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SOME ODD PROBLEMS FOR MODERN BEHAVIOR THEORY: THE CASE OF THE SWIMMING RATS

ALGUNOS PROBLEMAS EXTRAÑOS PARA UNA TEORÍA MODERNA DE LA CONDUCTA: EL CASO DE LAS RATAS NADANDO

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ABSTRACT

The swimming situation has been used extensively to study the role of stress on the shortening of the rat's life expectancy, including its sudden death. In contrast, the present paper describes some experiments on conditions that improve their life expectancy in the same situation. The first experiment showed that the rat's activity in the water predicts its life expectancy. The second experiment showed that repeated exposures to the swimming situation improve the rat's chances of survival. The third experiment showed that the rat's life expectancy in the swimming situation increases more rapidly with frequent than with infrequent practice. In the last experiment rescuing the rat from the water was suggested to be more important to increase its life expectancy than simple exposure to the swimming situation. These results were discussed as evidence of the influence of known conditioning variables on the life expectancy of organisms.

Key words: swimming situation, sudden death, survival, behavior analysis, rats.

RESUMEN

La situación de nado se ha usado ampliamente para estudiar el papel del estrés sobre la disminución de la expectativa de vida en las ratas, incluyendo su muerte súbita. En contraste, el presente trabajo describe algunos experimentos sobre condiciones que mejoran la expectativa de vida de las ratas en la misma situación. El primer experimento mostró que la actividad de las ratas en el agua predice su expectativa de vida. El

[1]This paper is dedicated to the memory of Nat Schoenfeld, teacher and friend. The author wishes to express gratitude to Andy Lattal for reviewing an earlier version of this manuscript. Also to Raúl Avila and Luis M. Gallardo for their help in preparing the final version of the paper. Reprints may be obtained from Carlos A. Bruner, Facultad de Psicología, Universidad Nacional Autónoma de México, Ave. Universidad 3004, Col. Copilco Universidad, México, D.F., 04510, México.

segundo experimento mostró que exposiciones repetidas a la situación de nado mejoran la oportunidad de supervivencia de las ratas. El tercer experimento mostró que la expectativa de vida de las ratas en la situación de nado incrementa más rapidamente con práctica frecuente que con práctica infrecuente. El último experimento sugirió que rescatar a las ratas del agua es más importante para incrementar su expectativa de vida, que la simple exposición a la situación de nado. Estos resultados se discuten como evidencia de la influencia de variables conocidas en el condicionamiento sobre la expectativa de vida de los organismos.

Palabras clave: situación de nado, muerte súbita, supervivencia, análisis de la conducta, ratas.

The title of the present paper is, of course, a play on the titles of two well known papers by Nat Schoenfeld (Schoenfeld, 1966; 1972), who taught the author to view the whole of psychology from the standpoint of conditioning. The title of the paper is also meant to emphasize that its research theme, is somewhat unconventional for a behavior analyst. Nevertheless, the author decided to describe his work on this area to pay homage to the breath of interests of his mentor.

Cannon (1942) conducted the first investigation on "voodoo" death and concluded that in such cases, psychological influences were responsible for a sort of heart failure among the victims. After Cannon's pioneering studies on death due to psychological stress, other instances, involving different populations were reported. For example, Moritz and Zamcheck (1946) reported cases of sudden death among prisoners and soldiers in combat. Fisher (unpublished, cited by Richter, 1957) reported such cases among persons who had previously attempted suicide and more recently, Grady (1982), reported cases of sudden death among refugees and immigrants from Southeast Asia living in the United States. In the latter report, culture shock seems to have been responsible for these premature deaths.

