SECOND-ORDER AUTOSHAPED KEY PECKING BASED ON AN AUDITORY STIMULUS

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In Experiment 1, pigeons were exposed either to paired or to unpaired presentations of a tone and grain, and then to paired presentations of a keylight with the tone. Substantial second-order conditioned pecking to the keylight was produced in the birds that had received paired presentations of tone and grain. In Experiment 2, second-order pecking to the keylight increased in probability across four groups that had received, respectively, 20, 80, 140, or 200 paired presentations of tone and grain. In Experiment 3, the amount of pecking directed towards a keylight which predicted the first-order, tone CS was as substantial in birds without a prior history of key pecking as in birds with such a history. A further experiment failed to discover any significant differences in the levels of second-order pecking to a keylight paired with a first-order tone CS or with a first-order keylight CS. Thus, an auditory signal that does not itself support pecking may enable a localized visual stimulus to evoke key pecking.

Key words: second-order conditioning, autoshaping, tone stimulus, key peck, pigeons

INTRODUCTION

Brown and Jenkins (1968) reported that hungry pigeons approached and pecked at a key whose illumination preceded grain delivery although there was no scheduled contingency between pecks and delivery of grain. The conditioning of directed movements to a stimulus positively correlated with an appetitive reinforcer has been termed autoshaping (Brown & Jenkins, 1968) or sign tracking (Hearst & Jenkins, 1974) and has been accorded fundamental importance in various treatments of conditioning (e.g., Mackintosh, 1974; Seligman & Hager, 1972).

The localizability of the predictive stimulus is an important determinant of the phenomenon. Localized visual cues readily condition directed movements (cf. Hearst & Jenkins, 1974), whereas diffuse visual cues do not (Wasserman, 1973). Auditory cues, which by their

nature are not readily localizable, do not in general evoke autoshaped approach or contact behavior (e.g., Bilbrey & Winokur, 1973; Schwartz, 1973), although certain arrangements may produce such conditioning; for example, where a sound source is favorably located with respect to the response key and food-delivery mechanism (Jenkins, cited in Hearst & Jenkins, 1974; Steinhauer, Davol, & Lee, 1977). The ability of an auditory signal to direct pecks toward a localized visual cue appears to depend upon the prior history with respect to the localized cue. Schwartz (1973) demonstrated that the occurrence of a predictive auditory cue was not accompanied by pecks at a continuously present keylight unless that keylight had previously been established as a signal for food.

Although nonlocalized signals do not, therefore, reliably condition pecking movements directed toward themselves or toward other cues in the environment, they do influence the control over pecking exerted by localized signals. Thus, for example, less pecking occurs to a localized signal for food when that signal appears in compound with a diffuse signal than when the localized signal is conditioned separately (Allaway, 1971; Wasserman, 1973). Moreover, a prior correlation between a diffuse stimulus and food enhances the ability of that signal to interfere with the pecking di-

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rected at a concomitantly present and otherwise effective localized signal (Leyland & Macintosh, 1978).

The present experiments employed a second-order conditioning procedure (cf. Pavlov, 1927; Rescorla, 1973) to examine further the nature of the control over autoshaped key pecking exerted by diffuse auditory signals. Specifically, they sought to determine whether auditory stimuli, already established as signals for food, could be employed as first-order conditioned stimuli to generate pecking toward an otherwise ineffective keylight. Previous investigations of such conditioning (Leyland, 1977; Rashotte, Griffin, & Sisk, 1977) employed subjects that had an experimental history of key pecking. Consequently, one aim of the present Experiments 1 and 3 was to determine whether an auditory first-order stimulus could generate second-order pecking as distinct from simply enhancing an experimentally preestablished response. Moreover, although substantial levels of second-order pecking were maintained by an auditory stimulus that had been established as a discriminative stimulus for operant pecking (Rashotte et al., 1977), low levels of such pecking were maintained by an auditory stimulus that had been established as a signal for food (Leyland, 1977). Consequently, a second aim of the present experiments was to evaluate the ability of an auditory stimulus, previously established as a signal for food, to generate second-order pecking. Thus, Experiment 2 examined the relation between the level of second-order pecking and the number of prior auditory CS-food pairings. Experiment 4 compared the levels of second-order pecking maintained by auditory and by visual, first-order stimuli.

