stimulus of a compound is retarded by prior experience with the other stimulus of the compound. Experiment 2 replicated Holland's (1984, 1985b) findings on unblocking by showing that unblocking was obtained with both increases and decreases in the amount of an appetitive US; it extends those findings to pigeons and the autoshaping procedure. Experiment 3 replicated Kre-

mer's (1978) findings on overexpectation by showing that stimuli will lose conditioning strength despite continued association with a US; it extends those findings to an appetitive US, again with pigeons and the autoshaping procedure.

In addition to replicating and extending previous findings on these phenomena to pigeons, autoshaping, and appetitive USs, the present experiments demonstrate the appropriateness of single-subject designs in addressing issues that have commonly been examined by means of more traditional group-statistical designs. More specifically, the present research has shown that single-subject experiments are capable of providing

convincing demonstrations of Pavlovian conditioning phenomena in individual subjects, relying on experimental rather than statistical control. These results greatly enhance the robustness and generality of the effects in question (Baron, 1990; Sidman, 1960).

By demonstrating that an autoshaping procedure with an appetitive US is suitable for the study of these and other classical conditioning effects (note also that all birds had previously been trained on operant variable-interval schedules), the present experiments also corroborate previous suggestions that past failures to produce blocking-like effects with the autoshaping procedure may be related more to the appropriateness of the stimuli used than to the possible interaction between operant and species-specific factors. As Williams (1981) suggested, superimposing stimuli on the same response key in compound training may alter the properties of such stimuli, resulting in a substantially different "stimulus configuration," which in turn reduces the significance of the previously trained element. The findings of the present research, along with those of previous research in which the salience or the significance of the pretrained element has been preserved, enhance the credibility of this argument (e.g., Blanchard & Honig, 1976; Williams, 1981).

Of course, even this argument has a limitation, in that Experiment 3 showed that the overexpectation effect will occur reliably with pigeons. Clearly, the pigeons do not necessarily treat each compound as a unique configuration of stimuli, such that conditioning begins anew. Some of the original behavioral significance of the previously trained stimuli must carry over, or else the effect would not occur.

The usual criticism of single-subject designs is that the prior experience of the subjects distorts the influence of a current condition, thereby making it difficult to understand the effects of any given manipulation. Accordingly, one might have expected the present research not to show any orderly effects. However, the data do show orderly effects. For example, a noteworthy feature of the present research is that the extinction trials were adequate as manipulations to separate the various training-test conditions. Ordinarily, extinction is not regarded as a treatment that

completely undoes the effects of all prior experiences, such that subjects revert to a naive state with respect to stimuli that have already been conditioned. The effect of the extinction trials is perhaps unanticipated but seems valid nevertheless, as judged by the consistently robust effects in the predicted directions.

Overall, most of the results of this study can be interpreted in terms of the Rescorla-Wagner (1972) model of Pavlovian conditioning. That is, the Rescorla-Wagner model can account for blocking in manipulations like those carried out in Experiment 1, the unblocking by increases in US magnitude in Experiment 2, and the overexpectation effect in Experiment 3. In addition, the effect of the extinction conditions in separating the various training conditions is also consistent with the Rescorla-Wagner model.

The principal difficulty for the Rescorla-Wagner (1972) model in the present research is the same as in Holland (1985b): the demonstration in Experiment 2 of unblocking with *decreases* in US magnitude. The Rescorla-Wagner model contains two relevant terms:  $\lambda$  and  $V$ . The term  $\lambda$  represents the asymptotic conditioning level possible to the CS. The value of this term is determined by the size of the US. The term  $V$  represents the current level of conditioning to the CS. The value of this term is determined by the number of previous trials in which the US has been associated with the CS. In brief, the model suggests that for a given value of  $\lambda$ , conditioning takes place until  $\lambda$  and  $V$  are in equilibrium. If  $\lambda$  changes, then  $V$  will change until equilibrium is reestablished.