Inspired by Cannon's studies of "voodoo" death, Richter (1957) investigated sudden death in recently-captured wild rats that were forced to swim in a cylinder filled with water. He found that if the rats were subjected to stress prior to the swimming session (such as forcefully immobilizing the rat or cutting its whiskers), the rat died, often within a few minutes after being dropped into the water. Other stressful events concurrent with swimming (such as shooting a jet of water over the rat's head or exposing the rats to very hot or cold water), also were conducive to sudden death. In addition to demonstrating that stress was involved in the sudden death of rats, Richter also observed that instead of drowning, the rats died as a consequence of a progressive slowing in heartbeat (also known as vagal death) and suggested the same kind of heart failure as an explanation of sudden death in humans.

Further research demonstrated that sudden death also occurs in domesticated rats (e.g., Griffiths, 1960) and that minor stress, such as rearing the rats in isolation (Rosellini, Binik and Seligman, 1976), or even handling the rats before swimming (Lynch and Katcher, 1974; Hughes and Lynch, 1978) could cause sudden death in the swimming situation. Furthermore, excessively overweight wild male rats were more prone to suffer a sudden death while swimming than were their domesticated, female or lean counterparts (Hughes and Lynch, 1978).

In addition to isolating independent variables related to the sudden death of swimming rats, some of the investigations mentioned above revealed that the swimming pattern was a good predictor of their life expectancy in the water. For example, Hughes and Lynch (1978) found that diving often precedes sudden death (see also Wolf, 1967). Binik, Theriault and Shustack (1977) and Binik, Deikel, Theriault, Shustack and Balthazard (1979) found, that in addition to diving, difficulties in staying afloat and, in general agitated movements, conducive to progressive sinking predicted the rat's demise. In contrast, swimming rhythmically and just floating, with few emotional reactions (e.g., defecation) predicted survival. Thus, in recent research, rats have been classified as "victims" or "survivors", based on behavioral criteria instead of actually letting the rats to die in the water, as originally done in Richter's studies.

The rest of this paper will describe some experiments conducted in the author's laboratory involving rats exposed to the swimming situation[2].

Experiment 1. Activity in the Water Predicts Life Expectancy in the Swimming Situation

Substituting the rat's behavior while swimming for the actual time alive as the dependent variable in this type of research not only avoided ethical objections, but, as will be described latter on, also enabled the study of the effects of independent variables that decrease the rat's chances of suffering a sudden death. The behavioral categories of "victim" and "survivor" were intended to classify individual subjects as such, but did not allow the continuous monitoring, at any given moment during a swimming session, of the individual rat's chances of survival. A possible solution to the problem of transforming the dichotomous categories of "victim" and "survivor" into a continuous dependent variable, was to observe the rat's general activity in the

[2]The experiments to be described have been arranged in this order to facilitate their description, but were neither, conducted nor published, in the same sequence.

water. Such an alternative dependent variable seemed plausible because the behavioral category of "victim" involved many non-specific movements that resulted in increased activity. By contrast, the behavioral category of "survivor" involved less activity or mobility in the water. Thus, Bruner and Vargas (1994) examined the validity of the rat's general activity in the water as an estimate of life expectancy in the swimming situation. In his pioneer studies on sudden death in rats, Richter (1957) measured the rat's actual survival time in the swimming situation under several water temperatures. While rats survived as long as 80 hours in 36°C water, increasing or decreasing the water temperature about this point, decreased survival times in an orderly manner. Under extreme temperatures of about 13 and 48°C, the rats died within minutes. Thus, corresponding variations in activity as a function of the same independent variable would confirm the validity of activity as a predictor of the rat's life expectancy.

For all of the following experiments a 40 cm square water tank was constructed. The tank was equipped with two sets of two equidistant light beams on each side, one set just below the water surface and the second set 10 cm deeper. When the rat swam across any of these beams counters were activated. Water temperature was set and monitored using a mercury thermometer.

Purpose

To observe the rat's activity as a function of different water temperatures.

Experimental Variables

Subjects and response: Fifty five-month old, female rats at their *ad libitum* weight; swimming.

Independent variable: Water temperature set at 14, 17, 20, 23, 29, 32, 35, 38, 41 and 47°C.

Dependent variable: Activity (rate of beam interruptions).

