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RESISTANCE TO CHANGE IN SCHEDULES OF AVOIDANCE AND TIMEOUT FROM AVOIDANCE

RESISTENCIA AL CAMBIO EN PROGRAMAS DE EVITACIÓN Y TIEMPO-FUERA DE EVITACIÓN

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ABSTRACT

Galizio (1999) reported that responding that produced a timeout from avoidance was more resistant to extinction than avoidance responding itself. The present study sought to extend this finding. Six times during each session, a signaled fixed-ratio 10 schedule was superimposed on a variable-cycle 60-s shock deletion schedule. By completing the ratio, rats produced a signaled 5- or 8-min timeout. Response rates maintained by avoidance and timeout were compared by analyzing responding during each FR presentation (timeout) and in the 5-min period before it (avoidance). Resistance to change was assessed by (a) increasing the variable-cycle parameter from 60 s to 120 s (Experiment 1), and (b) shock-omission extinction (Experiment 2). In both cases, timeout responding was more resistant to change than avoidance responding.

Key Words: avoidance, timeout, resistance to change, behavioral momentum, extinction, shock, lever press, rats.

RESUMEN

Galizio (1999) reportó que una respuesta que producía un tiempo fuera de la evitación era más resistente a la extinción que la respuesta de evitación

1. This research was conducted as part of a masters thesis by the first author, who now is at the College of Charleston. The authors would like to thank Leo Carlin and Todd Myers for assistance in computer programming, and Gary Duma at Eastern Michigan University for help in manuscript preparation. Correspondence should be addressed to the first author at the College of Charleston, Department of Psychology, 57 Coming Street, Charleston, SC 29424. (Email: GaluskaC@cofc.edu).

misma. El presente estudio busca extender ese hallazgo. Seis veces durante cada sesión, un programa señalado de razón fija 10 fue impuesto sobre un programa de eliminación de choque de ciclo variable choque-choque de 60 s. Al completar la razón, las ratas producían un tiempo fuera señalado de 5 u 8 minutos. Se compararon las tasas de respuesta mantenidas por la evitación y el tiempo fuera analizando la respuesta durante cada presentación (tiempo fuera) de la RF y en el período previo de 5 min (evitación). La resistencia al cambio fue determinada mediante (a) un incremento el parámetro de ciclo variable de 60 a 120 s (Experimento 1), y (b) una extinción por omisión de choques (Experimento 2). En ambos casos, la respuesta de tiempo fuera fue más resistente al cambio que la respuesta de evitación.

Palabras clave: evitación, tiempo fuera, resistencia al cambio, momentum conductual, extinción, choque, presión de palanca, ratas.

RESISTANCE TO CHANGE IN SCHEDULES OF AVOIDANCE AND TIMEOUT FROM AVOIDANCE

In certain contexts, behavior maintained by negative reinforcement may be highly resistant to extinction. An early series of studies demonstrating the persistence of avoidance responding during extinction was reported by Solomon and his colleagues (Solomon, Kamin, & Wynne, 1953; Solomon & Wynne, 1954), who employed a discrete-trial, signaled avoidance procedure. Dogs, confined to one side of a shuttle box, could avoid or escape signaled presentations of shock by jumping over a barrier to the other side of the box. Dogs quickly acquired the avoidance response; they jumped during the signal, before the shock. During an extinction condition in which shocks were omitted, they continued to jump for up to 200 trials without any decrease in response latency following the onset of the signal.

In a typical free-operant avoidance procedure, rats' lever presses postpone unsignaled shocks (Sidman, 1953). Such responding has been shown to decrease to near-zero levels within a few sessions of shock-omission extinction (Shnidman, 1968). These findings have led some investigators to conclude that the response strength associated with lever-press shock postponement is less than that associated with species-specific escape responding such as jumping or running (Bolles, 1970; Fanselow, 1997; Seligman, 1970).

Methodological differences between discrete-trial, signaled avoidance and free-operant, unsignaled avoidance may account for these observed differences. First, the discrete-trial procedure usually engenders perfect avoidance. For example, after the first few trials, the dogs in Solomon and colleagues' research never came into contact with shock again (Solomon et al., 1953; Solomon & Wynne, 1954). Therefore, extinction was indistinguishable from the avoidance procedure because both were shock-free periods. By comparison, in free-operant avoidance, even proficient animals encounter shock occasionally, thus fostering contact with the subsequent extinction condition.

Extinction also has been studied with procedures that allow comparison of two forms of negatively reinforced behavior: Responding maintained by avoidance and timeout from avoidance. In an early study (Verhave, 1962), rats' presses on one lever postponed shock while responses on a second lever produced a signaled timeout from avoidance (hereafter, such responding will be referred to as timeout responding) according to a fixed-ratio (FR) schedule. Extinction was studied by omitting all scheduled shocks. Verhave reported that both avoidance and timeout responding decreased gradually over the course of four sessions. Verhave's (1962) results must be interpreted cautiously because only one rat was exposed to the shock-omission extinction. In addition, Verhave reported difficulty maintaining behavior on schedules of timeout. He suggested that timeout was a weak reinforcer, but a growing body of research since the publication of his results has shown otherwise (for reviews of the reinforcing efficacy of timeout, see Courtney & Perone, 1992; Perone & Crawford, 1999; Perone & Galizio, 1987). Galizio (1999, Experiment 2) reported that responding that produced a timeout from avoidance was more resistant to shock-omission extinction than the avoidance behavior itself. Rats' presses on one lever postponed shock while presses on a second lever produced a signaled timeout according to a variable-ratio (VR) 15 schedule. After substantial exposure to the concurrent schedules of avoidance and timeout (a minimum of 230 sessions, each lasting 2 hr), shock-omission extinction was implemented. Galizio found that while responding on the avoidance lever extinguished within 2 to 15 sessions, responding on the timeout lever persisted longer. Indeed, timeout responding was maintained in one rat for over 100 sessions. Galizio concluded that, under certain conditions, timeout responding proved highly resistant to extinction, and that the biological preparedness of the operant may not be the critical feature underlying resistance to extinction.

