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THE ROLE OF INTERMITTENT SHOCK-POSTPONEMENT IN REINFORCEMENT BY TIMEOUT FROM AVOIDANCE

EL PAPEL DE LA POSPOSICIÓN INTERMITENTE DE UN CHOQUE EN EL REFORZAMIENTO MEDIANTE UN TIEMPO FUERA DE LA EVITACIÓN

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ABSTRACT

A signaled timeout from an avoidance contingency has been shown to reinforce behavior when programmed on various intermittent schedules, but most contemporary studies confound the timeout with shock-postponement: After each timeout, the avoidance contingency is restarted at the beginning of the response-shock interval, as if an avoidance response had occurred. The present experiment assessed the contribution of this intermittent avoidance function to the maintenance of the response leading to timeout. In baseline conditions, rats' presses on one lever postponed shock for 30 s while presses on another lever produced, according to a variable-interval schedule, a 90-s timeout during which the shock-postponement schedule was suspended and its correlated stimuli were removed. At the end of the timeout, the shock-postponement schedule was reset to the beginning of the 30-s response-shock interval. In the experimental condition, the timeout duration was reduced to 0 s, so that satisfying the VI schedule merely reset the response-shock interval. Responding on the avoidance lever was maintained throughout the experiment. Responding on the timeout lever was maintained under baseline conditions, but not when the timeout was reduced to 0 s. These results establish that responding on the timeout lever was maintained by the timeout, not by the shock-postponement that followed it, and that the confound present in so many studies of timeout from avoidance may be safely disregarded.

Key words: timeout from avoidance, avoidance, negative reinforcement, shock-frequency reduction, response effort, lever press, rats

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RESUMEN

Se ha mostrado que un tiempo fuera señalizado en una contingencia de evitación refuerza la conducta cuando dicho tiempo fuera se programa en varios programas de reforzamiento intermitente, pero en los estudios contemporáneos se confunde el tiempo fuera con la posposición de un choque: Después de cada tiempo fuera, se reestablece la contingencia de evitación al principio del intervalo respuesta-choque, como si hubiera ocurrido una respuesta de evitación. El presente experimento evaluó la contribución de esta función de evitación intermitente en el mantenimiento de la respuesta que conduce al tiempo fuera. En las condiciones de línea base, las presiones a una palanca por ratas pospusieron el choque por 30 s, mientras que las presiones a otra palanca produjeron, conforme con un programa de intervalo variable, un tiempo fuera de 90 s, durante el cual se suspendió el programa de posposición del choque y se removieron los estímulos correlacionados. Al final del tiempo fuera, se reinició el programa de posposición del choque al principio del intervalo respuesta-choque de 30 s. En la condición experimental la duración del tiempo fuera se redujo a 0 s, de tal forma que cuando se cumplía el VI, simplemente se reiniciaba el intervalo respuesta-choque. A través de todo el experimento, las respuestas en la palanca de evitación se mantuvieron. Las respuestas en la palanca de tiempo fuera se mantuvieron durante las condiciones de línea base, pero no cuando el tiempo fuera se redujo a 0 s. Estos resultados mostraron que el responder en la palanca de tiempo fuera fue mantenido por el tiempo fuera y no por la posposición del choque que le siguió y que la confusión presente en muchos estudios de tiempo fuera de la evitación puede ser fácilmente descartada.

Palabras clave: tiempo fuera durante la evitación, evitación, reforzamiento negativo, frecuencia de reducción del choque, palanqueo, ratas

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Studies of negative reinforcement have fueled theoretical debate about the relative merits of molar versus molecular accounts of behavior. Much of the debate has focused on the maintenance of avoidance behavior on free-operant schedules of shock-postponement (e.g., Sidman, 1953) or deletion (e.g., de Villiers, 1972). When avoidance behavior is proficient, it is difficult to discern short-term or molecular changes in the subject's environment before and after a response -- both usually are free of shock. Thus, it would appear that the maintenance of behavior must be attributed to long-term or molar factors such as the overall correlation between responding and shock frequency (e.g., Herrnstein, 1969; Hineline, 1981). Nevertheless, theorists of a molecular bent have proposed plausible hypotheses about short-term consequences of avoidance responses that might function as reinforcers (e.g, Anger, 1963; Dinsmoor, 1977). The problem is that these consequences involve changes in inconspicuous stimuli that generally fall outside the experimenter's control (for an interesting exception, see Dinsmoor & Sears, 1973).

