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RECENCY, REPEATABILITY, AND REINFORCER RETRENCHMENT: AN EXPERIMENTAL ANALYSIS OF RESURGENCE

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Four experiments were conducted with pigeons to assess the experimental conditions necessary for the occurrence of resurgence. The general procedure consisted of the following conditions: Condition 1—reinforcement of key pecking; Condition 2—reinforcement of treadle pressing and concurrent extinction of key pecking; and Condition 3—the resurgence condition wherein resurgence was defined as the recovery of key pecking. In Experiments 1 and 2, the resurgence condition was conventional extinction. The effect of recency on resurgence magnitude was examined in Experiment 1 by manipulating the number of sessions of Condition 2, above. Resurgence was not a function of recency with the parameters used. Repeating the three conditions revealed resurgence to be a repeatable effect in Experiment 2. In Experiment 3, a variable-time schedule was in effect for the resurgence condition. Resurgence was not produced by response-independent food delivery. In Experiment 4, the resurgence condition was a variable-interval schedule for treadle pressing that arranged a lower reinforcement rate than in Condition 2 (92% reduction in reinforcers per minute). Resurgence was lower in magnitude relative to conventional extinction, although resurgence was obtained with 2 out of 3 pigeons. The results are discussed in terms of the variables controlling resurgence and the relations between behavioral history, resurgence, and other forms of response recovery.

Key words: resurgence, extinction, response recovery, behavioral history, treadle, key peck, pigeon

Operant behavior is a joint function of past and present contingencies of reinforcement and punishment, including those responses deemed ''novel'' or ''creative.'' The relatively recent experimental analysis of how past reinforcement interacts with current contingencies has been undertaken in studies of behavioral history effects (e.g., Baron & Leinenweber, 1995; Freeman & Lattal, 1992; Tatham & Wanchisen, 1998; Wanchisen, Tatham, & Mooney, 1989; Weiner, 1965, 1969). The general method for the study of behavioral history consists of two conditions. In the first, a particular history of responding is established. In the second, the influence of this history on current performance is examined. Put another way, the persistence of behavioral effects is examined in adjacent experimental conditions.

Other ways of examining the contemporary effects of past conditions or contingencies include three-condition procedures such as those used to examine response recovery. As in the two-condition procedures described, the persistence of behavioral effects is examined as a function of preceding conditions. In the three-condition procedure, however, the rate of the response maintained initially is reduced to zero in the second condition prior to the persistence test. Response recovery has been demonstrated in studies of induction (e.g. Reynolds, 1964), operant reinstatement (e.g. Campbell, Phillips, Fixsen, & Crumbaugh, 1968; Franks & Lattal, 1976; Rescorla & Skucy, 1969) and resurgence (e.g. Epstein, 1983, 1985; Epstein & Skinner, 1980).

Although tests of induction, reinstatement, and resurgence differ procedurally, they are similar to the extent that each effect is an instance of response recovery. In each case, responding is maintained in the initial condition and then eliminated in the next condition. Responding then recurs in the final condition. It is this final condition that differs across the three procedures. Induction is produced by the delivery of response-dependent reinforcement; reinstatement by response-independent delivery of stimuli that previously functioned as reinforcers and resurgence by extinction. The examination of response re-

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covery in general is valuable to understanding operant behavior insofar as recovery reflects potential mechanisms through which behavioral variability is expressed. This learning history-dependent variation comprises part of the behavioral repertoire available for reinforcement at any given moment.

Resurgence is a potential mechanism of behavioral variation through which new or novel behavior emerges (and thereafter can be strengthened through reinforcement), a process labeled generativity by Epstein (1991). It also is a potential mechanism for creativity, problem solving (Shahan & Chase, 2002; see also Epstein, 1996), and ''action-at-a-distance'' phenomena generally attributed to memorial processes. In addition, extinction-induced recovery of behavior is a potential burden (or boon) with regard to the application of operant learning principles to the understanding and rectification of behavior problems of social significance, such as the clinical relapse of problem behavior (e.g., self-injury, drug-taking, etc). Despite the potential theoretical and applied significance for understanding the provenance and persistence of operants by an examination of resurgence, little is known about the variables controlling the magnitude of the resurgence effect, the probability of its occurrence, or the extent to which resurgence is a repeatable effect within individual organisms.

Previous investigations have demonstrated resurgence when reinforcement of alternative behavior is removed (e.g., Epstein, 1983, 1985; Leitenberg, Rawson, & Bath, 1970; Leitenberg, Rawson, & Mulick, 1975; Mulick, Leitenberg, & Rawson, 1976; Rawson, Leitenberg, Mulick, & Lefebvre, 1977) or when response-independent delivery of unconditioned stimuli is used to eliminate respondent key pecking and then removed (Epstein & Skinner, 1980, Lindblom & Jenkins, 1981). In each study, resurgence was produced by conventional extinction only. In addition, the period of time during which reinforcement of alternative behavior occurred was not varied systematically.

The results from investigations of induction and reinstatement, however, suggest that conditions other than conventional extinction, such as schedules of response-dependent and response-independent delivery of food, might produce resurgence. In addition, the findings of Reynolds (1964) and those of Leitenberg et al. (1975) suggest that the magnitude of response recovery, including the resurgence effect, may be a function, in part, of how recently the recovering response was reinforced. Reynolds arranged a three-component multiple schedule on a single response key. Pigeons' pecks then were eliminated in subsequent conditions one component at a time. When key pecking was at zero rates in all three components, the reinforcement schedule was reinstated during one of the components. Recovery of key pecking in the remaining two components depended upon how relatively recently extinction was implemented in that component. Pecking recovered more quickly and with a greater magnitude in the most recently eliminated component. Similarly, Leitenberg et al. demonstrated that responses reinforced in a relatively more remote past did not recover as much as more recently reinforced behavior when reinforcement of alternative behavior was removed. In their experiment, rats first were trained to lever press for food reinforcement. Alternative behavior (presses to a different lever) then was reinforced and the original response was extinguished concurrently. When this contingency for alternative behavior was continued for longer periods of time, subsequent extinction-induced recovery of the original response was less than when the contingency was in effect for a shorter period of time. Epstein (1983) demonstrated resurgence of key pecking following a brief condition (20 reinforcers) that arranged for reinforcement for alternative behavior (pecking a second key) on a fixed-ratio (FR) 1 schedule. Following this brief condition, reinforcement for alternative behavior was removed and key pecking recovered. The effect was termed resurgence due to its structural and (presumably) functional similarity to an effect of response recovery demonstrated by Epstein and Skinner (1980) in an autoshaping preparation. Although resurgence was demonstrated reliably across organisms, the conditions under which the effect occurs and the variables that modify it remain largely unidentified.

EXPERIMENT 1

In previous demonstrations of resurgence, the effect has been shown only during an initial transition to extinction. In addition, the initial transition to extinction has been too brief (for example, one session or less was reported in Epstein, 1983, but see Epstein, 1985) to allow for an examination of the time course of the resurgence effect. It is feasible that the magnitude of resurgence, or whether resurgence occurs at all, is a function of how recently the original response produced reinforcement (Reynolds, 1964). Experiment 1 examined the possibility that reinforcement recency, or the extensiveness of a prior history of reinforcement for alternative behavior, affects the magnitude of resurgence. This was done by manipulating the time between the last session in which the initial response was reinforced and the onset of the extinction condition in which the response was anticipated to recover. Said another way, the number of sessions in which alternative behavior was reinforced was manipulated. Experiment 1, therefore, was conducted (a) to evaluate the effects of recency of reinforcement for the initial response (i.e. the response that eventually resurges) on resurgence, and (b) to replicate Epstein's (1985) finding that resurgence occurs following reinforcement for alternative behavior that spans multiple sessions.