There are several limitations of Galizio's (1999) study. First, timeout and avoidance were programmed on two separate levers and the responses and consequences were not counterbalanced across rats. Although unlikely, perhaps an underlying response bias could account for the greater resistance to extinction on the timeout lever. In addition, the feedback stimuli for avoidance and timeout responding differed. Each avoidance response was followed by a 0.5-s offset of the white noise, while each timeout response was followed by a 0.5-s offset of the houselight. Perhaps differences in the discriminative or conditioned reinforcing value of the feedback stimuli could account for the results.

More significantly, it is unclear to what extent the rats' behavior in Galizio's (1999) experiment actually came in contact with the programmed extinction. In several previous studies investigating timeout from avoidance, the duration of the session was defined in terms of time spent in the avoidance (time-in) portion of the session (Courtney & Perone, 1992; Perone & Crawford, 1999; Perone & Galizio, 1987, Experiment 1). In Galizio's study, session duration was fixed at 2 hr, and rats spent the majority of the session in timeout. Because of this, rats did not receive substantial exposure to the time-in stimuli in the absence of shock. Perhaps such exposure would devalue the reinforcing efficacy of timeout.

Finally, it is not known if Galizio's (1999) results are peculiar to extinction or if they would generalize to other preparations, such as smaller reductions in the overall scheduled rate of shock presentation (as opposed to a reduction to zero, as in the case of shock-omission extinction).

In the present study, a procedure developed by DeWaard, Galizio, and Baron (1979) was adapted to address the above concerns. Rats pressed a single lever to avoid shock on a variable-cycle (VC; de Villiers, 1972) 60-s schedule of shock deletion. At six points in the session, an FR 10 schedule signaled by a flashing houselight was superimposed on the VC schedule. Completion of the FR resulted in a signaled timeout from avoidance during which no shocks were delivered.

We measured timeout responding during the superimposed FR schedule (although technically responding both avoided shock and produced timeout – this point is addressed in the General Discussion), and we measured avoidance responding during the 5-min period preceding each FR presentation. We assessed resistance to change in two ways. In Experiment 1, the VC parameter was increased from 60 s to 120 s, thus halving the scheduled shock rate. In Experiment 2, we attempted to replicate Galizio's (1999) results using shock-omission extinction.

Our procedure offers several advantages over Galizio's (1999). First, by using one lever, any difference in resistance to change between avoidance and timeout responding cannot be attributed to response biases due to differences in response topography, location, or feedback. Second, because the first opportunity to produce timeout did not occur until 30 min into the session and, thereafter presentations were separated by an average of 20 min, we ensured that behavior had substantial exposure to the changed conditions during time-in.

EXPERIMENT 1

The manipulations reported in Experiment 1 arose inductively out of a partial failure to replicate findings reported by DeWaard et al. (1979). DeWaard et al. exposed rats to a VC 60-s schedule of shock deletion. Six times during each session, completion of a superimposed FR 10 schedule, signaled by a flashing houselight, produced an 8-min timeout from avoidance. DeWaard et al.

reported that response rates during the FR presentation were enhanced relative to the 5-min avoidance period preceding each FR presentation, indicating the reinforcing functions of timeout.

We exposed eight rats to this procedure, as part of another experiment (Galuska, Myers, & Perone, 2000). Consistent with DeWaard et al. (1979), five rats showed elevated responding during the FR presentation. (These results are part of Galuska et al., 2000, and will not be reported here.) However, after more than 25 sessions, the behavior of two rats did not show elevated responding during the FR schedule and only a modest elevation was evident in the behavior of a third. The absolute response rates of these rats were higher than those of DeWaard et al., perhaps because of the lower force required to operate the lever in our experiment. We hypothesized that the avoidance response rate was too high to permit substantial enhancements by the superimposed timeout contingency; that is, a ceiling effect may have been masking the reinforcing functions of timeout.

To reduce overall response rates for these three rats, the VC parameter was increased from 60 s to 120 s. This manipulation allowed us to compare resistance to change of both avoidance and timeout responding when the underlying schedule of shock was reduced (but not removed entirely), thus assessing the generality of Galizio's (1999) findings. To the extent that both avoidance and timeout responding are determined by shock, both should decrease. If timeout responding is more resistant to change than avoidance responding, however, timeout responding should persist at higher relative rates than avoidance responding.

METHOD

Subjects

Three male Sprague-Dawley albino rats were housed individually under a reversed 12-hr light/dark cycle. Experimental sessions were conducted during the dark part of the cycle, when rats normally are active. To prevent fouling of the shock grid with feces, the rats were deprived of food for approximately 15 hr preceding each experimental session. Water was continuously available in the home cage. The rats were approximately 6 months old at the start of the experiment and previously had been exposed to shock-postponement (Sidman, 1953) and shock-deletion (de Villiers, 1972) schedules.