Method

The rats were distributed randomly into ten groups and subsequently, the five subjects within a group, were each exposed to two different water temperatures on two sessions conducted at the same time on consecutive days. Session duration was held constant at 20 minutes, unless the rat's behavior was that of a "victim", in which case the subject was rescued from the water and the session terminated earlier. Soiled water was replaced after each individual session and the fresh water was initially set at the prescribed temperature. However, when water temperature was set from 14 to 23°C, it increased 1 or 2°C during the 20-min session, and when water temperature was set from 29 to 47°C, it dropped 1 or 2°C.

Findings

None of the rats in this experiment died, although some had to be rescued from very cold or very warm water. For this reason the mean activity of each group is shown as a rate in Figure 1.

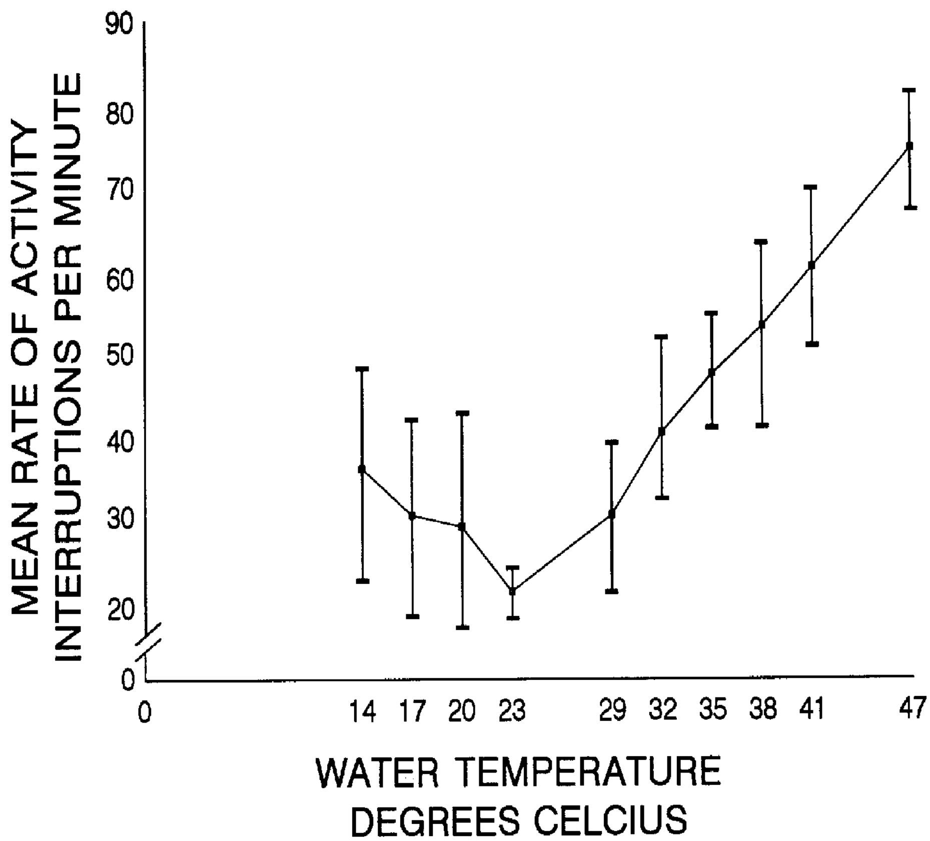

Figure 1. Mean activity as a function of water temperature. The brackets show a standard deviation about each five-subject mean. These data were obtained by averaging the first and the second sessions. From The activity of rats in a swimming situation as a function of water temperature, by C. À. Bruner and I. Vargas, 1994, *Physiology and Behavior, 55*, p. 27. Copyright 1993 by Pergamon Press Ltd. Reprinted with permission.