An alternative preparation for the analysis of negative reinforcement -- one that may be less susceptible to the theoretical and procedural contention that has surrounded free-operant avoidance -- was developed by Verhave (1962). In a typical application (e.g, Perone & Galizio, 1987), a rat is presented with concurrent schedules, each associated with its own response lever. By pressing one lever, the rat avoids shock on a conventional shock-postponement schedule. By pressing the other lever, the rat occasionally suspends the avoidance schedule and any correlated stimuli for a minute or two -- that is, it produces a signaled timeout from avoidance. Although timeout from avoidance is a complex environmental event, it has a clear locus in time and can be scheduled in essentially the same way as more common reinforcers such as food. Timeout from avoidance maintains steady-state responding on fixed-ratio (Sidman, 1962), fixed-interval (Findley & Ames, 1965), variable-interval (Courtney & Perone, 1992; Galizio & Liborio, 1995; Perone & Galizio, 1987), and variable-ratio (Galizio, Hale, Liborio, & Miller, 1993; Galizio & Liborio, 1995) schedules. Thus, the study of responding maintained by timeout from avoidance involves a situation in which the reinforcing event is clear and readily controlled. These are distinct advantages over the study of avoidance behavior, a situation in which the reinforcer is unclear and open to contention. From a procedural standpoint the timeout preparation is more complex than an avoidance-only preparation, but from an analytic standpoint it appears to be simpler.

Although it is established that timeout from avoidance can be an effective reinforcer, the specific variables that underlie its reinforcing function have not been determined. The investigation of these variables should prove fruitful in the analysis of molar and molecular control over behavior. A timeout involves several changes in the experimental environment. To date, research has considered the removal of stimuli associated with the avoidance contingency, the reduction in the rate of shock delivery from some prevailing rate during avoidance to zero during timeout, and the parallel reduction in response effort associated with avoidance.

Perone and Galizio (1987) eliminated stimulus change as a possible source of reinforcement. After establishing stable responding in rats on a variable-interval schedule of timeout, they replaced the timeouts with "sham timeouts" during which the usual stimulus changes occurred (removal of general illumination, white noise, and the timeout lever) but the avoidance contingency remained in effect. Responding on the timeout lever extinguished, and reinstatement of the real timeouts led to rapid recovery.

Courtney and Perone (1992) examined the contributions of reductions in shock frequency and response effort to the reinforcing efficacy of timeout from avoidance. By manipulating the parameters of the avoidance contingency, they generated a range of received shock rates during time-in as well as a range of avoidance response rates. Thus, a timeout afforded varying degrees of shock-frequency reduction and response-effort reduction. The generalized matching law (Baum, 1974) was used to assess the sensitivity of responding on the timeout lever to these two factors. Responding was weakly related to the degree of shock-frequency reduction afforded by the timeouts, but highly sensitive to the degree of effort reduction. Courtney and Perone concluded that timeout from avoidance is effective as a reinforcer because it allows the subject to escape a contingency that requires sustained responding and enter an alternative situation with no response requirement.

The present experiment was concerned with a less conspicuous aspect of the timeout preparation: the state of the environment immediately after the timeout. In most of the studies of timeout cited here (the exception is Courtney & Perone, 1992), the avoidance contingency involved the shock-postponement schedule developed by Sidman (1953). Shocks were programmed at short intervals (the shock-shock or SS interval, usually 5 s) unless the rat pressed the avoidance lever, which postponed the train of shocks for a longer interval (the response-shock or RS interval, usually 30 s). This shock-postponement schedule was suspended during a timeout. When the timeout ended and the shock-postponement schedule was reinstated, the RS interval was reset to the beginning, so that shocks were postponed for the full length of the RS interval. The alternative -- to restore the schedule to its state immediately before onset of the timeout -- was not feasible given the limitations of the electromechanical equipment used by Perone and Galizio (1987), and the precedent established in that work was followed in the subsequent studies. Thus, responding on the timeout lever may be regarded as having two consequences: the timeout itself, followed by the postponement of shock by the length of the RS interval.

We considered two possible methods to assess the contribution of the shock-postponement function. Both included a baseline condition in which pressing the timeout lever would produce, according to a variable-interval (VI) schedule, a 90-s timeout followed by a reset of the RS interval. The experimental conditions in the two methods differed. In one case, after each timeout the shock-postponement schedule would be restored to the exact point in effect when the timeout was initiated. To the extent that intermittent shock-postponement contributes to the maintenance of responding on the timeout lever during the baseline condition, responding should be reduced during the experimental condition. We decided against this procedure, however, because timeouts could be initiated late in the RS or SS interval and, in such cases, the timeout would be followed by essentially unavoidable shock. Responding on the timeout lever might be reduced by the pairing of timeout with shock (independently of the effect of removing the shock-postponement function), thus complicating interpretation. Instead we chose an experimental procedure in which the timeout duration would be reduced to 0 s, so that satisfying the VI schedule would merely reset the RS interval. If intermittent shock-postponement contributes to the maintenance of the responding on the timeout lever, responding in this experimental condition should be maintained.