Apparatus

One custom-built operant chamber and two commercial chambers (Lehigh Valley Electronics) were used. The interiors were approximately 30 cm long, 21 cm high, and 19 cm deep. In each commercial chamber, the side walls and ceilings were constructed of Plexiglas, and the end walls with stainless steel. The floor consisted of stainless steel rods, 0.5 cm in diameter, spaced 1.9 cm apart, center to center. Illumination was provided by a 28-V houselight (No. 1820) mounted behind a sheet of white paper on a side wall. Two levers were centered 10 cm apart on the front wall, 9 cm above the grid floor. In the custom-built chamber, the rear wall, ceiling, and one side wall were constructed of clear Plexiglas, the other side wall of stainless steel, and the front wall with aluminum. The levers were 8.5 cm apart, 9.6 cm above the floor, and the floor rods were spaced 1.7 cm apart. General illumination was provided by a houselight at the top of the front wall. In all three chambers, the left lever (BRS/LVE, RRL-015) was retracted and the right required a force of 0.3 N to operate. Each press of the right lever resulted in a 0.5-s white noise offset. Scrambled shock of 1mA intensity and 0.5-s duration was delivered from Grason-Stadler shock generators (E1064GS). Shock was delivered through the floors, the walls, and the levers. Each chamber was enclosed in a sound-attenuating box equipped with a fan for ventilation and a speaker for white noise (75 dB). Control and recording operations were accomplished with microcomputers connected to the chambers via digital interfaces (Computer Boards, Inc., CIO-PDIS08).

Procedure

Sessions lasting approximately 200 min were conducted three days per week with at least one day in between sessions. The beginning of each session was signaled by the onset of the white noise and the session terminated with the offset of the noise. Sessions were conducted with the houselight off for Rats C1 and C3, and on for Rat C5.

In the baseline condition, a VC 60-s schedule programmed shocks at irregular intervals, averaging 60 s, using Fleshler and Hoffman’s (1962) distribution, modified so that the minimum intershock interval was 5 s. The first response in an interval or cycle canceled the shock otherwise delivered at the end of the interval. Further responses during the interval had no effect. Whenever a shock was delivered from the VC schedule, the schedule was suspended and additional shocks were delivered every 5 s until a response occurred. The addition of this shock-shock (SS) interval (Sidman, 1953) has been shown to facilitate the acquisition and maintenance of responding (Courtney & Perone, 1992; DeWaard et al., 1979). When a response was made during the SS period, the VC schedule was reinstated and another lever press was required to cancel the shock programmed at the end of the interval. That is, responses during the SS period terminated the chain of shocks but did not cancel the next programmed VC shock.

Six times during each session, an FR 10 schedule was superimposed on the VC schedule. The VC schedule continued to operate during the superimposed FR schedule. Completion of the FR schedule produced an 8-min timeout from avoidance for Rats C1 and C3, and a 5-min timeout from avoidance for Rat C5. (Differences in the duration of the timeout and the stimulus conditions during time-in were the result of counterbalancing in another experiment. No systematic effects of either variable were found.) The FR schedule was signaled by a flashing houselight (0.5-s on, 0.5-s off). Timeout was signaled by the offset of the houselight and white noise. The VC schedule was suspended during the timeout. Responses during timeout were recorded but had no programmed consequence. The onset of white noise (and houselight for Rat C5) signaled the end of timeout. The first FR presentation occurred 30 min into the session; subsequent presentations were separated by a mean interval of 20 min (range 10 - 30 min), timed from the end of the preceding timeout. The session ended 30 min after the completion of the sixth timeout.

After 28 (Rat C1), 39 (Rat C3) or 30 (Rat C5) sessions, timeout responding during the superimposed FR schedule was not elevated relative to the avoidance baseline (the 5-min period preceding each FR presentation). At this point the VC parameter was increased from 60 s to 120 s and the minimum intershock interval was increased from 5 s to 10 s. All other procedural details remained the same. This condition lasted a minimum of 10 sessions, until both avoidance and timeout responding met a visual and mathematical stability criterion. In the absence of a visual trend, the mean response rates in the first 3 sessions and last 3 sessions of the last 6 consecutive sessions had to be within 15 percent of the overall mean of the 6 sessions.

Results

Table 1 shows the total number of sessions in each condition, mean avoidance and timeout response rates, response elevation during the superimposed FR schedule, overall obtained shock rates, and avoidance proficiency. Because a stability criterion was not employed in the VC 60-s condition, we arbitrarily selected the last 10 sessions to represent terminal performance. Results from the VC 120-s condition are based on the stable 6 sessions. For Rat C5, the VC 120-s condition was ended by mistake before timeout responding had met the mathematical stability criteria. This error did not, however, prevent observation of clear differences between avoidance and timeout responding with respect to the change in the VC parameter.

Avoidance proficiency was calculated as the number of canceled VC shocks divided by the number of scheduled VC shocks during the entire time-in portion of the session. All of the animals avoided at least 95 percent of the scheduled VC shocks on both the VC 60-s and 120-s schedules. Obtained shock rates were calculated as the total number of VC and SS shocks received divided by the time spent in the time-in portion of the session. The shock rates were low (0.01 – 0.04 shocks /min) in both conditions.