EXPERIMENT 1

Experiment 1 was designed to provide a demonstration of second-order conditioning of keylight pecking via an auditory stimulus previously established as a signal for a grain reinforcer. Thus, the experimental group, designated PP, received pairings (P) of an auditory stimulus (S1) with grain in Phase 1 and then pairings (P) of a keylight (S2) with S1 in Phase 2. To determine whether the auditory stimulus had acquired its ability to generate responses to the keylight, a control group, designated UP, was exposed to unpaired (U)

presentations of S1 and grain in Phase 1 and then to pairings (P) of S2 and S1 in Phase 2. A demonstration of second-order conditioning typically includes a second control group directed toward assessing the contribution to S2's responding of nonassociative factors, such as generalization (cf. Rescorla, 1973). Thus, such a group might have been exposed to pairings (P) of S1 and grain in Phase 1 and then to unpaired (U) presentations of S2 and S1 in Phase 2. Such a group was not included in the present study, but unpublished pilot studies confirmed that pigeons did not display pecking movements in the presence of the auditory signals employed in these arrangements: hence, there could be no basis for generalization of pecking from the auditory S1 to the visual S2.

METHOD

Subjects

16 adult hybrid pigeons, without prior experimental histories, were maintained at 75% of their free-feeding body weights. The birds were housed individually and water was available at all times in their home cages.

Apparatus

The apparatus consisted of eight standard experimental chambers (Coulbourn Instruments). A response key illuminated by an inline display (Industrial Electronics Engineers Inc.) was positioned 6 cm above the floor and 4 cm to the left of a food hopper which was located centrally and 3 cm above the floor. The visual stimuli were provided by transilluminating the response key with an 8 mm-wide white dot or with a diffuse green light. During reinforcement, which consisted of 5-sec access to mixed grain, the food hopper was illuminated by a 24-V, 2-W lamp mounted at one side of the aperture above the hopper tray. When a bird inserted its head into the aperture, interruption of the light beam broke a circuit with a phototransistor cell mounted on the opposite side of the tray. Each chamber was illuminated by a 24-V, 2.5-W houselight and was enclosed in a sound- and light-attenuating cubicle fitted with a ventilating fan which was in constant operation during each session. The fans provided an ambient noise level of approximately 55 decibels which was augmented by white noise (65 decibels) presented through speakers situated on the back

wall of each cubicle. The auditory stimulus consisted of a 400-hz sinusoidal tone which together with the fans and white noise yielded a sound level of 85 decibels. The presentation of stimuli and the collection of response data were controlled by automatic equipment in an adjoining room.

Procedure

Subjects were randomly allocated to Groups PP and UP ($n = 8$ per group). The first and second letters in a group's designation refers to the relations, paired (P) or unpaired (U), scheduled respectively in Phases 1 and 2.

Subjects were given 60 min of habituation to the experimental chambers on two consecutive days. The food hoppers were raised and loaded with grain for 20 min per day for a further 2 days to familiarize the birds with feeding in the chambers. The final stage of habituation consisted in arranging 20, 5-sec food presentations per session for 4 sessions. The intervals between food presentations, which were the same as those employed subsequently in conditioning, ranged from 20 to 320 sec with a mean intertrial interval of 180 sec.

During each of the 4 sessions of Phase 1, subjects in Group PP were exposed to 20, 5-sec presentations of the tone stimulus (S1) that terminated in the operation of the food hopper for a further 5 sec; subjects in Group UP were exposed to 20, 5-sec presentations of S1 that occurred quasi-independently of 20, 5-sec presentations of the food hopper. The restrictions on the schedules of S1 and of food presentations in Group UP were that the two events did not occur within 5 sec of each other and that no more than two presentations of S1 or of food were allowed to occur in succession. During each of the 8 sessions of Phase 2, subjects in Groups PP and UP were exposed to 10, 5-sec presentations of the visual stimulus, the white dot, (S2), that terminated in the presentation of S1 for a further 5 sec. These 10 S2-S1 trials were embedded within appropriate 'refresher' trials: thus, across the first 5 and the last 5 trials of a session, Group PP continued to receive paired presentations of S1 and food while Group UP received unpaired presentations of S1 and food. Each session lasted for approximately 1 hr and subjects were run daily.