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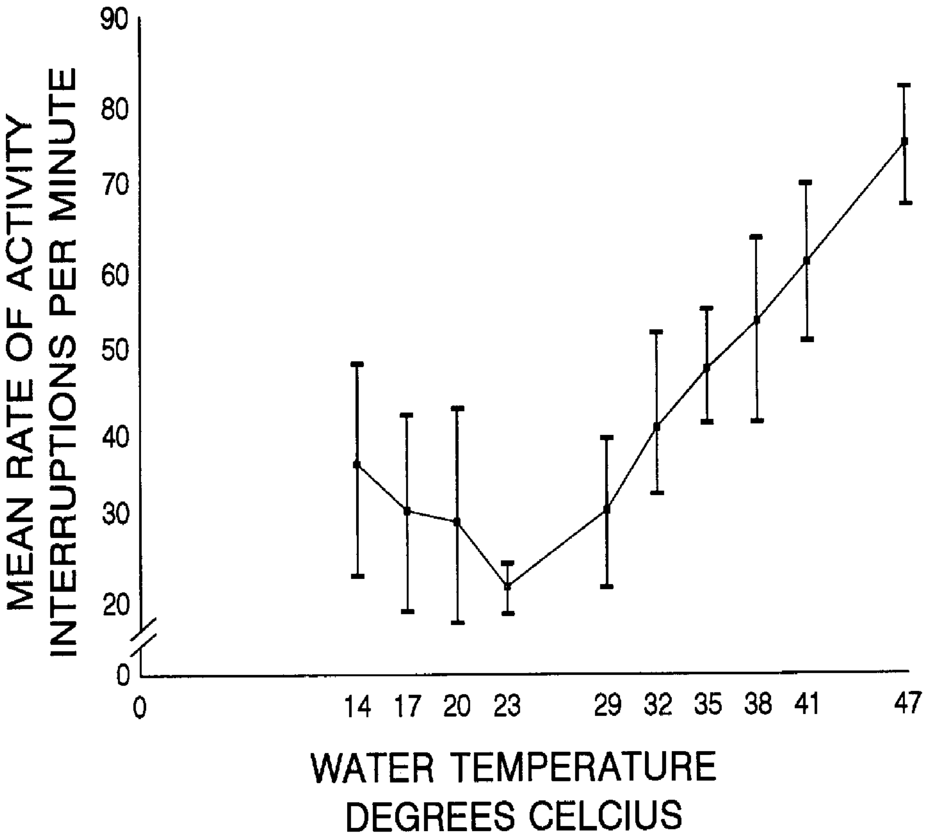

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Figure 1 shows that mean activity was lowest when the water temperature was 23°C and then increased constantly as the water temperature increased or decreased. In addition to recording activity, the behavioral categories of "victim" and "survivor" also were recorded by two independent observers. The observer's judgements were not only highly reliable (oscillating between rho=.95 to 1.0) but covaried precisely with activity. While in the range from 23 to 35°C all the rats were deemed "survivors", increasing and decreasing water temperature about this range increased the proportion of "victims", until at the extreme temperatures of 14 and 47°C, all the rats in the group were judged dead.

Discussion

The activity function shown in Figure 1 resembled the reciprocal of the function obtained by Richter, using actual survival times and therefore confirmed the validity of the rat's activity in the water as a predictor of its life expectancy. The precise covariation of the "victim" and "survivor" categories with activity, lent further credibility to activity as a predictor of life expectancy in the swimming situation.

Possibly because they actually let the rats to die in the water, most previous research involving the swimming situation focused on decreases in their life expectancy, of which sudden death, represented the extreme case. Yet, the opposite case; i.e., survival under adverse circumstances is at least equally interesting. For instance, the literature on sea disasters (e.g., Henderson and Bostock, 1977) includes many reports about castaways dying only a few minutes after a shipwreck, possibly being cases of sudden death. However, the same literature also includes cases of long periods or survival, even without means of flotation. Reports of helicopter crashes in the cold water of the North Sea (Hytten, 1989; Hytten and Herlofsen, 1989) are particularly interesting because, in addition to describing other cases of survival (along with other cases of apparent sudden death), an effort was made to isolate independent variables responsible for the variability in life expectancy. Not surprisingly, training and experience in dealing with emergency situations have proven effective in increasing survival.