Rat	VC	Sessions	Avoidance Resp / Min	Timeout Resp / Min	Timeout / Avoidance	Shock / Min	Avoidance Proficiency (%)
C1	60	28	18.7 (1.7)	19.0 (2.6)	1.0 (0.1)	0.01 (0.01)	99 (1.3)
	120	16	12.2 (1.8)	18.3 (1.4)	1.5 (0.2)	0.01 (0.01)	98 (1.4)
C3	60	39	13.0 (1.8)	13.0 (1.9)	1.0 (0.2)	0.04 (0.01)	95 (1.0)
	120	28	9.9 (1.2)	13.2 (1.7)	1.3 (0.2)	0.02 (0.01)	97 (0.9)
C5	60	30	18.1 (2.6)	21.2 (3.1)	1.2 (0.2)	0.01 (0.01)	99 (0.4)
	120	11	12.4 (1.5)	19.6 (2.7)	1.6 (0.1)	0.01 (0.01)	99 (0.9)

Table 1. Experiment 1. Number of sessions in the variable-cycle (VC) 60-s and 120-s conditions, avoidance and timeout response rates, an elevation ratio (timeout / avoidance), overall shock rate, and avoidance proficiency (percent of VC shocks avoided). Results are means based on the last ten sessions in the VC 60-s condition and the last six sessions in the VC 120-s condition. Standard deviations are shown in parentheses.

Consistent with DeWaard et al. (1979), we analyzed responding in the 5 min before each of the FR presentations (avoidance) and during each presentation (timeout). Because there were 6 FR presentations per session, the session-by-session response rates presented below are the means of 6 local response rates. For each session, an elevation ratio during the superimposed FR schedule was calculated as the ratio of these rates (timeout / avoidance). The response rates and elevation ratios shown in Table 1 are means of the last 10 sessions in the VC 60-s condition and the stable 6 sessions of the VC 120-s condition. In the VC 60-s condition, Rats C1 and C3 did not exhibit enhanced responding during the FR schedule, and Rat C5 exhibited only a modest enhancement. By comparison, in the VC 120-s condition, responding during the FR schedule was elevated for all three rats. Inspection of the absolute rates underlying these elevation ratios shows that timeout responding was relatively unchanged across conditions while avoidance responding decreased in the VC 120-s condition. Responding rarely occurred during timeout.

The left panel of Figure 1 shows avoidance and timeout responding during the last 10 sessions of the VC 60-s baseline and the first 10 and final 6 (stable) sessions of the VC 120-s condition (because only 11 and 16 sessions were conducted in the VC 120-s condition for Rats C5 and C1 respectively, all of the sessions are shown). For Rats C1 and C5, avoidance responding decreased within the first session of exposure to the VC 120-s schedule, while timeout responding was largely unaffected by the manipulation of the VC parameter. For Rat C3, avoidance and timeout responding initially decreased in

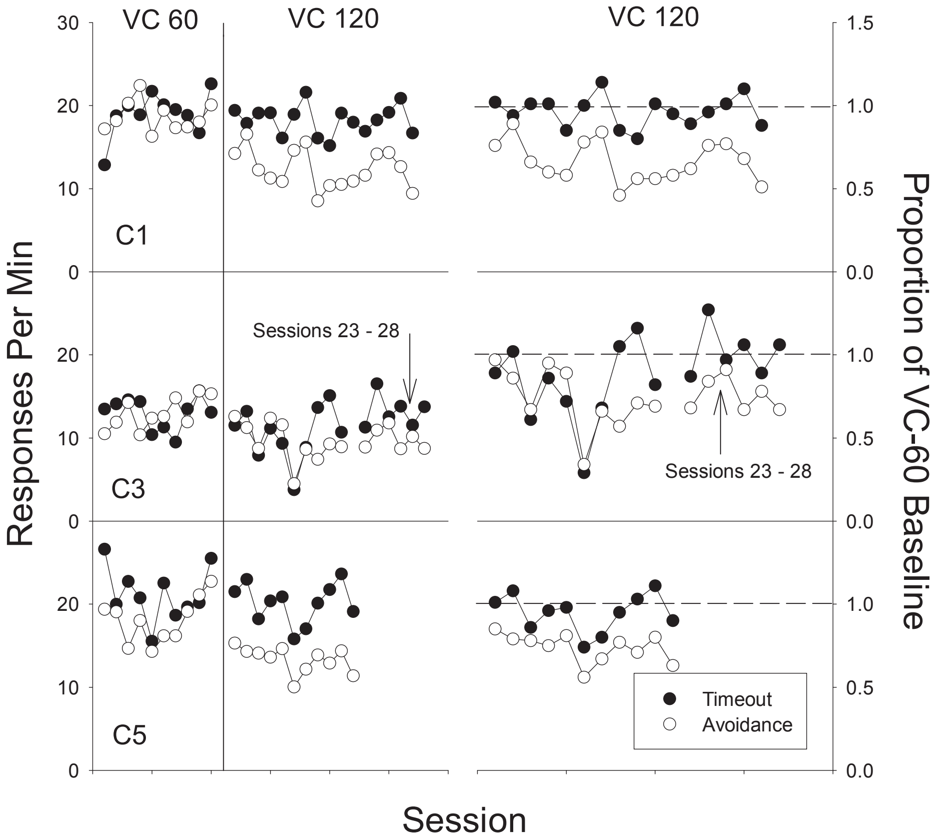

Figure 1. *Experiment 1*. Left panel: Avoidance and timeout response rates during the final 10 sessions of the VC 60-s condition, the first 10 sessions of the VC 120-s condition, and the 6 stable sessions of the VC 120-s condition. Right panel: Response rates in the VC 120-s condition expressed as a proportion of the mean response rates obtained in the VC 60-s condition. The reference line in the right panel indicates no change in responding from the VC 60-s condition. Filled circles represent timeout responding and empty circles represent avoidance responding.