RESULTS AND DISCUSSION

Unsystematic observations of the birds revealed between-group differences in the behavior that occurred in the presence of the auditory S1: pigeons exposed to paired presentations of the tone and the food hopper (Group PP) consistently displayed alerting responses that consisted in lifting movements of the head. These responses were generally accompanied and/or followed by head-bobbing movements while the birds faced the front panel of the experimental chamber. Such head-lifting and head-bobbing movements were not typically observed in birds exposed to unpaired presentations of the tone and the food hopper (Group UP). In line with these observations, very few pecks were recorded in the presence of the auditory S1 in either Phase 1 or Phase 2. In fact, no pecks were recorded during Phase 1. In Phase 2, pecks in the presence of the auditory S1 in Group PP were recorded on 3% of the refresher trials and on 13% of the S2-S1 trials; such pecks in Group UP were not recorded on any of the refresher trials, but on 3% of the S2-S1 trials. Moreover, 79% of the pecks recorded in the presence of S1 on S2-S1 trials occurred on trials when pecks were also recorded to S2, so that the pecks in S1 may simply have been carryovers from the prior pecking at S2.

The data of principal interest are the pecks directed toward the visual S2 during Phase 2. The percentage of S2 trials (10 per session) on which a response occurred is shown for each subject of Group PP in the left panel of Figure 1 and for each subject of Group UP in the right panel of this figure.

Consider, first, the birds in Group PP (left panel of Figure 1), that received paired presentations of the tone and food followed by paired presentations of the keylight and tone. Substantial pecking at the keylight, S2, was observed in 6 out of the 8 birds: at their asymptotes, each of these 6 birds was pecking on at least 50% of the S2 trials. In two of these 6 (Birds 3 and 5) the percentage of S2 trials on which a peck occurred increased and then decreased across sessions. This decrease in responding could reflect the development of inhibitory control by the keylight (cf. Holland & Rescorla, 1975) or some loss in the effectiveness of the auditory S1 occasioned by the relatively small number of S1-food pairings during

Fig. 1. Percentage of second-order trials on which a peck occurred to S2 for each subject in Groups PP and UP.

Phase 2. The two birds (4 and 6) that did not display any recorded pecks at S2, were typically observed to move toward and direct pecks at S2 (cf. Rashotte et al., 1977).

Consider now the birds in Group UP (right panel of Figure 1), which received unpaired presentations of the tone and food followed by paired presentations of the keylight and tone.

No pecks at the keylight, S2, were observed in three of the birds (9, 13, and 14); a minimal number of pecks was recorded in three other birds, (10, 12, and 15); and a substantial amount of pecking across the first two sessions occurred in the remaining two birds (11 and 16). Observations of birds in this group revealed no consistent approach toward, or pecks directed at, the visual S2. The difference between the two groups in the percentage of trials on which a response occurred to S2, averaged across sessions, was significant $F(1,14) = 8.2$, $p < .025$. Examination of the rate of pecking at S2 suggested similar conclusions. Response rate, however, was highly variable and was not analysed in this or subsequent experiments.

EXPERIMENT 2

The results of Experiment 1 confirm and extend those reported by Rashotte et al. (1977) and by Leyland (1977): pigeons with no prior history of key pecking peck at a keylight paired with a tone that has previously been paired with food. The significant difference in the amounts of pecking at S2 in Groups PP and UP attests to the importance of the pairing relation between S1 and food in enabling S1 to condition pecks at S2. The present experiment examined further the effect of the prior pairing relation between S1 and food upon second-order conditioned key pecks: specifically, it sought to establish whether the level of second-order conditioned key pecking varied with the number of prior S1-food pairings.

METHOD

Subjects and Apparatus

The subjects were 32 experimentally naive, male, hybrid pigeons, maintained throughout the experiment at 75% of their free-feeding body weights. The apparatus was the same as that used in Experiment 1.

Procedure

The experiment involved two phases: Phase 1, first-order conditioning of the auditory S1 via a food US; Phase 2, second-order conditioning of the visual S2 via the auditory S1. The subjects were randomly allocated to four groups ($n = 8$ per group). In Phase 1, subjects received either 1 (Group 20), 4 (Group 80), 7 (Group 140), or 10 (Group 200) sessions of first-

order conditioning, each of which involved 20 paired presentations of the tone S1 and the food US. In Phase 2, all groups received 4 sessions of second-order conditioning, each of which involved 10 paired presentations of the keylight S2 and the tone S1. These 10 second-order conditioning trials occurred after 5 first-order, tone-food, trials and before a further 5 first-order, tone-food, refresher trials in each session. The procedure was otherwise identical to that previously described.

