BEHAVIOR CHANGES DURING REPEATED EIGHT-DAY EXTINCTIONS¹

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Pigeons were given repeated two-day conditionings alternating with eight-day extinctions using a trial procedure. One group had different key colors during each of the first five conditioning-extinction pairs; another group had the same key color throughout. Total extinction responses of both groups were quite constant over successive extinctions. This finding differs from the rapid declines found in most previous studies with bar-press and key-peck responses. The difference probably was due to our longer extinctions, because responses early in each extinction did decrease. However, that decrease was neutralized by increases in responses late in each extinction. The two opposite changes indicate the influence of two different factors during repeated extinctions, with neither factor having much stimulus specificity. The reduction of early responses may result from feeding changes confounded with extinction. The increase in later extinction responses may result from a decrease in the effect of unreinforced responses after their repeated occurrence.

Key words: extinction, repeated extinctions, discrimination, key peck, pigeons

A variety of results have been obtained in repeated-extinction studies, *i.e.*, studies in which periods of operant reinforcement of a response alternate with periods during which that response is not reinforced. In studies with the bar-press and key-peck responses (Bullock, 1960; Bullock and Smith, 1953; Clark, 1964; Davenport, 1969; Jenkins, 1961; Perkins and Cacioppo, 1950), repeated extinctions have shown progressively fewer responses, though Wickens and Miles (1954) showed increases at first, followed by decreases after the third extinction. Studies with jumping stands and alleys have shown faster responding on successive extinctions (Lauer and Carterette, 1957; Lauer and Estes, 1955); or about the same responding (North and Morton, 1962). Capaldi, Leonard, and Ksir (1968) and Wolach, Latta, Manshio, and Aderman (1972) found both acceleration and deceleration of response speed during brief extinctions, depending on whether the extinctions were followed by reinforcements on the same day or not, and

depending on the intertrial interval (ITI). Such variability in findings is not surprising in view of the many important differences in procedures.

Comparisons among the above studies indicate that the following influences on repeated extinctions are likely, though in view of extensive confounding of variables these conclusions are tentative until carefully controlled comparisons are made. A decrease in successive extinctions seems to be favored by (1) use of bar-press or key-peck responses rather than alleys or jumping stands, (2) measurement of number of responses in extinction rather than latencies or running times, (3) massing of extinction responses by free-operant techniques or short ITIs as compared with several minute or 24-hr ITIs, (4) increase in extinction trials per extinction, (5) not giving reinforcements following the extinction and within the same daily session, (6) increasing the difference between the ITI during extinction and the ITI between the last unreinforced trial and the first reinforced trial, and (7) continuous rather than intermittent reinforcement.

Most of the above studies involved rather brief extinction periods, often only part of a session, and few data are available concerning repetition of long extinction periods. Jenkins (1961) gave pigeons two 10-day extinctions and found the usual decline, but the duration of his second conditioning was less than one

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seventh that of the first. A study by Schaeffer, Salzberg, Birkle, and Ryan (1967) with rats and four-day extinctions found the usual decline with repetition. Long extinctions that reduce responding to low levels need study, since they may introduce different features. One objective of the present study was to examine the repetition of eight-day extinctions with pigeons, with uniform conditioning and extinction treatments on each repetition. Another objective stems from the work with errorless discriminations of pigeons (Terrace, 1963), which indicates remarkable specificity of conditioning effects to particular colors. Terrace (1966) and Anger and Anger (1972) found errorless discrimination for color stimuli without the special techniques of fading-in and gradual lengthening of S- (the stimulus during which pecks are not reinforced). If the effects of both conditioning and extinction can be quite specific to different colors, then changing the key color between each conditioning-extinction pair may make the second conditioning-extinction pair more independent of the first, *etc.*, and thus may reduce the decline in responding between successive extinctions.

A discrimination procedure that permitted only one response during each S+ (stimulus during which responses were reinforced) was used to maximize the control of the measured response by the keylight, and to minimize influences from the bird's preceding responding (Anger, 1956; Ferster and Skinner, 1957; Morse, 1966).