METHOD

Subjects

Three adult male Sprague-Dawley rats were housed individually under a 12:12 hour reversed light/dark cycle with free access to food and water. Experimental sessions were conducted during the dark part of the cycle.

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 ceiling were constructed of Plexiglas, and the end walls of 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 of 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 retractable and the right was fixed in place. The levers required a force of approximately 0.3 N to operate. Grason-Stadler shock generators (E1064GS) could deliver scrambled 1-mA shocks lasting 0.5 s through the grid floors (but not the levers or walls). Each chamber was enclosed in a sound-attenuating box equipped with a fan for ventilation and a speaker for white noise. Throughout the experiment, activation of the white noise generator and houselight signaled the onset of the session, and these events were terminated at the end of the session, as well as during the timeout periods. Control and recording operations were accomplished with microcomputers.

Preliminary Training

Avoidance. With the left lever retracted, each rat was trained with a shaping procedure to avoid shock by pressing the right lever, the avoidance lever. The experimenter delivered or withheld shocks while successive approximations to lever-press responses were followed by 1.5 s offset of white noise (feedback stimulus) and a shock-free period of 60 s. After shaping, control was transferred to a free-operant avoidance schedule (Sidman, 1953) in which each response postponed shock for 60 s (RS interval) and in the absence of responding, shocks were delivered every 5 s (SS interval). Over several daily sessions, the response feedback was reduced from 1.5 s to 0.5 s and the RS interval was reduced from 60 s to 45 s to 30 s.

When each rat was consistently avoiding shock, the same procedure was used to establish responding on the left lever, with the right lever removed. When responding on the left lever was consistent, an alternating procedure was begun. On alternate sessions, only the left or right lever was mounted in the chamber; the purpose was to facilitate responding on both levers so that the avoidance and timeout schedules would be contacted when they were made available concurrently.

Response-independent timeout. A multiple schedule was used to establish a discrimination between periods of avoidance and timeout from avoidance. The sessions consisted of alternating 10-min components of avoidance (signaled by the houselight and the presence of white noise) and response-independent timeout (houselight and white noise off, shock-postponement schedule suspended). To facilitate extinction of avoidance responses during the timeout component, the component could not end within 1 min of a response. Perhaps because the stimuli accompanying timeout were the same as those before and after the sessions, this contingency was rarely contacted. As in the previous phase, the left and right levers were used on alternate days. Training on the multiple schedule continued until virtually all of the responses occurred during the avoidance component.

Response-dependent timeout. During the remainder of the study, presentations of timeout were contingent upon pressing the left lever (timeout lever). Both levers were inserted at the onset of the session, and responses on the avoidance lever (right lever) continued to postpone shocks while responses on the timeout lever produced an audible relay click (response feedback) and a 5-min timeout. As in the previous phase, timeout was accompanied by the offset of white noise and the houselight. In addition, the timeout lever was retracted (but the avoidance lever remained fixed in place). Over several sessions the timeout duration was reduced from 5 min to 90 s, and the timeout schedule was leaned from FR 1 to VI 45-s (Fleshler & Hoffman, 1962).

Procedure

In the experiment proper, as in the final phase of preliminary training, the avoidance and timeout schedules were programmed concurrently. The avoidance schedule was held constant: Throughout the experiment, pressing the avoidance lever postponed shock according to a free-operant schedule with an RS value of 30 s and an SS value of 5 s. The consequences of pressing the timeout lever were varied across the three experimental phases. In the first and third phases, responses on the timeout lever produced, according to a VI 45-s schedule, a 90-s timeout. After each timeout, the shock-postponement schedule was restarted at the beginning of the RS interval. In the other phase, the timeout duration was reduced to 0 s. The VI 45-s schedule of timeout production remained in effect, and satisfying the schedule continued to produce the post-timeout consequence: resetting the shock-postponement schedule to the beginning of the RS interval.

Table 1. Summary of conditions, response rates on the timeout (TO) and avoidance (Av.) levers, rates of timeout production, received rates of shock, avoidance proficiency based on the postponement of shocks programmed by the response-shock (RS) interval, and discrimination (Disc.) ratios (percentage of avoidance responses emitted during time-in). Data are means over the last 10 sessions in each condition, with standard deviations in parentheses.