RESULTS AND DISCUSSION

Figure 2 shows the mean percentage of trials upon which a peck occurred to S2 across the 4 sessions of second-order conditioning. It can be seen from the figure that pecks to S2 were, in general, positively related to the number of prior S1-food pairings. Thus, out of a total of 40 second-order trials, the median number of trials upon which a peck occurred to S2 across the 4 groups was: Group 20, 13.5 (range 0 to 27); Group 80, 21.5 (range 0 to 25); Group 140, 25 (range 0 to 28); Group 200, 31 (range 19 to 37). Some support for these observations comes from the statistical analysis. This assessed between-group differences in the overall percentage of trials upon which a response occurred via planned orthogonal contrasts which tested for trends across the groups (Hays, 1972, p. 581 ff.). The significant linear trend, $F(1,28) = 5.27$, $p < .05$, indicated that the overall level of responding to S2 varied directly with the number of prior S1-food pairings. This relation is especially clear in Figure 3, which shows the individual data of those birds preexposed to the least (Group 20, left panel), and the greatest (Group 200, right panel) number of S1-food pairings. Thus, as a further indication of the differences in acquisition and maintenance of responses to S2, it is instructive to note that 7 birds in Group 200 vs 3 birds in Group 20 were responding on at least 50% of the trials on Sessions 3 and 4.

EXPERIMENT 3

The results of Experiments 1 and 2 suggest the conclusions that pigeons, with no prior history of key pecking, come to peck at a keylight paired with a tone that has previously been paired with food and that the level of such second-order key pecking is positively related

Fig. 2. Mean percentage of second-order trials on which a peck occurred to S2 as a function of the number of prior S1-food pairings.

to the number of prior tone-food pairings. The present experiment was directed toward an examination of the influence of a prior history of key pecking upon subsequently established second-order conditioned pecking. Previous investigations of such conditioning (e.g., Leyland, 1977; Rashotte et al., 1977) have typically employed birds with a prior history of key pecking. Although Experiments 1 and 2 clearly demonstrated the second-order conditioning of pecks in birds without a prior history of key pecking, the question remains whether a prior history of key pecking augments such second-order conditioning. Thus, the two experimental groups, designated KPP and NPP, received pairings (P) of an auditory stimulus (S1) with grain in Phase 2 and then pairings (P) of a keylight (S2) with S1 in Phase 3. What distinguished the groups was Phase 1: Group KPP received pairings of a keylight with grain

(K) whereas Group NPP received no (N) preliminary autoshaping. The keylight stimulus employed in Phase 1 for Group KPP was different from that subsequently employed as the S2 during second-order conditioning in Phase 3. Two further groups were employed, both of which received preliminary autoshaping training involving the keylight and food (K) in Phase 1. One of these groups, KUP, subsequently received unpaired presentations of the tone and food in Phase 2 and then paired presentations of the keylight (S2) and the tone in Phase 3. The second of these groups, KPU, subsequently received paired presentations of the tone and food in Phase 2 and then unpaired presentations of S2 and the tone in Phase 3. These control groups, then, examine the contribution to the level of second-order responding in Group KPP of a prior history of key pecking. In addition, of

Fig. 3. Percentage of second-order trials on which a peck occurred to S2 for each subject in the groups pre-exposed to the least (Group 20) and the greatest (Group 200) number of S1-food pairings.

course, these control groups, in conjunction with Group KPP, constitute a further demonstration of second-order conditioning: Groups KUP and KPU comment respectively upon the

acquired ability of S1 to establish second-order responses and upon the ability of S1 to influence responses to S2 via generalization and/or sensitization.

SUBJECTS AND APPARATUS

METHOD

32 experimentally naive, male, hybrid pigeons were maintained at 75% of their free-feeding body weights throughout the course of the experiment. The apparatus was as previously described.