METHOD

Subjects

Four experimentally naive White Carneau pigeons, numbered 946, 957, 965, and 977, were used. Each was housed individually with free access to water and health grit and maintained at approximately 80% of ad libitum weight by postsession feedings.

Apparatus

A two-key pigeon operant chamber with a work area of 32.5 cm by 31 cm by 38 cm was used. The chamber was housed in a 34 cm by 61 cm by 40 cm sound-attenuating enclosure with a ventilation fan to mask additional extraneous noise. The right response key was transilluminated white and required approximately 0.15 N to operate. The left key remained dark and inoperative throughout all experiments. The center of the 2 cm diameter key was located on the work panel 26 cm from the floor of the chamber and 9 cm from the right wall. A response lever, 5 cm wide, protruded 2 cm from the work panel and was located 8 cm from the floor and 6 cm left of the hopper. An L-shaped treadle was suspended from the response lever during all conditions. The treadle was 5 cm wide at the lever and widened to 7 cm at the foot. The foot of the treadle protruded 5 cm from the base, and was approximately 2 cm from the floor of the chamber. Pigeons could step onto the treadle and release it. A microswitch was operated when the treadle was released, and its closure constituted the treadle-press response. Reinforcement consisted of 3-s access to a solenoid-operated food hopper that was raised into an aperture centered on the base of the work panel that was lit during reinforcement only. General illumination was provided at all times (except for the duration of reinforcement) by a houselight located behind a 4 cm by 4 cm opening, whose center was 6 cm from the right wall and 5.5 cm from the floor. A microcomputer operating with MED-PC® software was used to program contingencies and record experimental events and was located in an adjacent room.

Procedure

The following sections describe the specific procedure used in each condition. After pretraining, sessions were 30 minutes in duration and occurred 7 days a week at approximately the same time each day.

Pretraining and key peck reinforcement. Each session began with the transillumination of the houselight and key. Each pigeon first was trained to peck the right response key by the differential reinforcement of successive approximations (shaping). Following shaping, key pecking was placed on an FR schedule in which the ratio requirement was increased from 1 to 15, with one session in effect for each ratio until 15 was reached. The ratios used were 1, 3, 5, 10, and 15. Each session continued until 60 reinforcers were delivered. A variable-interval (VI) 30-s schedule then was implemented for key pecking, with intervals selected without replacement from the distribution described by Fleshler and Hoffman (1962). The VI 30-s schedule remained in effect for a minimum of 20 sessions and until response rates were stable. A variant of a relative stability criterion (Cumming & Schoenfeld, 1960; Perone, 1991) was used. The stability of response rates in the final six sessions of a condition was assessed in the following manner. The mean response rate for the final six sessions was compared to both the mean of the first three sessions (of the final six), and the mean of the second three sessions. If each of the two submeans differed from the overall mean by 10% or less, then the stability criterion was met and the condition changed, provided that the minimum number of sessions was conducted.

Throughout this condition, treadle presses were recorded but had no programmed consequences. Unless indicated otherwise, a 3-s changeover delay (COD) was in effect during conditions in which treadle presses or key pecks produced reinforcement. During these sessions, each response that was not capable of producing reinforcement (i.e., treadle presses during the key-peck reinforcement condition, and key pecks during the treadle-press reinforcement condition) started a 3-s timer, during which reinforcement for eligible responses was unavailable. Additional ineligible responses during the 3-s COD interval reset the timer. When the timer elapsed, responses again were eligible for reinforcement. Each VI 30-s session terminated after 60 reinforcers were delivered, and the houselight and keylight were extinguished at that time.

Explicit key peck elimination. Following the key-peck reinforcement condition, key pecking was extinguished for ten 30-min sessions prior to the treadle-press reinforcement condition. This was done to ensure that key pecking was eliminated to the same extent for all pigeons. For each subject, rates of key pecking were zero for at least three consecutive sessions by the end of the tenth session of extinction.

Treadle press reinforcement. In this condition, the VI schedule for key pecking was removed by withholding all reinforcement for the response (i.e., conventional extinction), and the treadle-press response was shaped. Following shaping, the treadle-press response was reinforced on an FR schedule in which the ratio requirement was increased from 1 to 15, with one session in effect for each ratio until 15 was reached. The ratios used were 1, 3, 5, 10, and 15. Each session continued until 60 reinforcers were delivered. A VI 30-s schedule of food delivery, identical to the one described in the preceding section, was then implemented for treadle pressing. Key pecks were recorded but had no programmed consequences during shaping, FR sessions, or the remainder of this condition. Reinforcement of treadle pressing was in effect for five sessions for Pigeons 957 and 965 and 30 sessions for Pigeons 946 and 977. Differences in resurgence following this history conceivably could be due in part to differences in the rate of key pecking when the resurgence condition was implemented, hence the condition to eliminate key pecking prior to the treadle-press reinforcement condition. As in the preceding conditions, sessions were terminated after 60 reinforcers.

Resurgence. In this condition, all reinforcement was withheld. Resurgence was defined as the number of key pecks per extinction session. Sessions were 30 min in duration, and the condition was in effect for 10 sessions.

RESULTS

Each pigeon emitted many pecking responses (1500 to 3000 per session) and treadling responses (450 to 800 per session) in the respective conditions in which these topographies were reinforced. Performances in these conditions were typical of VI-schedule performance, with moderately high and steady response rates. The number of key pecks per session during extinction (the extinction of key pecking prior to treadle reinforcement), treadle reinforcement, and extinction is shown in Figure 1 for each pigeon. For the 2 pigeons that received 30 sessions of treadle reinforcement (Pigeons 946 and 977), the number of key pecks during the final 10 sessions of that condition is shown. Resurgence occurred for each pigeon during the resurgence (second extinction) condition. Although key pecking was extinguished prior to the treadle-press reinforcement condition, responding recurred briefly during this condition for all 4 pigeons (not shown for 946 and 977). By the end of this condition, however, key pecking had once again ceased for all pigeons except 965.

To assess whether the number of sessions of treadle reinforcement affected resurgence differentially, key pecks were expressed as a proportion of baseline, and are shown in Figure 2. The number of responses is shown as a proportion of the mean number of key