Rat	TO (s)	Sessions	TO Resp. per Min	TO's per Min	Av. Resp per Min	Shocks per Min	% RS Avoided	Disc. Ratio
C1	90	31	1.83	0.85	8.56	0.96	58.5	100.0
			(0.48)	(0.08)	(1.41)	(0.17)	(8.9)	(0.0)
	0	10	0.05	0.05	8.34	0.24	89.4	--
			(0.08)	(0.07)	(0.89)	(0.11)	(4.5)	--
	90	21	1.88	0.89	6.57	0.98	61.1	100.0
			(0.22)	(0.06)	(0.80)	(0.23)	(9.1)	(0.0)
C4	90	23	3.40	0.99	7.33	0.05	97.8	99.9
			(0.43)	(0.47)	(1.71)	(0.03)	(1.4)	(0.3)
	0	11	0.13	0.11	7.91	0.03	98.2	--
			(0.12)	(0.09)	(0.93)	(0.02)	(0.6)	--
	90	32	2.53	0.94	6.64	0.08	97.5	100.0
			(0.28)	(0.06)	(0.80)	(0.07)	(2.2)	(0.0)
R4	90	22	2.41	0.90	10.70	0.29	91.7	99.9
			(0.67)	(0.12)	(1.32)	(0.09)	(2.6)	(0.0)
	0	13	0.04	0.04	7.41	0.14	94.9	--
			(0.03)	(0.03)	(1.14)	(0.06)	(1.9)	--
	90	32	3.22	0.97	5.36	0.73	77.6	100.0
			(0.41)	(0.04)	(0.58)	(0.18)	(5.8)	(0.0)

Sessions lasted 120 min (including timeouts). The 90-s timeout conditions lasted at least 20 sessions, until it was apparent by visual inspection that the procedures maintained steady rates of responding on the timeout lever over the last 10 sessions. The 0-s timeout condition was ended when the mean rate on the timeout lever over the last 10 sessions fell to 10% or less of the mean rate over the last 5 sessions of the previous 90-s condition. The number of sessions per condition is shown in Table 1.

RESULTS

The results are taken from the final 100 min of the last 10 sessions of each condition. As is customary in studies of avoidance, the first 20 min of each session constituted a "warm-up" period and the data collected during this period are not reported.

Figure 1 shows session-by-session responses rates on the timeout lever. Responding was maintained at low but steady rates in the initial 90-s timeout condition. When the timeout duration was reduced to 0 s, however, responding extinguished, even though satisfying the VI schedule continued to restart the shock-postponement schedule at the beginning of the RS interval. When the 90-s timeout was restored in the final phase, responding on the timeout lever recovered.

Table 1 summarizes several additional aspects of the rats' performances. Response rates on the avoidance lever did not vary systematically as a function of timeout duration, but there was a tendency for rates to fall over the course of the experiment. All three rats responded at their lowest rate in the final phase and, as a consequence, experienced the highest rate of shock. Avoidance proficiency varied considerably. The table shows two measures of proficiency: percentage of the RS shocks avoided (see Perone & Galizio, 1987, p. 101, for an explanation) and rate of received shocks (a measure that includes both RS and SS shocks). Rat C4 was highly proficient throughout the experiment, avoiding about 98% of the RS shocks and receiving shock at rates of less than 0.10 per min. Rat R4 also was proficient, especially in the first two phases when it avoided over 90% of the RS shocks and received less than 0.3 shocks per min. Rat C1's avoidance was relatively poor except in the 0-s timeout condition, when its performance nearly matched Rat R4. Perhaps the extinction of responding on the timeout lever was a factor: Removing the competing source of reinforcement on the timeout lever may have allowed the shock-postponement schedule to take more effective control over responding on the avoidance lever. Table 1 also shows the percentage of avoidance responses made during time-in, while the shock-postponement schedule was in effect. The percentages approach 100 in every case, showing that the rats almost never pressed the avoidance lever while a timeout was in progress.