Procedure

The experiment involved three phases: Phase 1, autoshaping; Phase 2, auditory conditioning; Phase 3, second-order conditioning. The subjects were randomly allocated to four groups ($n = 8$ per group). In Phase 1, subjects in Groups KPP, KPU, and KUP received a 5-sec presentation of a green keylight followed immediately by a 5-sec presentation of the food hopper; subjects in Group NPP remained in their home cages. In Phase 2, subjects in Groups KPP, NPP, and KPU received a 5-sec

presentation of the tone (S1) followed immediately by a 5-sec presentation of the food hopper; subjects in Group KUP received unpaired presentations of S1 and the food hopper. In Phase 3, subjects in Groups KPP, NPP, and KUP received a 5-sec presentation of the white dot (S2) followed by a 5-sec presentation of S1; subjects in Group KPU received unpaired presentations of S2 and S1. During Phase 3, the S2-S1 trials were embedded in appropriate S1-food trials: thus, the 10 daily S2-S1 trials were preceded by 5 and followed by 5 S1-food trials which consisted in paired presentations of S1 and food for Groups KPP, NPP, and KPU and in unpaired presentations of S1 and food for Group KUP. Each of the 4 sessions of Phase 1, the 4 sessions of Phase 2, and the 5 sessions of Phase 3 lasted for approximately 1 hr during which there were 20 trials with an average intertrial interval of 3 min. The procedure was otherwise identical to that previously described.

Fig. 4. Mean percentage of trials on which a peck occurred for those birds given first-order autoshaping (left panel) and the mean percentage of second-order trials on which a peck occurred to S2 (right panel).

RESULTS AND DISCUSSION

The left panel of Figure 4 shows the mean level of responding maintained by the green keylight during Phase 1 in Groups KPP, KPU, and KUP; the right panel of this figure shows the level of responding maintained by the white dot during Phase 3 in all 4 groups.

Consider the left panel of Figure 4. It is evident that a high level of pecking was maintained by the green keylight: on the final session of Phase 1, 22 out of the 24 birds pecked the key on at least 75% of the trials. The remaining two birds, one in Group KPP and one in Group KUP, pecked respectively on 65% and 50% of the final session's trials, but had pecked on 95% and 90% of the previous session's trials. In spite of the high level of responding thus established in Phase 1, pecks were recorded on less than 2% of the tone presentations across Phase 2, auditory conditioning, and in the auditory refresher trials of Phase 3.

The data of principal interest are the pecks directed towards the white dot, S2, during Phase 3 (right panel of Figure 4). Consider, first, the birds that had a prior experimental history of key pecking (groups KPP, KPU, and KUP). It is evident that the level of pecking on the first session of Phase 3 reflected the relations arranged between S1 and food and between S2 and S1: specifically, a relatively high level of responding (median, 7 trials out of 10 with a peck, range 1 to 10) in birds exposed to pairings of both S1 and food and S2 and S1 (Group KPP); an intermediate level (median, 3, range 0 to 8) in birds exposed to pairings of S1 and food and unpaired presentations of S2 and S1 (Group KPU); and a low level (median, 1, range 0 to 5) in birds exposed to unpaired presentations of S1 and food and pairings of S2 and S1 (Group KUP). It is also evident that substantial levels of responding were maintained only in Group KPP: on the final session of Phase 3, none of the birds in Group KPU pecked at S2 while two of the birds in Group KUP pecked on a total of three occasions; in contrast, all of the birds in Group KPP pecked at S2 (median, 5, range 1 to 8). These observations were confirmed by the statistical analysis which revealed a significant difference between Group KPP and Groups KPU and KUP, $F(1, 23) = 50.2$, $p < .01$. The difference between

groups KPU and KUP, however, was not significant ($F < 1$).

Consider, finally, the birds that did (Group KPP) and did not (Group NPP) receive a history of key pecking in advance of S1-food pairings and S2-S1 pairings, whose individual data are shown in Figure 5. There was considerably less pecking in Group NPP (median, 1.5, range 0 to 8) than in Group KPP (median, 7, range 1 to 10) on the first session of Phase 3. This was confirmed by a Mann-Whitney U test on the differences between the groups, $U = 14$, $p < .05$. It is also evident, however, that such differences had disappeared by the third session of Phase 3 (numbered experimental Session 11 in Figure 5). For example, on the final session of Phase 3 (numbered experimental Session 13) the median number of trials on which a peck occurred in Group NPP was 6 (range 0 to 10) vs 5 (range 1 to 8) in Group KPP. These differences, of course, were not statistically significant ($U = 28.5$, $p > .05$).