Given the ethical constrains on exploring independent variables involved in increasing life expectation in dangerous situations with human subjects, Richter's swimming situation with rats seemed suitable for the purpose. The experiments that follow will describe some efforts to isolate independent variables involved in increasing the life expectancy of rats in the swimming situation.

Experiment 2. Experience Improves Life Expectancy in the Swimming Situation

In the course of his studies on the sudden death of rats in the swimming situation, Richter (1957) observed that a brief swimming session, followed by the rat's rescue from the water, decreased its risk of sudden death during subsequent tests. Binik, Theriault and Shustack (1977), using behavioral criteria to classify their rats as "victims" or "survivors", exposed different groups of rats to one, three or six 1-minute swimming sessions. They found that the proportion of "survivors" increased with the number of sessions. Bruner and Vargas (1992 a), after establishing that the rat's activity in the water predicts life expectancy at any given moment during the swimming sessions, extended the rat's exposure to the swimming situation.

Purpose

To observe the rat's activity during 40 sessions.

Experimental Variables

Subjects and response: Four five-month old, female rats at their *ad libitum* weight; swimming

Independent Variable: Forty 20-min sessions conducted at the same time every day over consecutive days (seven days per week).

Dependent Variable: Activity (rate of beam interruptions).

Method

The four rats were each allowed to swim in newly replaced water, set at 36°C at the beginning of every new session. The water temperature, however, dropped 1 or 2°C in the course of the session.

Findings

Figure 2 shows the mean rate of activity of the four rats distributed across four 5-min subintervals of the swimming session over eight blocks of sessions. Activity decreased with repeated exposures to the swimming situation. Such decreases occurred both from session to session and within sessions.

Discussion

If activity decreases reflect increases in life expectancy, then these results indicate a continuous improvement in the rat's chances of survival over 40 sessions. Furthermore, the intrasession decreases in activity suggest that the rat's chances of survival improved from the beginning to the end of the sessions.