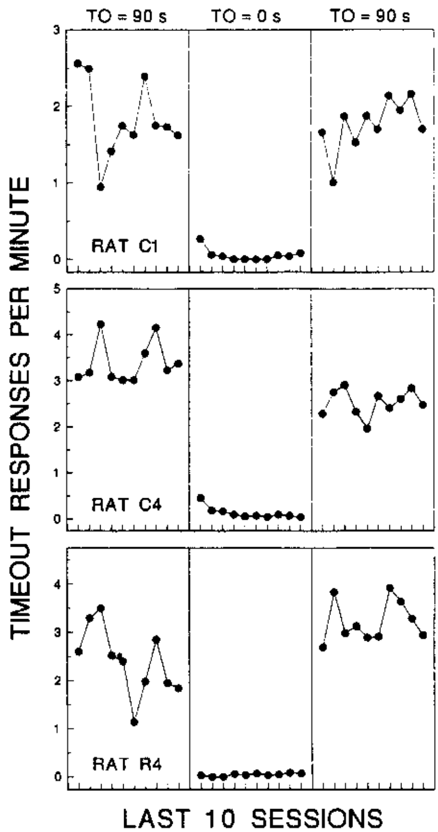

Figure 1. Response rates on the timeout lever during the last 10 sessions of each condition. Note that the scale of the ordinate varies across the three rats.

DISCUSSION

By satisfying a VI 45-s schedule, responding on the timeout lever occasionally reset the shock-postponement contingency on the avoidance lever to the start of the RS interval. When this was the sole consequence arranged by the VI schedule, responding on the timeout lever extinguished. But when shock-postponement was preceded by a 90-s timeout, responding was maintained. These results establish that responding on the timeout lever was maintained by the timeout from avoidance, not by the shock-postponement that followed the timeout.

Consideration of the results in terms of delay-of-reinforcement also argues against a significant role for shock-postponement in the maintenance of responding on the timeout lever. In the baseline condition, any reinforcing effect of shock-postponement should have been *reduced* by the 90-s timeout which necessarily delayed the onset of this event. But responding on the timeout lever was maintained in the baseline condition. When the delay was eliminated by reducing the timeout to 0 s in the experimental condition, the reinforcing efficacy of shock-postponement should have been *increased*. Nevertheless, responding on the timeout lever extinguished.

The reinforcing efficacy of the 90-s timeout was clear in all three rats, despite individual differences in avoidance proficiency and contact with shock. Even the highly proficient Rat C4, whose avoidance was so successful that shock rates were always below 0.10 per min, responded reliably on the timeout lever. It seems unlikely that the reinforcing efficacy of timeout could be based on escape from such a low rate of shock. Further evidence against a shock-frequency account comes from the other two rats, who contacted shock at rates 5 to 20 times higher than Rat C4, but whose rates of responding on the timeout lever were no higher than C4's. If the effectiveness of timeout is based on shock-frequency reduction, one would hope to see some hint of a relation across so wide a relative range of the critical variable.

Why, then, was timeout reinforcing? Previous research (Courtney & Perone, 1992) has pointed to the escape from the effort of avoidance responding, and the present results suggest a reason why this should be so. Of the two events interrupted by timeout, avoidance responses occurred far more frequently than shocks. Inspection of Table 1 shows that, in the conditions with the 90-s timeout, avoidance responses occurred at rates that were 7 to 147 times higher than the rates of shock. At either extreme, it seems plausible that the change in responding controlled by the timeout would be more salient than the change in shock frequency associated with the timeout. Consider Rat C4's initial condition, in which an avoidance response occurred about every 8 s on average and a shock occurred every 20 *minutes*. Interruption of responding by a timeout would be contacted shortly after its onset, but contact with the interruption of shock would depend on an accumulation of more than 13 instances of timeout. At the other extreme is Rat C1's final condition, in which a response occurred every 9 s and a shock every minute. Still, the interruption of responding would be contacted shortly after the onset of a timeout, whereas the change in shock rate would be delayed until the majority of the timeout had transpired.

Because intermittent shock-postponement was ineffective in reinforcing responding on the timeout lever, the present experiment might be seen as suggesting a limit on the extent to which remote consequences can influence behavior. But the results do not preclude the possibility of an effect in more suitable circumstances. The reinforcing effect of an event cannot be isolated from the context of its occurrence. In the present experiment, the intermittent shock-postponement produced by pressing the timeout lever occurred in a context in which an alternative response -- the avoidance response -- produced the same degree of shock-postponement on a continuous basis. Given a choice between a VI 45-s schedule and a continuous schedule leading to the same consequence, consideration of the matching law (Baum, 1974) leads to the prediction that the continuous schedule will control behavior. Perhaps in the absence of such a strong competitor, an intermittent schedule of shock-postponement, arranged by itself, could be effective. The issue motivating the present experiment, however, is the confound between timeout and intermittent shock-postponement when timeout and avoidance from timeout have been programmed concurrently. Thus, the experiment was designed specifically to assess the reinforcing efficacy of intermittent shock-postponement in the context of a concurrent shock-postponement schedule. By showing that behavior is insensitive to intermittent shock-postponement in this context, the present results indicate that the confound in so many studies of timeout from avoidance may be safely disregarded.

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