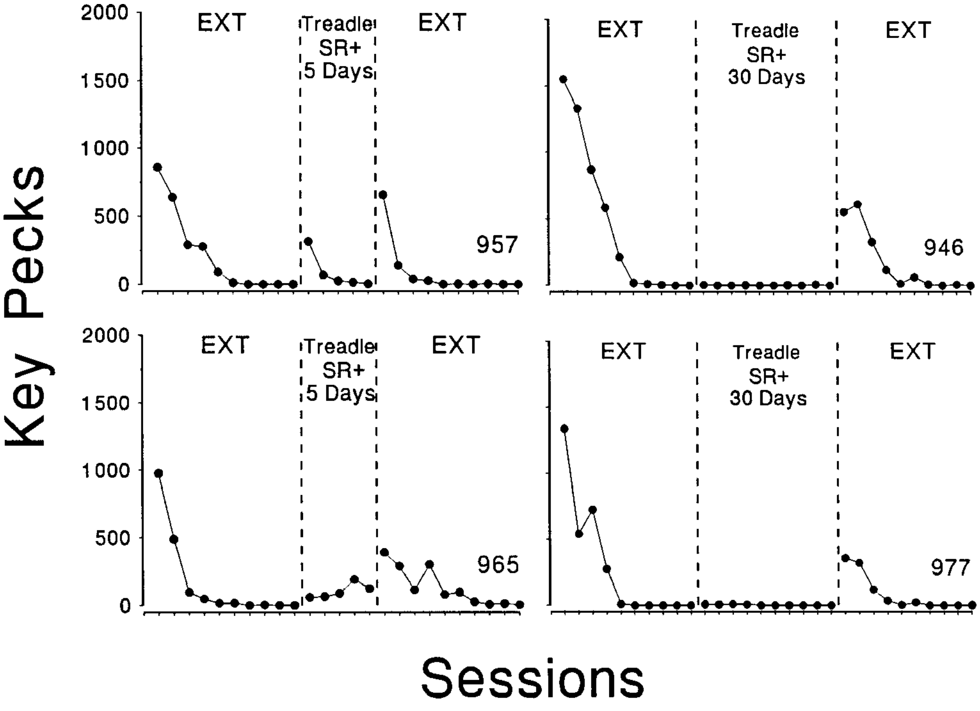

Fig. 1. Total number of key pecks for each pigeon during the 10 sessions in which key pecking was extinguished, treadle reinforcement, and the 10 sessions of extinction in Experiment 1. For Pigeons 946 and 977, the final 10 sessions of the 30 sessions of reinforcement for treadle pressing are shown.

pecks over the final six sessions of the key peck reinforcement baseline. The data in Figure 2 show that there were no systematic, proportional differences in resurgence between Pigeons 957 and 965, which received five sessions of treadle reinforcement, and Pigeons 946 and 977, which received 30 sessions of treadle reinforcement.

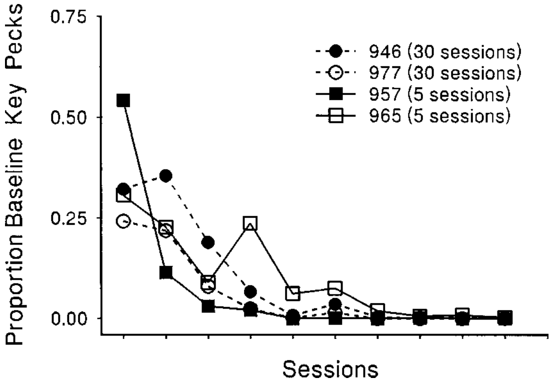

Fig. 2. Number of key pecks per extinction session as a proportion of the mean of the final six sessions in the key peck reinforcement baseline of Experiment 1. The 2 pigeons that received five sessions of treadle training are indicated with square symbols.

DISCUSSION

Unlike Reynolds (1964) and Leitenberg et al. (1975), the present investigation demonstrated similar levels of response recovery following relatively more and less recent conditions during which the recovering response previously was reinforced. The results from Experiment 1 replicate those of Epstein (1983, 1985), even though reinforcement for alternative behavior was prolonged and intermittent. Resurgence does not depend, therefore, on a brief period of relatively rich reinforcement prior to the final extinction condition.

Within-subject comparisons of reinforcement recency on resurgence were not conducted due to the uncertain effects of a second exposure to the resurgence condition. It was decided, therefore, to make between-subject comparisons. The question remains, however, as to whether the recovery process in previous demonstrations of resurgence depends on an organism's initial exposure to extinction. Previous work (e.g. Ferster & Skinner, 1957) suggests that the effects of repeated exposure to extinction may attenuate its behavioral effects on resurgence. Experiment 2 was conducted to investigate the extent to which resurgence is a repeatable effect within subjects.

EXPERIMENT 2

In previous demonstrations of resurgence, the effect has been shown only during an initial transition to extinction. In addition, this transition has been too brief to allow for an examination of the time course of the resurgence effect (e.g., Epstein, 1983). The extent to which resurgence is a replicable effect within an individual subject; that is, the potential effect of repeated exposure to the conditions that engender resurgence, is not known. Experiment 2 determined both the time course of the effect across multiple sessions of extinction and whether resurgence is repeatable with a second exposure to the resurgence procedure.

METHOD

Subjects

Four experimentally naive White Carneau pigeons, numbered 16 to 19, served as subjects. Each was housed individually with free access to water and health grit and maintained at 80% (± 10 g) of ad libitum weight by postsession feedings.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

The sequence of conditions and number of sessions at each are shown in Table 1. The pretraining, key-peck reinforcement, treadle-press reinforcement, and resurgence conditions were as described in Experiment 1. Key pecking was reinforced for a minimum of 15 sessions, with each session terminated after 60 reinforcers. The condition was terminated when the stability criterion was met, as described in Experiment 1. The condition in Experiment 1 in which key pecking was eliminated prior to the onset of the treadle-press reinforcement condition was not conducted. Occasionally, rates of key pecking remained high during the transition into the condition in which treadle presses produced reinforcement. To reduce high rates of key pecking, the 3-s COD was increased to 10 s and was in effect for up to three sessions and until rates of key pecking decreased to less than five responses per minute, after which the COD again was 3 s. The treadle-press reinforcement condition remained in effect for at least 15 sessions and until rates of key pecking for Pigeons 18 and 19 were zero or near zero (i.e., less than one response per minute) for at least three consecutive sessions. For Pigeons 16 and 17, however, this condition was completed and key peck rates were greater than one per minute. It was decided to terminate the condition with peck rates higher than one per minute to avoid large differences in the number of sessions across pigeons. Thus the resurgence condition was implemented for these 2 pigeons to maximize the possibility of producing resurgence and to allow for an examination of the repeatability of

Table 1

Sequence of conditions and number of sessions conducted for each subject in Experiment 2.

Pigeon	Condition Key peck	 Treadle	Number of sessions
16	VI 30 s	EXT	20
	EXT	VI 30 s	19
	EXT	EXT	10
	VI 30 s	EXT	22
	EXT	VI 30 s	20
	EXT	EXT	10
17	VI 30 s	EXT	20
	EXT	VI 30 s	20
	EXT	EXT	10
	VI 30 s	EXT	22
	EXT	VI 30 s	38
	EXT	EXT	10
18	VI 30 s	EXT	22
	EXT	VI 30 s	18
	EXT	EXT	10
	VI 30 s	EXT	24
	EXT	VI 30 s	15
	EXT	EXT	10
19	VI 30 s	EXT	22
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	25
	EXT	VI 30 s	15
	EXT	EXT	10