METHOD

Subjects

Each of 25 female White-King pigeons (retired breeders) was gradually reduced to approximately 80% of its free-feeding weight, and a daily feeding amount that kept the body weight stable was determined. This daily feeding was given 1 hr after the experimental session, and the amount of food was changed only to offset changes in the amount of food received during the experimental session or to eliminate a consistent trend in body weight.

Apparatus

The pigeon enclosure was 30.8 by 30.8 by 34.3 cm high. The front panel was stainless steel and contained a key 2.5 cm in diameter

with its center 15.4 cm from each side and 24.1 cm above the mesh floor. The center of the grain hopper (Lehigh Valley) aperture was 12.7 cm directly below the key. Two other walls were made of wood and were painted flat black, and the fourth wall (to the right of the front panel) had a 27.9 cm wide by 32.4 cm high observing window with glass on the outside and copper screen on the inside. The chamber was illuminated by a 67-W bulb carrying 0.34 Amperes ac to prolong its life. The bulb was outside the box (to decrease box heating) with its light passing through a 7.6-cm diameter hole in the top of the box (covered with heat absorbing glass) onto a frosted glass ceiling that covered the entire pigeon chamber. The center of the light-entrance hole was 7.6 cm from the front panel and 7.6 cm from the door to provide good illumination of the pigeon while it pecked the key. The force required to operate the key was 0.15 to 0.16 N. Masking noise was provided by a ventilation fan. The key could be illuminated by five different colors (each provided by two Christmas-tree bulbs): red, green, blue, orange, and white. The brightness of the colors was matched for the human eye.

Procedure

To reduce both the variability in treatment of different birds and the variability between the successive conditionings of the same bird, an adaptation of the Brown and Jenkins (1968) autoshaping procedure was used. The autoshaping was followed by a quite similar discrimination procedure to facilitate the transition from conditioning to discrimination.

Conditioning phase 1 (autoshaping). After magazine training, birds received this autoshaping phase in which 7-sec presentations of the lighted key were followed by 3 sec of access to grain. A key peck during the lighted key terminated the keylight and produced the 3-sec food access. These trials were given at variable intervals averaging 1 min. A peck on the dark key had no consequence. This treatment continued until the bird made five pecks on the lighted key, at which time and within the same session the next phase began. If five pecks did not occur within 45 pairings of the lighted key with food, the session was terminated and repeated on the following day. Eighteen birds made the required five pecks on the first day; the three remaining birds

that were used made the five pecks on the second day. Four birds were discarded that did not make the five pecks on any of the first three days.

Conditioning phase 2. This phase began immediately after the fifth peck on the lighted key, at which point the schedule of stimulus presentations was changed to the one used in all phases of the experiment except conditioning phase 1. In the new schedule, the lighted-key (S+) and dark-key (S-) periods alternated, with light onsets always 26 sec apart. When the bird did not peck the lighted key, the light was on for 16 sec and off for 10 sec. When the bird did peck the lighted key, the light went off immediately, and stayed off for the remainder of the 26-sec cycle. In this phase, food no longer followed the lighted key when no key peck occurred, but every peck on the lighted key (every first response of a trial) was still followed by 3-sec access to grain. This phase terminated after 10 reinforced pecks within the phase, and the session also terminated at that time. Thus, all 21 birds received autoshaping and 15 reinforced pecks from conditioning phases 1 and 2 on one day; 18 had all their autoshaping on that day, and none on the preceding day, while three birds had 45 autoshaping trials on the preceding day.

Conditioning phase 3. This phase of training was the same as conditioning phase 2 except that not all first responses were reinforced. This phase always lasted one session (the session following the day on which the bird made 15 reinforced pecks), and it employed the same 26-sec cycle used in conditioning phase 2, i.e., when the bird did not peck the lighted key, the light was on for 16 sec and off for 10 sec; when the bird did peck the lighted key, the light went off immediately, and stayed off until 26 sec after the preceding light onset. No responses other than the first response to each S+ presentation were ever reinforced, but in this phase those first responses to an S+ were reinforced on a variable-ratio (VR) schedule with the ratio requirement gradually increasing from VR 1 on the first four trials to VR 5 during the last 20 trials of the session. Every S+ presentation was terminated immediately after the first response, whether or not the response was reinforced. The session terminated after 100 first responses and 45 reinforcements.