Consequently, the model predicts that, on the one hand, an increase in the size of the US during compound training should result in excitatory learning and an increase in the associative strength of the CS, manifested as an increase in responding to the CS. In the language of the model,  $\lambda$  has increased, so that  $\lambda > V$ . Consequently, excitatory learning should occur for both stimuli on each trial until  $\lambda = V$ . The data supported this prediction.

On the other hand, the model predicts that a decrease in the size of the US during compound training should result in inhibitory learning and a decrease in the associative strength of the CS, manifested as a decrease

in responding to the CS. In the language of the model,  $\lambda$  has decreased so that  $\lambda < V$ . Consequently, inhibitory learning should occur for both stimuli on each trial until  $\lambda = V$ . The data did not generally support this prediction: On average for the 4 birds in Experiment 2, the keylights elicited approximately the same number of responses per trial when the size of the US decreased as when the size of the US increased. Although the keylights did elicit fewer responses per trial for Birds 1 and 2 when the size of the US decreased relative to when it increased (an outcome conceivably reconcilable with the Rescorla–Wagner model), the keylights elicited more responses per trial for Birds 3 and 4.

As noted above, the finding in Experiment 2 that responding is maintained despite decreases in the magnitude of the US does corroborate other recent reports on this issue, such as Holland's (1984, 1985b). However, Wagner et al. (1980) have provided evidence to the contrary. Wagner et al. indicated that compounding a new CS with a CS that was previously associated with a US (shock) of greater intensity than the one used in compound training resulted in "greater blocking of excitatory learning" (p. 381) than when the US of the same intensity was used in both the pretraining and compound phases. Wagner et al. argued that their results constituted further evidence in support of Rescorla and Wagner's (1972) predictions.

It is possible that the difference between the outcomes of the present study and Holland's (1985b), on the one hand, and the outcome of Wagner et al.'s (1980) study, on the other, may be a result of procedural differences. Although Wagner et al. employed a conditioned suppression procedure rather than an appetitive conditioning procedure, a more important difference may have been that subjects in Wagner et al.'s study were exposed to two types of trials in pretraining (e.g., A++ and B+). In contrast, subjects in the present experiment were presented with only one or the other type in pretraining.

Although one can only speculate on whether this difference in pretraining caused the conflicting outcomes, the results of Neely and Wagner (1974), involving appetitive operant conditioning and pretraining similar to that used in the present experiment, appear to support the present findings. Specifically,

Neely and Wagner found that more excitatory conditioning was exhibited by subjects exposed to the A++/AX+ training than by those exposed to the B+/BX+ training. Neely and Wagner suggested that "schedule-generated contextual cues" (p. 762) might be involved in such outcomes (see also Wagner, 1978). This suggestion, which centers on the notion of generalization decrement, holds that a change in reinforcement schedule (e.g., from A++ to AX+) could disrupt conditioning accrued during pretraining (e.g., to A). The discrepancy between  $\lambda$  and  $V$  could increase because  $V$  decreased rather than because  $\lambda$  increased.

To be sure, given the numerous findings and effects in the classical conditioning literature, an overview of the field reveals no shortage of theories to account for the relevant data. For example, Rescorla and Colwill (1983) postulated that blocking and unblocking manipulations may result in the formation of between-element associations (e.g., between the pretrained and added CSs). In addition, Holland (1985a, p. 240) has postulated that the mechanisms of unblocking in upshift and downshift procedures are not identical (cf. Dickinson et al., 1976). Rescorla (1985) has suggested that a stimulus element can play a "facilitating" role in compound procedures, and Holland (1985a) has proposed that it can play an "occasion setting" role (for additional discussion of the role of the CS, see Mackintosh, 1978; Pearce & Hall, 1980). Despite the potential usefulness of such theories, at present researchers may be well advised to accept Holland's (1984) caution that many of these effects seem to be "both multiply determined and poorly understood" (p. 495). The verification of the actual principles determining these effects may depend largely on the ability of future researchers to disentangle what appears to be a complex interplay among CS, US, and possibly other related factors such as context.

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