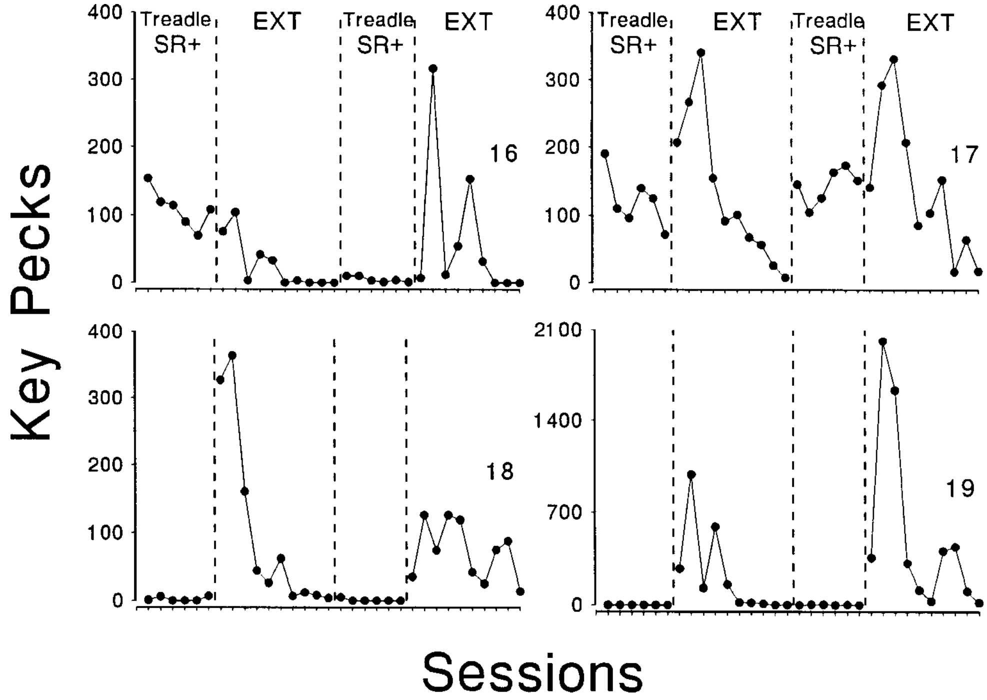

Fig. 3. Total number of key pecks for each pigeon during the final six sessions of treadle reinforcement and during the 10 sessions of extinction in Experiment 2. The third and fourth panels refer to the replication. Note the difference in scale on the y-axis for Pigeon 19.

the effect. The resurgence condition (as described in Experiment 1) was implemented for Pigeon 16 after 19 sessions and for Pigeon 17 after 20 sessions (see Table 1).

Replication

Following completion of the 10 extinction sessions in the resurgence condition, the previous sequence of conditions was repeated. Key pecks again were reinforced on a VI 30-s schedule for a minimum of 15 sessions. Key pecking then was extinguished, and treadle presses were reinforced on a VI 30-s schedule for a minimum of 15 sessions until rates of key pecking were zero or near zero for at least three consecutive sessions. Each session during the key-peck reinforcement and treadle-press reinforcement conditions was terminated after 60 reinforcers. All reinforcement then was withheld for ten 30-min sessions. Rates of key pecking in extinction (i.e., the resurgence condition) were compared visually to the prior resurgence condition for each subject.

As in the initial exposure to the treadle-press reinforcement condition, key pecking persisted at low rates (approximately six responses per minute) for Pigeon 17 during the second treadle-press reinforcement condition. As described previously, the resurgence condition was introduced after 38 sessions of treadle reinforcement because of the potential attenuation of the resurgence effect with the passage of time.

RESULTS

In Figure 3, key pecks during the final six sessions of the treadle-press reinforcement condition are shown, along with the 10 sessions of extinction that followed, during both the initial exposure to the procedure and during the replication. Resurgence of key pecking was obtained during seven out of the eight resurgence conditions. As can be seen in Figure 3, Pigeons 16 and 17 continued to key peck during the treadle-press reinforcement condition. Although key pecking occurred in extinction for Pigeon 16, the total number of key pecks in extinction during the first test did not differ from those in the preceding six sessions of the treadle-press reinforcement condition. For Pigeon 17, howev-

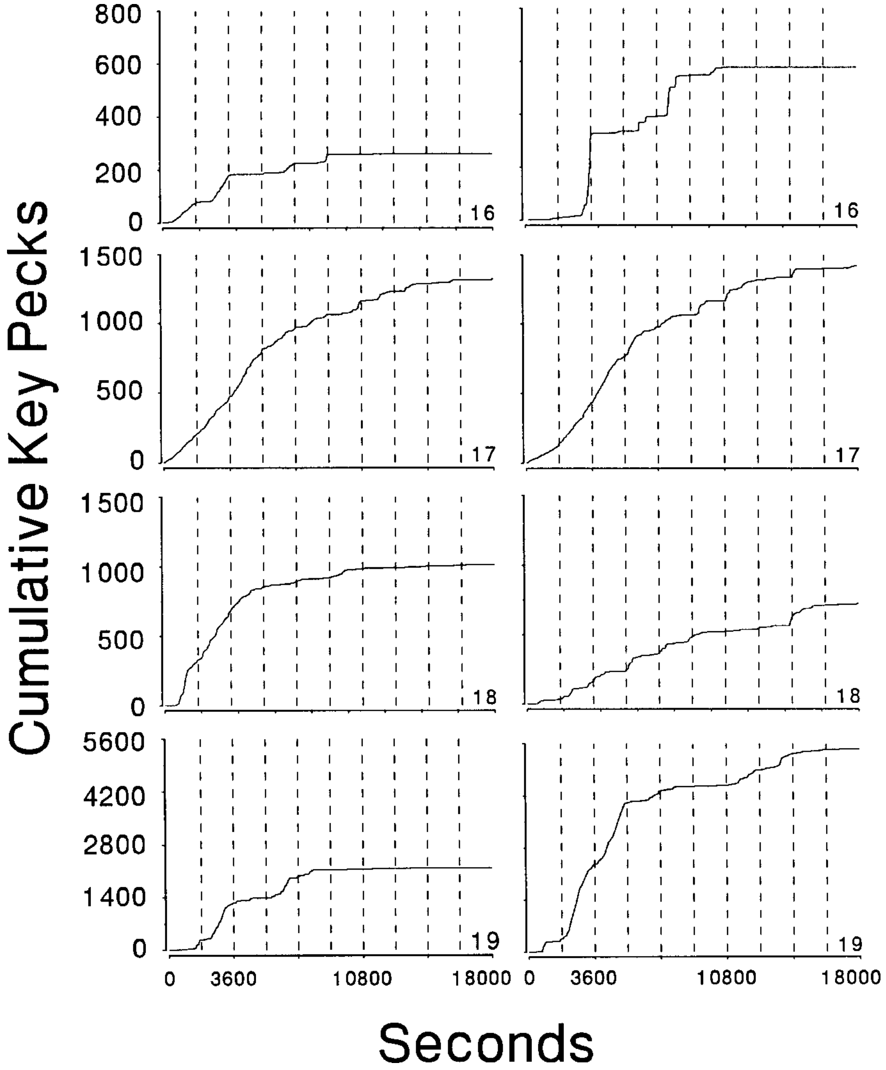

Fig. 4. Cumulative key pecks across seconds for each pigeon during the 20 sessions of extinction in Experiment 2. The graphs on the left depict responding during the initial 10 sessions of exposure to extinction, and the graphs on the right depict responding during the 10 sessions in which the extinction condition was replicated. Note the difference in scale for Pigeon 19.

er, a greater number of key pecks occurred in extinction than in the preceding six sessions of the treadle-press reinforcement condition. The data in Figure 3 also show that resurgence of key pecking was obtained with all pigeons in the replication. The resurgence effect did not diminish in the second exposure to extinction conditions.

The patterns of resurgence obtained in Experiment 2 are shown in Figure 4. Cumulative records were constructed by plotting cumulative key pecks as a function of time in seconds. The dashed lines demarcate the individual resurgence sessions comprising the resurgence condition. Resurgence during the initial exposure to extinction is shown in the four panels on the left side of Figure 4, and resurgence during the replication is shown on the right. Across sessions, the overall pattern of responding tended to be sigmoidal. That is, the pattern consists of low rates early in the first session of extinction, followed by a positively accelerated increase in responding, and a decrease to zero by Session 10 of extinction. Although there was variation in within session patterning of key pecking across pigeons, responding during the second session of extinction tended to be undifferentiated, as during the VI-schedule baseline.