Extinction phase. Beginning on the day after the conditioning phase 3, the birds' responses were extinguished for eight days, 100 trials per day, with all other conditions the same as during the conditioning phase 3, except that no reinforcements were given.

After eight days of extinction, the above-described three phases of conditioning were repeated exactly, and followed by another eight-day extinction phase. On reconditionings the birds always began pecking quickly, so that conditioning phases 1 and 2 always occurred within one day, and phase 3 on the following day. Consequently, this procedure resulted in just two days of peck reinforcements on every conditioning with 15 peck reinforcements on the first day and 45 on the second. The only difference between initial and later conditionings was that more pairings of keylight and food occurred before birds began to key peck in the first conditioning, while in reconditionings few and often no light-food pairings occurred before pecking began.

Birds were given from six to 20 such conditionings and extinctions, and most received at least eight. The 13 birds in the color-change group received a different color stimulus for each of the first five conditionings and extinctions. Since only five colors were available, after the fifth extinction the fifth color was repeated for following extinctions. One bird (3447) in this group received only three color changes before repetition of the last color, and two other birds (4164 and 3605) received only four color changes before repetition. Six different sequences of stimulus colors were used for different birds. Another group of eight birds received the same color stimulus for at least the first six extinctions. Four birds received red throughout and four received green.

RESULTS

In the following analysis and figures, the only pecks considered are the first pecks on an S+ presentation, which were the only pecks with the keylight on. Consequently, the maximum number of responses per day was 100. Additional pecks after the keylight terminated were negligible: the color-change birds averaged 0.034 dark-key pecks per trial during eight extinctions, and the no-color-change birds averaged 0.015 dark-key pecks per trial

during six extinctions. Most of those dark-key pecks occurred soon after the first peck that always turned off the keylight.

Figure 1 shows the mean total responses during the eight days of extinction for each successive extinction for both groups. The solid triangles show the 13 birds with the key-color change after each of the first five extinctions, and the open circles show the eight birds with the same key color on all extinctions. With the color-change procedure, there was remarkably little change in total responses during the first five extinctions with the color change. However, the birds without the color changes did not show any appreciable decrease either.

Thus, neither group showed the rapid decline in extinction responses reported so often in the literature for bar presses and key pecking. At first sight, these findings might seem to indicate that the present procedure provides a useful baseline for extinction studies, but closer inspection indicates otherwise. Figure 2 shows the changes in the total responses on the successive extinctions of the five birds that received red on the first and green on the second extinction. It shows that the mean curves concealed considerable variability among birds in the changes between the first and second extinction. Some birds made half as many responses on the second extinction as on the first extinction, while others made double, and others showed little change. This

Fig. 2. Total extinction responses on successive extinctions for each of the five color-change birds that received a red stimulus for the first extinction and a green stimulus for the second extinction.

large fluctuation continued out to five and sometimes more extinctions. Similar fluctuation was found in the birds with no color change.

Although Figure 1 shows that the total responses in extinction averaged across birds was rather stable with repetition, the average responses on individual days of each extinction showed large and systematic changes with successive extinctions. Figure 3 shows those changes for the 13 color-change birds. The curve of solid circles compares for different extinctions the means of the responses on the first day of successive extinctions, the solid

Fig. 1. Mean total extinction responses (sum of responses during the eight days of extinction) for each of the eight extinctions of the color-change group (solid triangles) and for each of the six extinctions of the no-color-change group (open circles).

Fig. 3. Changes during successive extinctions in responding on the different days of extinction for the 13 color-change birds. The solid circles show the mean responses on Day 1 of the different extinctions, solid triangles show Day 2 responses, open circles show responses per day on Days 3 through 5, and open triangles show responses per day on Days 6 through 8.

triangles compare the means of Day 2, the open circles compare the mean responses per day on Days 3, 4, and 5, and the open triangles compare the mean responses per day on Days 6, 7, and 8. The responses on Days 3, 4, and 5 were fairly similar to each other, as were those for Days 6, 7, and 8; consequently they were averaged to simplify the figure. Figure 4 shows the same plot for five of the eight birds without color change. Three of the eight birds in this group were omitted from this graph for reasons explained below. All eight birds were included in the following statistical analyses.