EXPERIMENT 4

The results of Experiment 3 may be summarized as follows. First, the conditioning of pecking to a visual stimulus (S2) by an auditory stimulus (S1) depends upon the pairing of S2 and S1 and upon the pairing of S1 and food (Group KPP vs KPU and KUP). Second, a prior history of key pecking facilitates the acquisition of second-order pecks (Group KPP vs Group NPP, first session of Phase 3). But, third, does not affect the maintenance of such pecks (Group KPP vs Group NPP, last session of Phase 3). Thus, a stimulus which does not itself support pecking can as readily condition such movements at a localized visual stimulus in birds that have, as in birds that do not have, a prior history of key pecking. A remaining question, addressed in Experiment 4, concerns the absolute levels of second-order conditioned key pecking observed in the present experiments: in particular, whether the level of second-order conditioned key pecking varies with the response-controlling properties of the stimulus employed as the first-order stimulus. Thus, Experiment 4 compared the abilities of a first-order auditory stimulus, which did not itself support pecking, and of a first-order keylight stimulus, which did support pecking, to condition pecks at a second-order key stimulus.

Fig. 5. Percentage of second-order trials on which a peck occurred to S2 for each subject in the groups with (Group KPP) and without (Group NPP) a history of key pecking in advance of S1-food pairings and S2-S1 pairings.

METHOD

Subjects and Apparatus

16 experimentally naive, male, hybrid pigeons were maintained at 75% of their free-feeding body weights throughout the course of the experiment. The apparatus was as previously described.

Procedure

The experiment involved 3 phases: Phase 1, autoshaping to a green keylight; Phase 2, auditory conditioning; Phase 3, second-order conditioning to a white dot. The subjects were randomly allocated to two groups ($n = 8$ per group). In Phase 1, all subjects received a 5-sec presentation of the green keylight followed immediately by a 5-sec presentation of the food hopper. In Phase 2, all subjects received a 5-sec presentation of the tone followed immediately

by a 5-sec presentation of the food hopper. In Phase 3, subjects received a 5-sec presentation of the white dot followed immediately by a 5-sec presentation of the green keylight (Group Light) or by a 5-sec presentation of the tone (Group Tone). These white dot-green keylight and white dot-tone pairings were embedded in appropriate first-order refresher trials: thus, Group Light received 5 pairings of the green keylight and food, followed by 10 pairings of the dot and green keylight followed by a further 5 pairings of the green keylight and food; Group Tone received 5 pairings of the tone and food, followed by 10 pairings of the dot and tone, followed by 5 pairings of tone and food. Each of the 4 sessions of Phase 1, the 4 sessions of Phase 2, and the 6 sessions of Phase 3 lasted for approximately 1 hr during which there were 20 trials with an average intertrial interval of 3 min. The procedure was otherwise identical to that previously described.

Fig. 6. Number of second-order trials on which a peck occurred to S2 cumulated across sessions for each subject in Group S2-keylight S1 (left panel) and in Group S2-tone S1 (center panel). The mean scores for these groups are shown in the right panel.

RESULTS AND DISCUSSION

On the final session of Phase 1, autoshaping, all birds were reliably pecking at the green key: 14 out of the 16 birds pecked on at least 18 out of the 20 trials; the remaining birds (one from each group), each pecked on 11 out of the 20 trials. During Phase 2, auditory conditioning, very few pecks were recorded in the presence of the Tone S1 (2% of S1 trials). However, the data of principal interest are the number of second-order conditioning trials upon which a peck occurred in the 2 groups. The left panel of Figure 6 shows the number of S2 trials upon which a peck occurred cumulated across the 6 sessions of Phase 3 for each of the birds in Group Light; the center panel shows the comparable data for each of the birds in Group Tone; the right panel shows the mean number of S2 trials upon which a response occurred cumulated across the 6 sessions for the two groups.

Inspection of the averaged performance (right panel) suggests that the groups were essentially similar but that the birds trained with the keylight S1 might have displayed slightly higher levels of responding to S2 than the birds trained with the tone S1. Indeed, 5 of the 8 birds in Group Light (left panel) vs 3 of the birds in Group Tone (center panel) responded to S2 at a high level across the several sessions; and 2 of the birds in Group Light vs 3 of the birds in Group Tone responded to S2 at a low level across the several sessions. These observations, however, were not supported by the statistical analysis, which failed to reveal either significant differences between the groups ($F < 1$) or a significant groups $\times$ sessions interaction ($F < 1$). Moreover, a comparison on Session 5, when the between-group differences were greatest, approached but did not reach a conventional level of significance ($U = 16$, $p > .05$). The similarities in responding to S2 in the two groups, therefore, suggest the conclusion that an auditory stimulus, which does not itself support pecking, is as effective as a visual stimulus, which does support pecking, in generating second-order conditioned pecking.