Discussion

The results of Experiment 2 demonstrate that the resurgence effect occurred reliably and was repeatable within individual subjects, not diminishing systematically in magnitude with a second exposure to extinction. The repeatable within-subjects resurgence supports other evidence that repeated exposure to extinction does not attenuate its effects (e.g., Weissman, 1960, but see Ferster & Skinner, 1957, for the effects of prolonged exposure to extinction conditions). The effect occurred in seven out of eight extinction conditions, and the reasons for the absence of an effect in the initial extinction condition for Pigeon 16 are unclear. The overall shape of the function for Pigeon 16 during the first resurgence condition is similar to the functions obtained for the other subjects; that is, an increase in responding over the first two sessions of extinction followed by a decrease to zero.

Resurgence occurred whether or not key pecking was extinguished entirely at the onset of the terminal extinction condition. This suggests that the response-prevention hypothesis of response recovery (Rawson et al., 1977) does not account adequately for the resurgence effect. According to the response-prevention hypothesis, response recovery occurs because the recovering response is not ‘‘allowed’’ to undergo extinction; that is, the reinforcement contingency for the second response (in this case, the treadle press) prevents the extinction of the first response. By this reasoning, resurgence should occur in the procedure used in Experiment 2 *only* when key pecking quickly reaches zero rates in the treadle-press reinforcement condition when conventional extinction is implemented. For Pigeons 18 and 19, resurgence was obtained twice after key pecking was at zero rates (i.e., had extingushed completely) during the treadle-press reinforcement condition. For Pigeons 16 and 17, resurgence occurred in three of four tests even though key pecking had occurred over several sessions during treadle reinforcement. Resurgence thus does not seem to depend on the extent to which the first response is extinguished.

In Experiments 1 and 2, resurgence was produced reliably by conventional extinction. That is, recovery of previously effective behavior (key pecking) occurred when reinforcement for alternative behavior was removed chronically, and that particular reinforcer was unavailable. In Experiments 3 and 4, the extent to which conditions other than extinction produce resurgence was investigated. In Experiment 3, the extent to which a second kind of extinction (Rescorla & Skucy, 1969) produces resurgence was examined. This second kind of extinction refers to conditions in which the reinforcer continues to occur, but the dependency between responding and reinforcement is absent.

EXPERIMENT 3

Experiment 3 was conducted to assess whether extinction, when implemented as the removal of the response-reinforcer relation, produces resurgence as did conventional extinction in Experiments 1 and 2.

Method

Subjects

Three experimentally naive White Carneau pigeons, numbered 901, 944, and 907, were used. Each was housed individually with free access to water and health grit and maintained at approximately 80% of ad libitum weight by postsession feedings.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

The sequence of conditions and number of sessions during each condition are shown in Table 2 for each pigeon. The pretraining, key-peck reinforcement, and treadle-press reinforcement conditions were as in Experiment 2. That is, key pecking was shaped and then maintained on a VI 30-s schedule for at least 15 sessions. Treadle pressing then was shaped and maintained on a VI 30-s schedule for a minimum of 15 sessions. During both key-peck reinforcement and treadle-press re-

Table 2

Sequence of conditions and number of sessions conducted for each subject in Experiment 3.

Pigeon	Condition Key peck	 Treadle	Number of sessions
944	VI 30 s	EXT	26
	EXT	VI 30 s	15
	EXT	VT 30 s	24
	EXT	EXT	5
	VI 120 s	EXT	20
	EXT	VI 120 s	39
	EXT	VT 120 s	10
	EXT	EXT	10
974	VI 30 s	EXT	28
	EXT	VI 30 s	17
	EXT	VT 30 s	22
	EXT	EXT	5
	VI 120 s	EXT	21
	EXT	VI 120 s	34
	EXT	VT 120 s	10
	EXT	EXT	10
901	VI 30 s	EXT	20
	EXT	VI 30 s	16
	EXT	VT 30 s	26
	EXT	EXT	5
	VI 120 s	EXT	24
	EXT	VI 120 s	16
	EXT	VT 120 s	10
	EXT	EXT	10

inforcement conditions, sessions were terminated after 60 reinforcers.

During the resurgence condition, the VI 30-s schedule for treadle pressing was replaced by a variable-time (VT) 30-s schedule of response-independent food delivery. The resurgence condition remained in effect for ten 30-min sessions. Resurgence did not occur during the VT schedule for any of the pigeons, so conventional extinction then was implemented for five sessions for each pigeon to determine whether resurgence could be produced. Next, the sequence of conditions described above was repeated. The values of the VI and VT schedules, however, were changed to 120 s because the VT 30-s schedule was ineffective in eliminating responses to the treadle and key.

RESULTS

Rates of treadling and key pecking are shown in Figure 5 for each session up to the initial resurgence condition. Although rates of key pecking were low during the final six sessions of the treadle-press reinforcement condition, resurgence of key pecking did not occur when the schedule of food delivery was changed to VT 30 s. This perhaps was due to the persistence of treadle pressing during the VT schedule. As a result, the VT schedule was continued longer than 10 sessions. Conventional extinction then was implemented for each pigeon to ensure that the resurgence effect could be produced. The total number of key pecks in the final sessions of each condition of Experiment 3 is shown in Figure 6. These data show that resurgence of key pecking was obtained for each pigeon when conventional extinction was implemented.

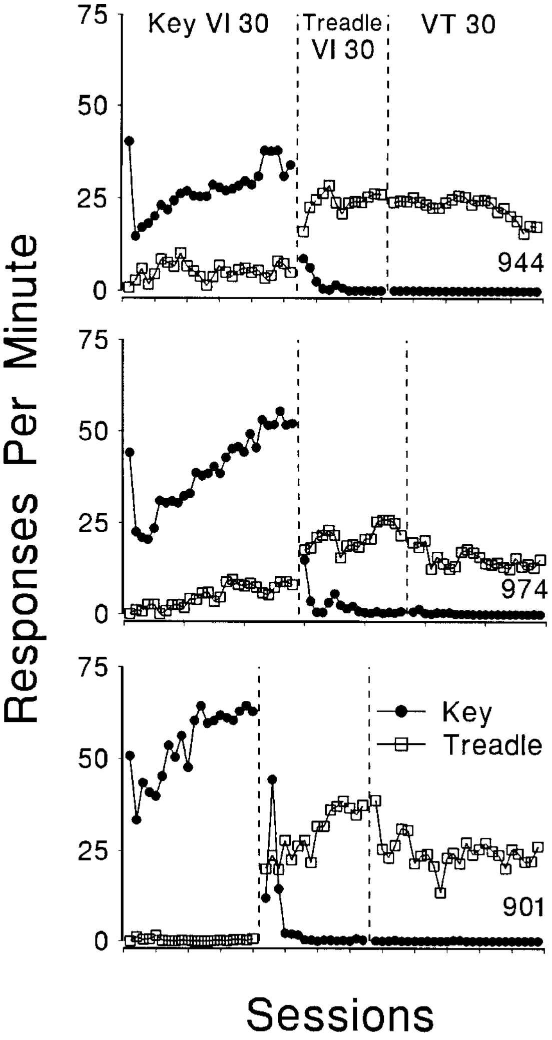

Fig. 5. Responses per minute, for each pigeon, on the treadle (squares) and key (circles) during the initial exposure to the VI key peck, VI treadle, and VT conditions of Experiment 3.