It is apparent in both Figures 3 and 4 that within the first extinction there were large differences in the responding on different days, since a wide separation is present between the curves on the left side of the graph. The responding was high on the first day (solid circle) and declined on successive days of the first extinction to low levels on the last three days (open triangle). Analyses of variance showed significant differences among days of the first extinction for both groups ($p < 0.01$ for both). Trend analyses of the days of the first extinction showed significant linear, quadratic, and cubic trends for both groups (all $p < 0.01$).

In contrast with the above situation on the first extinction, after repeated extinctions the responding on the different days of extinction drew close together (right side of both Figures 3 and 4). With the color-change group, an

analysis of variance showed no significant differences among the eight days of the eighth extinction ($p > 0.25$), and no significant trends remained. With the no-color-change group, analysis of variance among the days of the sixth extinction was significant ($p < 0.05$), even though the differences between the means were extremely small, as seen in Figure 4. A significant ($p < 0.01$) linear trend remained, too.

With the first no-color-change birds tested, the responding on different days became quite similar by the sixth extinction, so some were terminated after six extinctions. However, some birds tested later required more extinctions to develop similar responding. Figure 5 shows individual extinction curves for all eight birds in the no-color-change group. The top five rows show extinctions 1, 3, and 6 of the five birds included in Figure 4. The right column shows how flat the response curves of these birds were during the sixth extinction. The lower three rows show extinctions 1, 6, and 12 of the three birds omitted from Figure 4. This lower portion of Figure 5 shows that by the sixth extinction, the responding of Birds 6666 and 3613 had not equalized (become approximately the same on different days of one extinction) as had the responding of the other birds, but that the responding had equalized by the twelfth extinction. Those two birds probably were responsible for the significant analysis of variance and linear trend on the sixth extinction. The other bird (3601) in the lower portion of Figure 5 showed an unusually high response rate throughout all extinctions. Its responding equalized by the sixth extinction, but inclusion of its high rate in the average of Figure 4 would have made the average curve unrepresentative of any individual bird. Thus, Figure 4 did not include those three birds so that its average curves would be representative of the individual curves. Figure 5 illustrates the individual variation, and shows that in spite of both variation in average rate, and in number of extinctions necessary, all birds started out with a prominent decline in responses during extinction, and all eventually developed remarkably uniform responding on the different days of each extinction.

The similarity among the days of the later extinctions resulted to a major degree from a large decline in responses on the first days

Fig. 4. Changes during successive extinctions in responding on the different days of extinction for five of the eight no-color-change birds. The solid circles show the mean responses on Day 1 of the different extinctions, solid triangles show Day 2 responses, open circles show responses per day on Days 3 through 5, and open triangles show the responses per day on Days 6 through 8.

Fig. 5. The changes in responding during extinctions 1, 3, and 6 for the five no-color-change birds shown in Figure 4, and during extinctions 1, 6, and 12 for the remaining three no-color-change birds.

of each successive extinction (solid-circle curves in Figures 3 and 4). For both the color-change and no-color-change groups, *t* tests showed that the Day 1 responses during the first extinction were significantly greater than the Day 1 responses during the last extinction

shown ($p < 0.005$ for color change, $p < 0.025$ for no color change).

Small but significant rises in the responses during the last six days of the repeated extinctions (open circles and triangles) were also shown by *t* tests. The sum of responses on Days 3 through 8 increased from the first to the eighth extinction in the color-change groups, and from the first to the sixth extinction in the no-color-change group ($p < 0.005$ for both groups).

Those two opposite effects, the decline of Day 1 responding and the rise of responding later in extinction, cancelled each other out, and produced the roughly constant total extinction responses seen in Figure 1. Although the response increases were small for Days 3, 4, and 5, and for Days 6, 7, and 8, each of those curves was the average of three days, so that a given rise in each curve represents three times more responses than the same decline in the curve for the first day of extinction. That factor, together with the presence of two such groups (3, 4, and 5, plus 6, 7, and 8), enabled the small rise of the late response curves to cancel the large drop of the first-day curve.