the VC 120-s condition, but timeout responding gradually recovered and its enhancement relative to avoidance responding is evident in the stable sessions. The right panel of Figure 1 shows response rates as a proportion of the mean avoidance and timeout response rates obtained in the VC 60-s condition. For Rats C1 and C5, timeout responding persisted at a higher rate than avoidance responding, relative to their respective baselines. This effect is evident in the first session of the VC 120-s condition onward. For Rat C3, both avoidance and timeout responding initially decreased, relative to their respective baselines. In the stable 6 sessions of the condition, however, timeout responding persisted at a higher relative rate than avoidance responding.

Discussion

If the underlying avoidance schedule solely controlled responding during FR presentations, both avoidance and timeout responding should have decreased at similar rates when the VC parameter was increased from 60 s to 120 s. The results show, however, that timeout responding remained near, or recovered to, baseline levels while avoidance responding decreased within the first few sessions of the VC 120-s condition. These findings support the contention that behavior was sensitive to the timeout during the VC 60-s condition, and that the relatively high avoidance response rates may have masked control by the superimposed timeout contingency. These results also suggest that the VC parameter was not an important determinant of timeout responding. A 50% reduction in the scheduled shock rate decreased avoidance responding markedly, but did not affect timeout responding.

In general, the pattern of results obtained in Experiment 1 is consistent with Galizio's (1999) results. Responding that produced a timeout from avoidance persisted at a higher rate than the avoidance behavior itself when the underlying scheduled rate of shock was reduced.

EXPERIMENT 2

Galizio (1999) assessed the resistance of avoidance and timeout responding to shock-omission extinction. The extent to which the rats in Galizio's study contacted the programmed extinction is unclear because they spent the majority of the session in timeout. Experiment 2 was designed to extend Galizio's extinction findings using the general procedure of Experiment 1, which ensured extended contact with the programmed extinction.

Subjects

Four rats were maintained under the same conditions as in Experiment 1. The rats were approximately 20 months old at the beginning of the experiment and had extensive experience with the general procedure developed by DeWaard et al. (1979; described in detail above), as part of another experiment. Two of the rats (C1 and C5) had served in Experiment 1.

Procedure

In the baseline condition, Rats C1 and C5 were exposed to a VC 120-s schedule, while Rats C2 and C7 were exposed to a VC 60-s schedule. (For each rat, the VC parameter that maintained elevated timeout responding relative to avoidance responding was used.) Six times during each session, completion of a superimposed FR 10 schedule produced a 5- (Rat C5) or 8-min timeout, as in Experiment 1. Sessions were conducted with the houselight on for Rats C2, C5, and C7, and off for Rat C1. For all rats, presentation of the FR schedule was signaled by a flashing houselight and timeout was signaled by the offset of the houselight and white noise.

After timeout and avoidance responding met the mathematical stability criteria described in Experiment 1, extinction was programmed by omitting all scheduled shocks. A second procedural modification also was made. Up to this point, sessions ended 30 min after the completion of the sixth timeout presentation. Because session termination depended on the completion of six superimposed FR schedules, sessions theoretically could last indefinitely if responding ceased. Therefore, the extinction sessions were limited to a maximum of 300 min. We planned to terminate the condition after three consecutive sessions in which no more than two timeouts were earned or after 50 sessions, whichever came first. Rats C5 and C7 became ill and were dropped from the experiment before meeting either requirement, after 43 and 20 sessions respectively. Rats C1 and C2 completed 50 sessions of extinction.

Results

Table 2 shows the total number of sessions, avoidance and timeout response rates, elevation ratios during the superimposed FR schedule, obtained shock rate, and avoidance proficiency for the baseline condition. All means were calculated from the stable six sessions preceding extinction. All rats avoided at least 84 percent of the scheduled VC shocks. The overall shock rate for Rat C5 during this condition was rounded to 0.00 shocks per min; in the six sessions preceding extinction, this rat received two shocks. Rats C2 and C7, exposed to a denser programmed shock rate, received more shocks than Rats C1 and C5. Absolute shock rates were low, 0.30 shocks per min or less. Response rates were elevated during the superimposed FR schedule, indicating the reinforcing functions of timeout. The elevations observed for Rats C1 and C5 were greater in this condition than in the VC 120-s condition in Experiment 1. Presumably, this reflects the substantial exposure to the gen-

Rat	VC	Sessions	Avoidance Resp / Min	Timeout Resp / Min	Timeout / Avoidance	Shock / Min	Avoidance Proficiency (%)
C1	120	10	12.2 (0.9)	21.1 (1.9)	1.7 (0.2)	0.01 (0.00)	99 (1.0)
C2	60	13	9.8 (1.7)	16.3 (2.4)	1.7 (0.1)	0.24 (0.09)	84 (3.0)
C5	120	12	11.5 (1.4)	23.3 (2.6)	2.0 (0.2)	0.00 (0.00)	100 (0.0)
C7	60	13	5.5 (0.8)	15.7 (1.7)	2.9 (0.2)	0.30 (0.09)	86 (3.1)

Table 2. Experiment 2. Baseline performance in the stable six sessions preceding extinction. See Table 1 for more details.

eral procedure as part of other research in the months between Experiments 1 and 2. Responding rarely occurred during timeout.