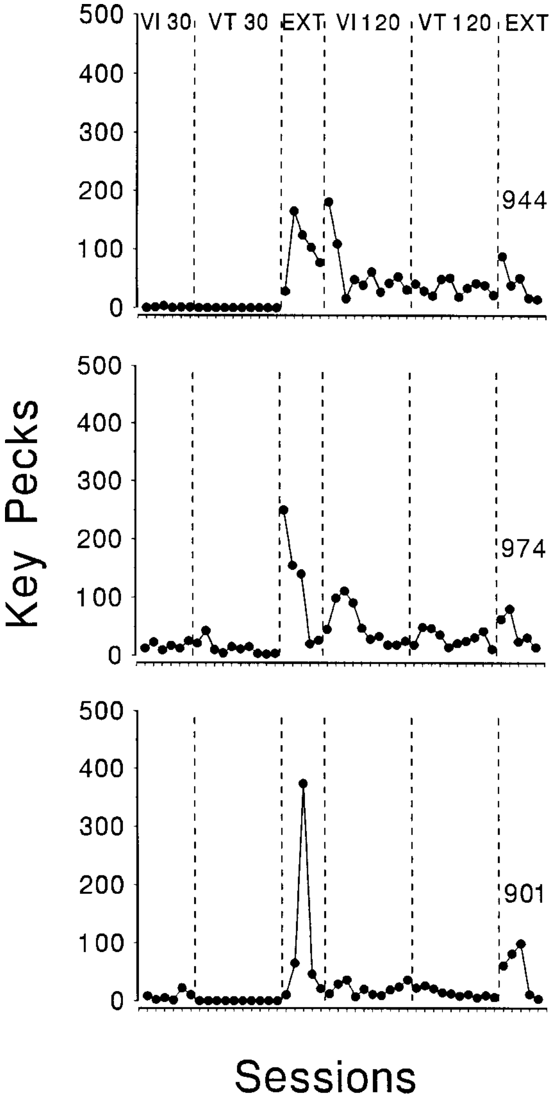

Fig. 6. Total number of key pecks for each pigeon during the final six sessions of treadle reinforcement (condition label VI 30), VT food delivery, and during the 10 sessions of extinction in Experiment 3. The third and fourth panels depict the replication, in which the values of the VI and VT were changed from 30 to 120.

If treadle pressing was maintained adventitiously by the VT 30-s schedule, then a leaner schedule may have allowed the response to be eliminated. During the VT 120-s schedule, however, the results were similar to those shown in Figure 5. As can be seen in Figure 6, resurgence of key pecking was not obtained when the response-reinforcer dependency was removed from the VI 120-s schedule. The transition from VI 120 s to VT 120 s did not produce resurgence of key pecking. Resurgence of key pecking occurred, however, when conventional extinction was implemented, replicating the effect shown following the VT 30-s schedule.

The resurgence of key pecking produced by extinction for each pigeon occurred in six out of six extinction conditions in Experiment 3. Interestingly, the magnitudes of resurgence were less during the second exposure to extinction for each pigeon. In Experiment 2, resurgence did not diminish in magnitude with a second exposure to the resurgence procedure. In Experiment 3, however, the second exposure to the procedure involved baselines for key pecking and treadle pressing on VI 120-s schedules, as opposed to the VI 30-s schedules used during the initial exposure to the procedure. The lower recovery may be, at least in part, a function of the lower response rates maintained by these VI 120-s schedules.

DISCUSSION

Although Rescorla and Skucy (1969) concluded that response-independent food delivery was functionally equivalent to conventional extinction, their interpretation seems limited if both forms of extinction are expected to have similar behavioral effects in other arenas, such as the production of resurgence (see also Lattal, 1972). The removal of a response-reinforcer dependency is not sufficient to produce resurgence, but resurgence occurred quickly and reliably when conventional extinction was implemented. This finding suggests that resurgence may be a function only of the absence of reinforcing events. If resurgence is a function only of extinction, then the response-independent delivery of food may have adventitiously maintained classes of other behavior such as treadle pressing (Henton & Iverson, 1978). Resurgence may occur only when all responses are ineffective, as in conventional extinction.

In the present experiment, the extent to which response-independent delivery of stimuli previously functioning as reinforcers produces resurgence was examined as a second form of extinction. Resurgence has been demonstrated with extinction conditions wherein all reinforcement is withheld chronically; that is, over a series of successive ses-

Table 3

Sequence of conditions, number of sessions conducted for each condition, mean number of treadle presses, and obtained reinforcers per session for each pigeon in Experiment 4. Standard deviations are shown in parentheses.

	Condition		Number of		
Pigeon	Key peck	Treadle	sessions	Treadles	S^R
916	VI 30 s	EXT	20		
	EXT	VI 30 s	24	668 (187)	60
	EXT	VI 360 s	10	167 (71)	5 (3)
	EXT	EXT	10		
964	VI 30 s	EXT	24		
	EXT	VI 30 s	28	676 (143)	60
	EXT	VI 360 s	10	231 (83)	4 (1)
	EXT	EXT	10		
955	VI 30 s	EXT	24		
	EXT	VI 30 s	24	469 (82)	60
	EXT	VI 360 s	10	253 (66)	5 (1)
	EXT	EXT	10		

sions. Might resurgence also occur, however, during more local time frames that are relatively ''extinction-like?'' A relatively lean schedule of positive reinforcement, for example, resembles extinction during long interreinforcement intervals in that reinforcement is absent for some extended period.

EXPERIMENT 4

The possibility that local periods of nonreinforcement can produce resurgence by the imposition of a lean reinforcement schedule was examined in Experiment 4.

METHOD

Subjects

Three experimentally naive White Carneau pigeons, numbered 916, 955, and 964, were used. Each was housed individually with free access to water and health grit and maintained at approximately 80% of ad libitum weight by postsession feedings.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

The sequence of conditions and the number of sessions that each condition was in effect for each pigeon are shown in Table 3. The pretraining, key-peck reinforcement, and treadle-press reinforcement conditions were as in Experiment 2. That is, key pecking was shaped and then maintained on a VI 30-s schedule for at least 15 sessions. Each session was terminated after 60 reinforcers. Treadle pressing then was shaped and maintained on a VI 30-s schedule. Each session terminated after 60 reinforcers and the condition remained in effect for a minimum of 15 sessions.

During the resurgence condition, the VI 30-s schedule in effect for treadle pressing was changed to a VI 360-s schedule and remained in effect for ten 30-min sessions. Following 10 sessions of VI 360 s, treadle pressing was extinguished to compare directly the effects of the lean VI and extinction on resurgence of key pecking. The extinction sessions were terminated after 30 min.

RESULTS

Total treadle presses and obtained reinforcers per session during baseline and resurgence conditions are shown in Table 3. Mean obtained reinforcers were 60 per session in VI 30 s and 4.4 to 5 per session when the schedule was changed to VI 360 s. Thus responding on the treadle was sustained at a sufficiently high level on the VI 360-s schedule that all programmed reinforcers were collected. The number of key pecks during the final 10 sessions of the treadle-press reinforcement condition (VI 30 s) and during the 10 sessions of the lean VI schedule is shown in Figure 7. For Pigeon 916, resurgence of key pecking did not occur when the schedule for treadle pressing was changed abruptly from a VI 30-s to a VI 360-s schedule. For Pigeons 964 and 955, however, a small, transient increase in key pecking was obtained when the reinforcement rate was decreased. A typical resurgence effect occurred with each pigeon when extinction followed the VI 360-s schedule.