DISCUSSION

The present experiments can be summarized as follows. An auditory signal for food did

not elicit movements directed toward itself (Experiment 1), but was capable of conditioning such movements toward a second-order localized visual cue (Experiments 1, 2, 3, & 4). The magnitude of conditioning to the visual cue was a direct function of the number of prior pairings of the auditory signal and food (Experiment 2) and was as substantial in birds without a previous history of key pecking as in birds with such a history (Experiment 3). Finally, there were no statistically reliable differences in the amount of second-order pecking when S1 was a visual vs. an auditory stimulus (Experiment 4).

The failure to observe movements toward an auditory signal for food cannot be ascribed to a failure of that signal to become associated with food. The present demonstrations of second-order conditioning of pecking to a visual S2 by an auditory S1 converge with other reports (e.g., Leyland & Mackintosh, 1978) on the conclusion that directed movements are an imperfect index of a cue's associability with an appetitive event, and reinforce the proposition (e.g., Wasserman, 1973; Williams,¹) that a stimulus must be both informative and localized to autoshape movements.

The present results comment adversely on the generalization account of autoshaping (Logan, 1971; Steinhäuser et al., 1977). Such a view attributes the appearance of key pecks in an autoshaping procedure to generalization of food-hopper pecks, and the maintenance of key pecks to implicit reinforcement contingencies. In the present experiments, pecks emerged to the second-order S2 although this stimulus was never paired with grain nor with a stimulus (the auditory S1) that evoked pecking. These observations accord with the finding that autoshaped key pecking does not depend upon hopper illumination during grain delivery (Oberdieck, Cheney, & Strong, 1978). Moreover, several subjects from the control condition (Group UP, Experiment 1) never pecked nor were ever observed to move toward the Key S2. To the extent that pecks to a keylight originate in generalization from food-hopper pecks, pecks to the S2 key stimulus should have been observed in all the birds in the control condition.

¹Williams, D. R. *Biconditional behavior: Conditioning without constraint*. Unpublished manuscript, University of Pennsylvania, 1974.

The present results are also incompatible with the view that second-order conditioning procedures result in stimulus-response learning: Rescorla (1973), for example, has provided considerable evidence from various conditioning procedures involving both appetitive and aversive stimuli which supports the interpretation that an S2 comes to evoke those responses already controlled by the S1. The difficulty for this view, of course, was that the behavior conditioned to S2 (approach and pecking) was different from that observed in the presence of S1 (head-bobbing). This observation accords with the much more systematic observations of Holland and Rescorla (1975), which similarly revealed disparities in the behavior conditioned to S2 and to S1 in an activity-conditioning procedure with rat subjects. Further support for the view that second-order autoshaped key pecking does not come about via the formation of stimulus-response connections has been provided by those studies (e.g., Leyland, 1977; Rashotte et al., 1977) that altered the significance of the S1 and found allied changes in the ability of S2 to evoke responses. This pattern of results suggests that second-order conditioned key pecking involves some form of stimulus-stimulus learning.

The present results, therefore, can be more readily interpreted in terms of those accounts of autoshaping (e.g., Jenkins & Moore, 1973; Williams, 1974) which start from the fact that the phenomenon depends upon the pairing or contingency relation between a signal and, say, food. Such relations are assumed to be internalized in an association between the signal and food such that the signal becomes a food-surrogate (Jenkins & Moore, 1973), or in an association between the signal, the food, and "a mandibular analysis indicating food-in-the-mouth" such that the signal releases species-typical behavior appropriate to getting food in the mouth (Williams, 1974). Such accounts, in a similar fashion, might begin with the fact that the conditioning of pecking at an S2 depends upon the pairing relation between the S2 and the S1 and assume that this relation is internalized in an association involving S2 and S1. S2, then, might come to control pecking by virtue of its association with S1 or with the "memory of food" aroused by S1. If the auditory S1 functions as a surrogate food-object or serves to arouse the "memory of food-in-the-

mouth," then the mechanism by which the association between S2 and S1 results in directed movements to S2 is identical to that subserving the conditioning of movements to a key-light paired with food.

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