In the extinction condition, rats generally earned three to six timeouts per session. The left panel of Figure 2 shows avoidance (open circles) and timeout response rates (closed circles) during extinction. The right panel expresses these response rates as a proportion of the mean response rates obtained in the baseline condition. Because of the low rate of responding during extinction, the results are displayed on a logarithmic scale. Because the log of zero is undefined, response rates of 0.0 responses per min were assigned a value of 0.01. Proportions of baseline of 0.0 were assigned a value of 0.001. We chose these values because they were the closest power of ten that accommodated all of the non-zero results.

Both avoidance and timeout responding decreased to low levels within the first 10 sessions of extinction. The behavior of Rat C5 is a notable exception. For this rat, avoidance and timeout responding decreased gradually and persisted at rates comparable to baseline for approximately 18 sessions. For all rats, timeout responding persisted at low rates, with occasional bursts, for the remainder of the extinction condition. In general, avoidance response rates were lower than timeout response rates and remained at or near zero responses per min. An exception is the avoidance responding of Rat C1 during the last 5 sessions of extinction. It is unclear why avoidance responding began to recover for this rat, and the rat died shortly thereafter, preventing further investigation.

The right panel of Figure 2 indicates that, with the exception of Rat C5, timeout responding persisted at a higher rate, relative to baseline, than avoidance responding during the first 10 sessions of extinction, and remained at a higher proportion of baseline thereafter. For Rat C5, avoidance and timeout responding decreased at a similar rate, relative to their respective baselines, for approximately 18 sessions. Thereafter, timeout responding generally persisted at a higher relative rate than avoidance responding.

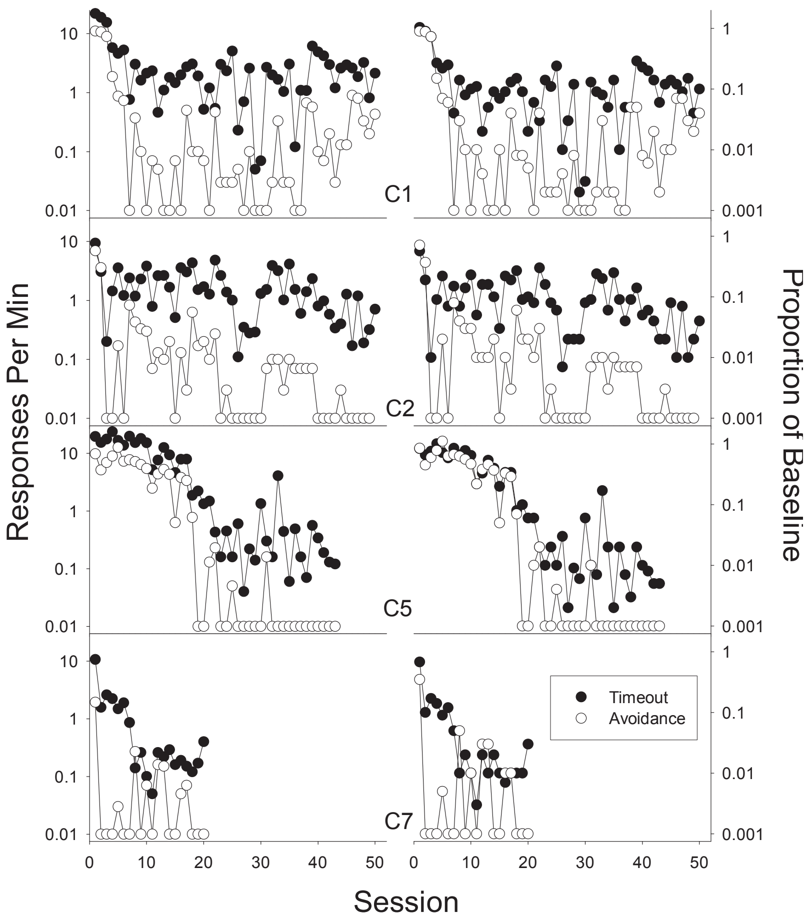

Figure 2. Experiment 2. Left panel: Avoidance (open circles) and timeout response rates (closed circles) during extinction. Values equal to 0.0 were assigned a value of 0.01. Right panel: Response rates expressed as a proportion of the mean response rates obtained in the preceding VC condition. Values equal to 0.0 were assigned a value of 0.001.