Although resurgence did not occur systematically in each of the 3 pigeons, nor did it occur at a magnitude comparable to that produced by extinction, key pecking did resurge when the schedule was changed to a VI 360 s. Key pecks as a function of the obtained interreinforcement interval in which they occurred are shown in Figure 8 for Pigeons 964 and 955. The analysis was not conducted for Pigeon 916, which did not peck after the VI

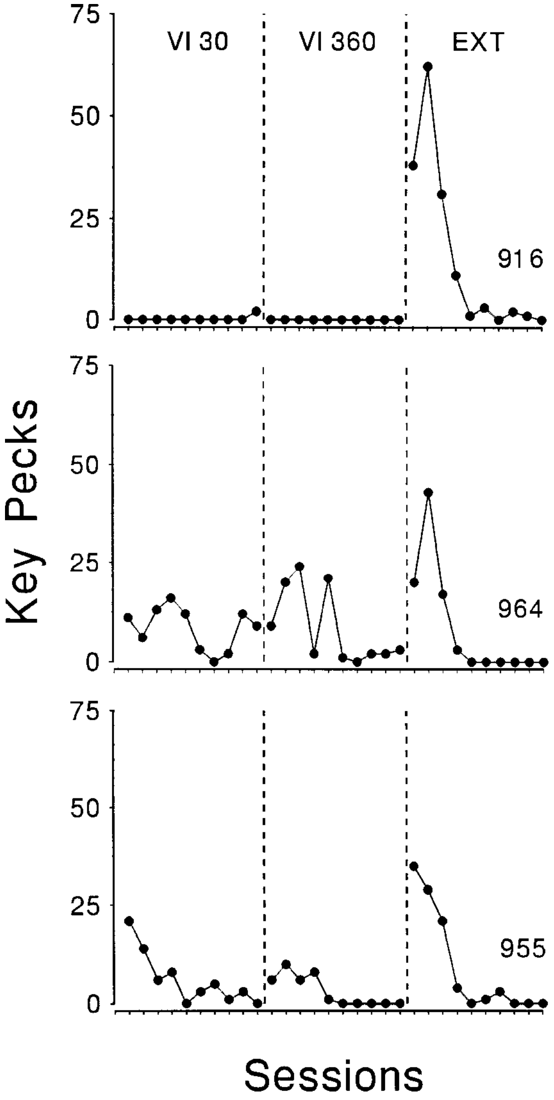

Fig. 7. Total number of key pecks for each pigeon during the final six sessions of treadle reinforcement, the 10 sessions of VI 360 s, and the 10 sessions of extinction in Experiment 4.

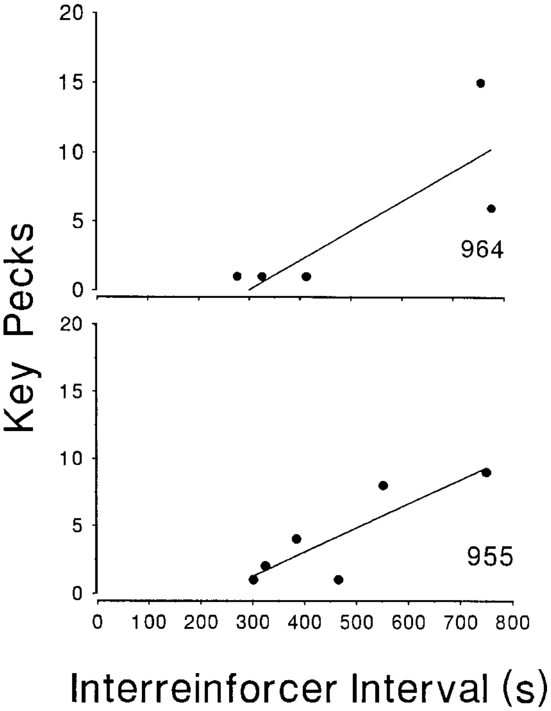

Fig. 8. Total number of key pecks for Pigeons 964 and 955 as a function of the obtained interreinforcer interval (in seconds) in which they occurred during the first five sessions of VI 360 s for Pigeon 964, and during the first four sessions for Pigeon 955 in Experiment 4.

schedule was changed. Interreinforcement intervals during which pecks occurred are shown as a function of the number of pecks that occurred during that particular interval. During some sessions for both pigeons, a burst of key pecking occurred at the onset of the session and prior to the delivery of the first reinforcer. These pecks are shown in Table 4 and were unrelated to interval duration. Excluding these initial bursts, key pecking was more likely for both pigeons during relatively longer interreinforcement intervals, suggesting that resurgence may have occurred at a local level. It must be noted, however, that the correlation could be misleading; it might be the case that the higher number of key pecks caused the interval to be prolonged due to the COD in effect and

Table 4

Bursts of pecks that occurred during the interval between session onset and the delivery of the first reinforcer for Pigeons 964 and 955 in Experiment 4. Sessions during which no bursts occurred are not shown.

Pigeon	Key pecks	Session onset to delivery of first reinforcer
964		
	9	293.38
	4	541.63
	22	309.78
	1	447.05
955	13	281.35
	6	331.34

the competition between the peck and treadle responses. These results do suggest that resurgence can be produced locally during the transition to a schedule of positive reinforcement that arranges for relatively lower rates of reinforcement.

DISCUSSION

Decreasing the rate of reinforcement for treadle pressing produced local increases in key pecking for 2 out of 3 pigeons that tended to occur during longer interreinforcement intervals. These local increases were smaller relative to the resurgence produced by extinction during subsequent resurgence tests. Resurgence therefore does not depend on chronic periods of nonreinforcement as is the case during extinction conditions that involve several sessions in which the reinforcer is completely unavailable. The results of Experiment 4 thus are consistent with Epstein's (1985, p. 148) suggestion that ''single and concurrent schedules of intermittent reinforcement should produce extinction effects,'' and thus resurgence. It is possible that the conditions that evoke resurgence (and other effects of nonreinforcement) lie on a continuum in their extinction-like characteristics (i.e., the parameters of the schedule of stimulus delivery). At one end of the spectrum, the pertinent reinforcer is unavailable for long periods of time, as in conventional extinction. At the other end, the reinforcer is unavailable for relatively brief periods of time, as in relatively rich schedules of intermittent reinforcement, and during short delays to reinforcement. As schedules of reinforcement become more intermittent (i.e. the interreinforcement intervals become larger), the periods during which reinforcement is unavailable may become more functionally equivalent to conventional extinction, and thus produce more resurgence. In addition, the ''strength'' of the alternative behavior also may affect the magnitude or latency of resurgence. The variables that have been shown to engender greater persistence and resistance to change (e.g., Nevin, Mandell, & Atak, 1983), for example, may affect resurgence.

GENERAL DISCUSSION

The results reveal three properties of the resurgence effect: (a) that resurgence is an effect of recent reinforcement history, (b) that the effect is repeatable within subjects, and (c) that the effect appears to be limited to reinforcer retrenchment. That is, resurgence seems to be produced only during conditions that involve relative decreases, reductions, or diminutions in reinforcer availability.

Although the degree of resurgence was not shown to vary as a function of how recently the resurgent response was reinforced in Experiment 1, the magnitude of the resurgence effect was modified by recent history in Experiment 3, and thus showed the first property. The resurgence induced by extinction following reinforcement for both key pecking and treadle pressing on VI 120-s schedules was less than that produced following VI 30-s schedules. The second property was shown in Experiments 2 and 3. Resurgence was produced by extinction for all pigeons during a second exposure to resurgence tests. The third property was shown in all experiments. Resurgence was produced reliably by both global (Experiments 1, 2, 3, and 4) and local (Experiment 4) periods of nonreinforcement. Resurgence did not occur during conditions that arranged for the delivery of reinforcers independently of responding, as in Experiment 3. The failure of response-independent food delivery to produce resurgence of previously reinforced behavior in Experiment 3 is consistent with previous demonstrations of resurgence that involved autoshaping preparations (Epstein & Skinner, 1980; Lindblom & Jenkins, 1981). In those studies, the delivery of the unconditioned stimuli (food) does not evoke response recovery. Only the cessation of food delivery was sufficient for resurgence. Resurgence thus appears to be limited to conditions involving a relative shift in reinforcer availability that results in fewer reinforcer deliveries and, necessarily, longer periods of nonreinforcement. The results of all four experiments also bear on two theoretical issues that have arisen in previous discussions of resurgence and related phenomena: The notion that resurgence is a function of response prevention during the second, reinforcement-of-an-alternative-response, condition and the relation between resurgence and other, similar behavioral processes.