The 13 color-change birds were more homogeneous, and all were tested for eight extinctions, by which time their responding had equalized. Figure 6 shows the mean responses

Fig. 6. Mean responses on each of the days of each extinction for the 13 color-change birds.

per day on successive days of each extinction. The same reduction of responses on the first day of extinction, and increase in late-extinction responses produced remarkably flat curves by the eighth extinction.

DISCUSSION

Clearly, our results did not show the steep decline in responses with repeated extinctions that has been reported with bar-press and key-peck responses in the literature (Bullock, 1960; Bullock and Smith, 1953; Clark, 1964; Davenport, 1969; Jenkins, 1961; Perkins and Cacioppo, 1950; Schaeffer *et al.*, 1967, Wickens and Miles, 1954). However, some factor other than the color-change technique seems to eliminate the decline, because even without color changes the decline was absent. The difference does not seem to be due just to our use of a trial procedure, because three of the above studies (Davenport, 1969; Jenkins, 1961; and Perkins and Cacioppo, 1950) found the decline with a trial procedure. The most obvious difference between our procedure and those in the literature is that most of the published studies used shorter extinction periods, usually a single day and some as short as 30 min, in contrast with our 8 hr spread over eight days. Furthermore, if we look at only the first days of our extinctions, we see the decline with repetition that is reported in the literature with single days.

However, there have been two studies with longer than single-day extinctions. One was the study of Jenkins (1961) with 10-day extinctions, though only one repetition. He found less than half as many extinction responses on the second extinction as on the first. However, his first conditioning ranged from 22 to 32 days long, while his reconditioning lasted only three days. Thus, the decrease on his second extinction may have been due to the large decrease in reinforcements on his second conditioning. All our conditioning periods were the same, and only two days long. Close examination of Figure 1 of Jenkins (1961) does reveal some evidence of a rise in late-extinction responses. Although the total extinction responses of all three of his groups were less on the second extinction than on the first, still his Figure 1 shows that one of his three groups (discrimination group) made more responses per day on the later days of

his second extinction than were made on the corresponding days of the first extinction. This increase in late-extinction responses is similar to our finding, and in the Jenkins study it occurred in spite of a large difference in conditioning, which favored a response difference in the opposite direction.

The other repeated-extinction study with longer extinctions was a study with four-day extinctions in rats by Schaeffer *et al.* (1967). Like us, they found that repetition equalized responses among days within their extinctions. However, repetition reduced their total extinction responses by reducing both late and early responding, and equalization resulted from more reduction of early than of late responding. Again, they did have slight evidence of an increase in late responding, since responses on their fourth extinction day increased from the first to the second extinction, but thereafter decreased. Probably one reason we found more rise in late-extinction responses is that we had a larger sample of them, four more days. In our results, the rise on any one day was quite small, but when multiplied by six days it became appreciable. However, Schaeffer *et al.* saw some decline on the fourth day, so probably other differences between our procedures were important too. It seems likely that their use of 100% reinforcement without trials, which concentrated all their reinforcements in a short time, may have contributed. Our use of a variable-ratio schedule and a 26-sec spacing of trials spread out responses over about 43 min during both conditioning and extinction.

Thus, one major reason that the rise in late-extinction responses has not been reported before is that repeated extinctions have not been studied with as long extinctions as we used and with conditioning held constant. However, both of the above studies do provide a little evidence of increases in late-extinction responses, and indicate that such increases probably are a function of the differences in conditions among them and our study, as well as the differences among groups in the Jenkins study. Thus, these comparisons support the other evidence that our constancy of overall extinction responses resulted from conditions that produced by chance an approximate balance between decrementing and augmenting factors. Different conditions can probably change one or both factors so that their com-

bined effect results in an overall decline, or possibly an overall rise.