It is important to note that a potential confound may account for the results reported in Figure 2. In some instances, the opportunities to emit timeout responses lasted as long as several hundred minutes; until the rat completed the FR 10 requirement. Nevertheless, the period used to assess avoidance responding was fixed at the 5 min preceding the FR presentation. Perhaps this arbitrary sample of avoidance behavior artificially enhanced the observed differences in avoidance and timeout responding. For example, consider the case in which a rat does not respond in the 5 min preceding the FR presentation and then requires 100 min to complete the FR 10 requirement and produce the timeout. In the analysis shown in Figure 2, an avoidance response rate would be assigned a value of 0.01 and the timeout response rate would be assigned a value of 0.1. The magnitude of this difference appears large on a logarithmic scale, although is small in absolute terms and may represent merely a restricted sample of avoidance behavior relative to timeout behavior (5 min vs. 100 min).

To eliminate this confound, we reanalyzed the timeout response rates shown in Figure 2. If FR presentations lasted more than 5 min, only the response rate during the first 5 min was included in the analysis. Thus, any observed difference between avoidance and timeout responding cannot be attributed to extended sampling of timeout responding. The reanalysis is presented in Figure 3. In general, timeout responding persisted at higher rates, both in absolute terms and as a proportion of baseline, than avoidance responding. Note, however, that the effect is attenuated relative to Figure 2 (most notably for Rat C5, and subsequent to Session 10 for Rat C7).

Discussion

Prior to shock-omission extinction, response rates were elevated during the superimposed FR schedule. The magnitude of this elevation ranged from 70-to-290% (Table 2), indicating clear control by the timeout contingency. For all rats, avoidance and timeout responding decreased to low levels following the introduction of shock-omission extinction. For three of four rats, avoidance responding decreased more quickly than timeout responding. Moreover, once responding had reached near-zero levels, timeout responding persisted at a higher rate than avoidance responding for all rats.

In general, these results support Galizio's (1999) findings that timeout responding is more resistant to extinction than avoidance responding. One difference between the sets of results is that the magnitude of the effect in the current study is substantially less than the one reported by Galizio, who obtained higher timeout response rates during extinction than we did, in both absolute and relative terms. This may be due to the fact that the current procedure maximized the possibility that the removal of shock would be contacted, as a substantial portion of the extinction session was spent in the presence of the time-in stimuli in the absence of shock.

General Discussion

In most studies investigating resistance to change within the framework of positive reinforcement, responding is maintained on a multiple schedule

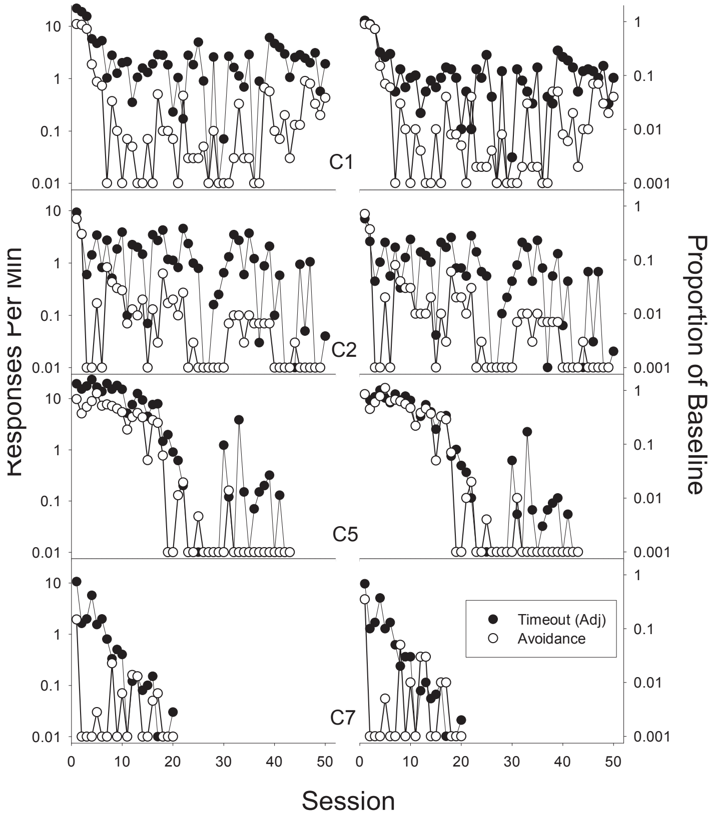

Figure 3. *Experiment 2. Left panel: Avoidance (open circles) and adjusted timeout rates (closed circles) during extinction. Values equal to 0.0 were assigned a value of 0.01. Right panel: Response rates expressed as a proportion of the mean response rates obtained in the preceding VC condition. Values equal to 0.0 were assigned a value of 0.001. See text for more details on how timeout response rates were adjusted.*

whose schedule components differ in terms of reinforcer rate or reinforcer magnitude. Responding in the richer component usually is more resistant to disruptors (e.g., prefeeding, response-independent food delivery, extinction) than responding in the lean component (for a review, see Nevin & Grace, 2000). Although procedurally different, the current study, as well as that of Galizio (1999), extends the resistance to change analysis to situations involving negative reinforcement.

A major limitation of our procedure is that responding during the superimposed FR schedule both avoided shock and produced timeout. Because this responding may have been controlled by both the avoidance and timeout contingencies, describing it simply as timeout responding is problematic. Moreover, ambiguities regarding the determinants of this responding makes an explanation of the results challenging.