The results from each experiment demonstrate that resurgence does not depend on the extinction–prevention of the resurging response (Leitenberg et al., 1970; Mulick et al., 1976), a finding that replicates Epstein's (1983) results. In Experiment 1, key pecking first was extinguished prior to the treadle-press reinforcement condition for each pigeon. Thus the subsequent recovery of key pecking in the resurgence condition can not be attributed to interference with the extinction of key pecking by the reinforcement contingency for treadle pressing. Although formal extinction conditions were not conducted prior to treadle-press reinforcement conditions in Experiments 2, 3, and 4, the same conclusions can be drawn. In these experiments, several sessions (at least six, and more if more than one shaping session was required to establish the treadle press response) occurred between the key-peck reinforcement and treadle-press reinforcement conditions (see the Procedure section of Experiment 2). During these sessions, key pecking was placed on extinction and treadle presses were established via shaping. In subsequent ''treadle pretraining'' sessions, treadle presses produced reinforcement on FR schedules of increasing response requirements, until the terminal VI 30-s schedule was implemented. During all of these sessions, key pecks had no consequences.

The resurgence procedure also can be brought to bear on behavioral phenomena that are similar to the resurgence effect. In an operant reinstatement procedure (e.g., Franks & Lattal, 1976), for example, responding is maintained by reinforcement (e.g., food) and thereafter extinguished. Responding then is reinstated by the response-independent delivery of food. The reinstatement occurs, presumably, because the delivery of food acquires discriminative as well as reinforcing properties in baseline (cf. Cruse, Vittuli, & Dertke, 1966). During conventional extinction, the discriminative function of food delivery remains unchanged. When food then is delivered in the absence of a contingency, response recovery occurs. This discriminative mechanism of reinstatement also plays a role in the induction reported by Reynolds (1964). Responding was maintained initially in a multiple schedule during which reinforcement became discriminative for responding on a key. When responding to each of three components was extinguished, the reintroduction of a reinforcement schedule in one of the components engendered a temporary increase in responding to the key in the other two components. There are two possible mechanisms that can be used to explain the induction that occurred and both may have operated simultaneously. First, the fact that the same reinforcer was used in all three components may have given rise to a reinstatement-like effect as in Franks and Lattal. Second, the fact that topographically identical responses produced reinforcement in all three components may have allowed the delivery of food in one component to override the stimulus control over pecking in the other two components.

The mechanisms for reinstatement and induction, then, depend to some extent, or at least indirectly, on the persistence of the discriminative function of food delivery. That is, food delivery engenders response recovery directly in a reinstatement procedure but perhaps indirectly in an induction procedure. In an induction procedure, the delivery of the reinforcer induces an increase in responding in other stimulus contexts (other components of a multiple schedule, for example). In a reinstatement procedure, however, food delivery increases responding that occurred previously in the same stimulus context. In both cases, it is the delivery of food that engenders an increase in previously maintained responding.

In the present experiments, however, only periods of nonreinforcement (as in conventional extinction or during relatively long interreinforcement intervals) resulted in resurgence. If the mechanism of resurgence is similar to that of reinstatement and induction, then prolonged periods of nonreinforcement have become discriminative for responding, as food delivery is discriminative for responding in reinstatement and induction procedures. Is it possible that periods of nonreinforcement of Response B become discriminative for Response A during shaping and pretraining of the alternative response? Although unlikely, it is possible that units of behavior are formed during shaping of the alternative response, such that pecks are followed by treadles that in turn are followed by food. These units may be reinstated later by periods of nonreinforcement. If so, then perhaps a mechanism of resurgence is similar to that of reinstatement and induction. After prolonged exposure to reinforcement, the implementation of conventional extinction may reinstate behavior that historically has followed periods of nonreinforcement. The similarities and differences between effects such as spontaneous recovery, resurgence, reinstatement, and induction have yet to be examined directly. Such analyses will shed further light on the mechanisms of response recovery. The resurgence effect, however, appears to be as robust (if not more so) than other forms of recovery. The magnitude and time course of the effect appears relatively greater than that of these other forms of recovery, although only direct comparisons among these effects will inform our understanding of their functional equivalence.

The resurgence procedure may be a useful baseline to examine effects of behavioral history and the persistence of distal operants. The procedure allows for an examination of how an organism's ontogenetic past is brought to bear on current circumstances. The three-condition procedure used to examine resurgence in the present study provides an additional class of historical variables to the two-condition procedures used in the study of behavioral history (i.e., an examination of the influence of training from one condition into a second, history-test condition). This additional class of variables can influence how current contingencies (or lack of contingencies) interact with an organism's behavior, and consists of those operants that have produced reinforcement in the past but have since been ''eliminated.'' Behavioral variability, both within and between subjects, that occurs when new reinforcement contingencies are imposed, therefore is a function of two classes of historical variables. First, such current variability is a function in part of recently reinforced (and ongoing) behavioral patterns. Second, current variability is a function of more distal, historically effective response patterns that have been extinguished sometime in the past and can recur through resurgence and other types of response recovery. To capture the orderliness of response recovery (including resurgence), mathematical models of the effects may prove useful for the prediction and control of operant variability when contingencies change, as in the attempt to model resurgence in an account of generativity (Epstein, 1996). Future work that systematically varies the parameters of the conditions used to (a) maintain the initial response, (b) maintain the alternative response, and (c) evoke the resurgence of the initial response may be modeled to describe mathematically the magnitude and latency of resurgence.

The procedures that produce resurgence are potentially useful tools in determining an organism's history of reinforcement with respect to a particular response. This potential window on the learning history of an organism has both theoretical and applied utility. Operant learning theory with regard to variability, creativity, and provenance may be furthered through an empirical analysis of how learning history engenders behavioral variation without the use of learning history as a hypothetical construct. Application of behavioral history paradigms, including resurgence, may be fruitful in the development of behavioral technologies. One of the primary goals of the functional analysis method that is used in the development of behavioral treatments for severe behavior disorders (e.g., Iwata, Dorsey, Slifer, Bauman, & Richman, 1994), for example, is to determine the stimuli that most likely functioned as reinforcers for problem behavior in the past. Reductive treatments then are developed based on the premises provided by these functional analyses. In addition to potentially augmenting assessment procedures, resurgence also may provide a framework for characterizing clinical relapse. When behavioral treatments are degraded through programmed generalization procedures or through treatment noncompliance, problem behavior may recur under conditions that are extinction-like. Further research on resurgence and other effects of behavioral history therefore has potential applicability.

It is therefore promising to pursue further a prescient question formulated by Reynolds (1964): ''can a difference be shown between the strengths of two discriminated operants at a time when no responses . . . are emitted in the presence of each stimulus?'' (p. 173). This question, rephrased, is concerned with the relative strengths of distal operants; those operants that have been effective in the past but have been eliminated. An understanding of how response strength and persistence relate to resurgence and other forms of response recovery is essential in characterizing both the provenance and dynamic variability of operant behavior.

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