Our finding that eventually the birds responded about the same on all days of extinction agrees with the view that the birds had learned a discrimination: they had learned to respond during some stimulus present during days with reinforcement and to minimize responding during a different stimulus present on all days without reinforcement. This is an old interpretation, dating back to Sheffield (1949) and Hull (1952). More recent examples of this analysis can be found in Logan and Wagner (1965) and Capaldi (1967). Food is the most obvious stimulus that was present early on every conditioning day, while no food was presented on an extinction day. Consequently, after a few initial responses each day, food-recently could be an S+ and no-food-recently could be an S-. If after a few initial responses birds learned to respond after food-recently and to not respond after no-food-recently, that would account for the decrease in responses early in extinction and the equal responding on all extinction days. However, a discrimination is not the only way that the large feeding decrease, which is confounded with the elimination of reinforcement, could contribute to a behavior decrease. Low feeding could reduce responding without a discrimination, for example, by producing lower activity or decreasing some motivational variable below its level during a period of feeding.

Rescorla and Skucy (1969) with several different techniques have shown that noncontingent food during extinction increased extinction responding. Thus, the difference in feeding between conditioning and extinction is a major variable confounded with the change in reinforcement, the change in food contingent on bar pressing. Since the confounded change in feeding could produce a decrease in extinction responding in at least two different ways, *i.e.*, either a discrimination or a motivational effect, let us use the term *low-food effect* as a group term (and an empirical term) for all possible effects of reduced feeding apart from the decrease in reinforcement. Thus, the low-food effect includes both the possibility of a discrimination and the possibility of motivational effects.

The low-food effect accounts for the decrease in early extinction responses and the equalization of extinction responses on the different

days. The days without food come to produce low responding while the conditioning days with high feeding produce high responding. The lack of specificity to the color of the key is also reasonable if the responding is controlled by the feeding level.

However, such a low-food effect does not account for the rise in responses on the later days of extinction, because that rise is in the wrong direction for such an account. A different factor seems to be responsible for those rises. The bird's first exposure to unreinforced responses seems to produce lower responding late in extinction than is seen in subsequent exposures to the same zero reinforcement; with repetition the effect of unreinforced responses is reduced. Thus, the responses late in extinction are reduced more on the first exposure to an abrupt decrease in reinforcement than on subsequent exposures to the same reinforcement decrease. That unrepeatable or temporary effect of the first abrupt reinforcement decrease is similar to ratio strain. Ratio strain refers to the finding that with ratio schedules abrupt decreases in reinforcement frequency produce breaks in or cessation of responding, but those response reductions do not occur if reinforcement decreases are made in small, widely spaced steps (*e.g.*, Ferster and Skinner, 1957). Thus, ratio-strain provides evidence that an abrupt onset of a low level of reinforcement reduces responding more than the same low level of reinforcement attained gradually. A formulation that would encompass both our findings and the ratio-strain results would be that an initial abrupt exposure of an animal to a high fraction of unreinforced responses produces a temporary response decrease that is lessened with continued, repeated, or gradually increasing exposure to unreinforced responses. In other words, some of the effect of unreinforced responses may habituate with exposure to them under some conditions. Let us use the term *abrupt effect* for such a temporary effect of abrupt changes. Such an effect could well be independent of key color, hence the lack of influence by key-color changes that was found here.

The abrupt effect is also similar to the well-known partial reinforcement effect (PRE), *i.e.*, the slower extinction found after partial reinforcement than after continuous reinforcement (*e.g.*, Amsel, 1958; Jenkins and Stanley, 1950; Lewis, 1960). The usual explanation of

PRE is that unreinforced responses become an S+ for responding after being followed by reinforced responses. However, that explanation is not a satisfactory one for our results, because in our procedure no responses were reinforced on extinction days. It is on those extinction days that the responding increases, and the differentiation between conditioning and extinction became increasingly clear with extinction repetition. Partial reinforcement did occur on the reconditioning days, but the same partial reinforcement occurred on the initial conditioning before the first extinction. Thus, it may be that the abrupt effect is also a source of the PRE: the faster extinction after continuous reinforcement may be partly due to an abrupt effect that is reduced by exposure to unreinforced responses during partial reinforcement.

The usual single-extinction procedure confounds the low-food effect, the abrupt effect, and the effect of the absolute level of reinforcements. In this study with repeated eight-day extinctions, the different changes of early and late-extinction responses indicate the separate actions of the low-food effect and abrupt effect. The low-food effect was seen in the decline of early extinction responses across repeated extinctions, while the decrease in the abrupt effect with exposure to unreinforced responses was seen in the rise of late-extinction responses across repeated extinctions.

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