One conclusion that can be made is that responding that avoided shock and produced timeout was more resistant to change than responding that only avoided shock. We feel, however, that this conclusion is overly conservative. The data strongly suggest that responding during the superimposed FR schedule was determined primarily by the timeout. In Experiment 1, manipulating the avoidance schedule via a 50% reduction in the scheduled shock frequency did not affect timeout responding, but did reduce avoidance responding. In Experiment 2, prior to extinction, the elevations in responding during the superimposed FR schedule are clearly evident, again suggesting control by the timeout contingency. Finally, even granting the possibility that timeout responding may have been in part determined by the avoidance contingency, the responding that occurred during the superimposed FR schedule after avoidance responding extinguished (Experiment 2) must have been the result of the timeout because the avoidance contingency (or lack thereof) was no longer sufficient to maintain responding.

The fact that timeout responding has been shown to be more resistant to change than avoidance is of theoretical interest. If the two forms of behavior are controlled by shock-frequency reduction (de Villiers, 1974; Herrnstein, 1969; Herrnstein & Hineline, 1966; Sidman, 1966) both avoidance and timeout responding should decrease at the same rate when the shock rate is reduced or removed entirely. The results also are inconsistent with cognitive explanations of avoidance couched in terms of fear reduction (Ayres, 1998; Levis, 1989; Miller, 1948; Mowher, 1939; Mowher & Lamoreaux, 1946). As Galizio (1999) noted, if timeout responding is negatively reinforced via reduced fear, why is that fear insufficient to maintain avoidance?

Other accounts have emphasized the importance of the suspension of the avoidance schedule as the critical variable underlying responding maintained by timeout from avoidance (Courtney & Perone, 1992; Perone & Crawford, 1999; Perone & Galizio, 1987). Here, timeout from avoidance functions as a negative reinforcer because it is correlated with local reductions in response effort, as responding is not required to avoid shock during timeout. If timeout responding is maintained by effort reduction, however, why should it persist after the effort exerted by avoidance responding decreases to near-zero levels?

Several factors may help reconcile the present set of findings with traditional theories of negative reinforcement. Galizio (1999) discussed two: conditioned reinforcement and reinforcement magnitude. Timeout is associated with a salient stimulus change that acquires conditioned reinforcing properties by functioning as a safety signal (for additional discussion of safety signals, see Dinsmoor, 1977, 2001). Perhaps timeout responding persisted during extinction because such responding continued to produce conditioned reinforcement. This interpretation is incomplete for several reasons. First, previous research has eliminated stimulus change as the sole reinforcer of timeout responding (Perone & Galizio, 1987). Second, conditioned reinforcement also is available for avoidance responding. Even when no explicit immediate consequence for avoidance responding is arranged, subtle stimuli paired with the response may function as safety signals because they are never paired with shock (Dinsmoor, 1977, 2001). While it could be argued that the conditioned reinforcement associated with timeout is greater than that associated with avoidance, why this is so remains a question of interest.

Galizio (1999) speculated that the magnitude of reinforcement for timeout responding may be greater than that of avoidance. While the reinforcer magnitude for timeout responding is specified (here, a 5- or 8-min signaled shock-free period), it is difficult to assess the magnitude of reinforcement for avoidance responding. Given the low rates of shock obtained in the present study, any given avoidance response often was followed by an extended shock-free period. Indeed, in some sessions, rats avoided all of the scheduled shocks. Despite these complications, additional support for the reinforcer magnitude interpretation is provided by Denny (1991), who argued that the duration of the safety signal, and not the duration of the shock-free period *per se*, is the critical variable in assessing reinforcer magnitude. The duration of the safety signal associated with timeout (5 or 8 min) was considerably longer than the safety signal associated with an avoidance response (0.5-s whitenoise offset).

As discussed earlier, the finding that timeout responding is more resistant to change than avoidance responding previously has not been predicted by accounts of timeout based on shock-frequency or effort reduction. Conceptualizing timeout responding as maintained by effort reduction, however, may provide an additional clue as to why timeout responding has been shown to be more resistant to change than avoidance responding when shock is reduced or omitted altogether. Perone and Crawford (1999) argued that the effort reduction afforded by timeout is more salient than shock-frequency reduction, as effort reduction is contacted immediately at the onset of timeout. Because of the low rates of shock during time-in, many presentations of timeout have to accrue before the shock-frequency reduction is contacted. Thus, shock may function as only an indirect determinant of timeout responding.

In one respect, the situation is analogous to Pavlovian higher-order conditioning (for a review, see Rescorla, 1980). After a relation between a conditioned stimulus (CS_1) and an unconditioned stimulus (US) has been established, a second stimulus (CS_2) is paired with the CS_1 in the absence of the US. After repeated pairings, the CS_2 will elicit responding even though it has never been paired with the US. A number of studies have shown that responding elicited by the CS_2 persists even after responding to the CS_1 is extinguished or the US is degraded or removed entirely (Archer & Sjoeden, 1982; Compton, White, & Robbins, 1977; Holland & Rescorla, 1975a, 1975b; Rescorla, 1979, 1982; Rizley & Rescorla, 1972; Williams & Hurlburt, 2000). This pattern of results suggests that the reinforcing value of the CS_2 is not derived through relations with either the US or the CS_1 but rather to the conditioned response elicited by the CS_1 (Rescorla, 1980). With respect to timeout from avoidance, timeout responding is maintained via an association with avoidance responding and is only indirectly related to shock. Avoidance, on the other hand, seems more closely related to the schedule of shock presentation. For this reason, timeout responding may be less sensitive than avoidance to alterations in the underlying schedule of shock.

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