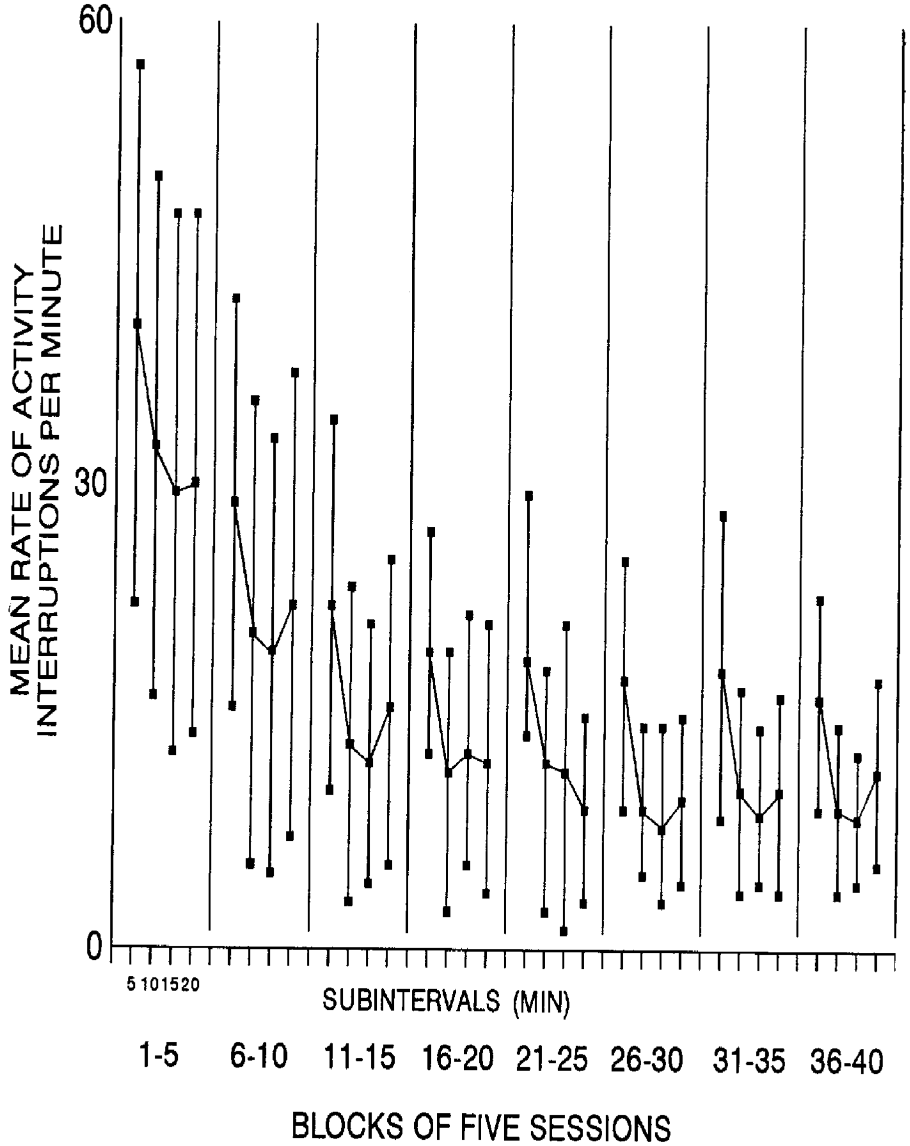

Figure 2. Mean activity distributed across successive 5-min subintervals of the 20-min swimming session. Each panel of the figure shows these data as an average of a 5-session block. Brackets show a standard deviation about each four-subject mean. From Un modelo animal para el estudio de la esperanza, by C. A. Bruner and I. Vargas, 1992, In *La Psicología Social en México, 4*, p. 376. Copyright 1992 by Asociación Mexicana de Psicología Social. Adapted with permission.

Experiment 3. Frequent Practice in the Swimming Situation Increases Life Expectancy more than Infrequent Practice

The data shown in Figure 2 were similar to data reported in a similar format on the extinction of a previously reinforced operant response (Schoenfeld, Antonitis and Bersh, 1950). The similarity between the time course of the swimming activity and other extinction functions, suggested that possibly the former was due to the extinction of fear of swimming (or as Nevin suggested to the author in a personal communication in 1992, due to simple habituation). Such an interpretation, of course, does not rule out the simultaneous acquisition of adaptive responses to the situation, as suggested by Hawkins, Hicks, Phillips and Moore (1978).

Maier, Seligman and Solomon (1969) demonstrated that frequent exposure to a fear-eliciting situation produces faster extinction of the emotional response than infrequent exposure, thus supporting "fear-incubation" theory (e.g., Eysenck, 1976). If, as suspected, improvement in the rat's life expectancy depended on the extinction of an emotional response over repeated exposures to the swimming situation, then different inter-session periods should produce different degrees of activity. To test this possibility Bruner and Vargas (1992 b) conducted the following experiment.

Purpose

To observe activity in swimming sessions separated by different periods of time.

Experimental Variables

Subjects and response: Four five-month old, female rats at their *ad libitum* weight; swimming.

Independent Variable: Forty 20-min sessions spaced 12 or 48 hours apart.

Dependent Variable: Activity (rate of beam interruptions).

Method

Two rats were exposed to swimming sessions spaced 12 hours apart while two different rats were exposed to swimming sessions spaced 48 hours apart. After each session the soiled water was replaced by fresh water and set initially at 36°C, but dropped 1 or 2°C in the course of each individual 20-min session.

Findings

Figure 3 shows the mean rate of activity for each pair of rats separately. As in the preceding figure, mean activity is shown distributed across four subintervals of the swimming sessions over successive five-session blocks.

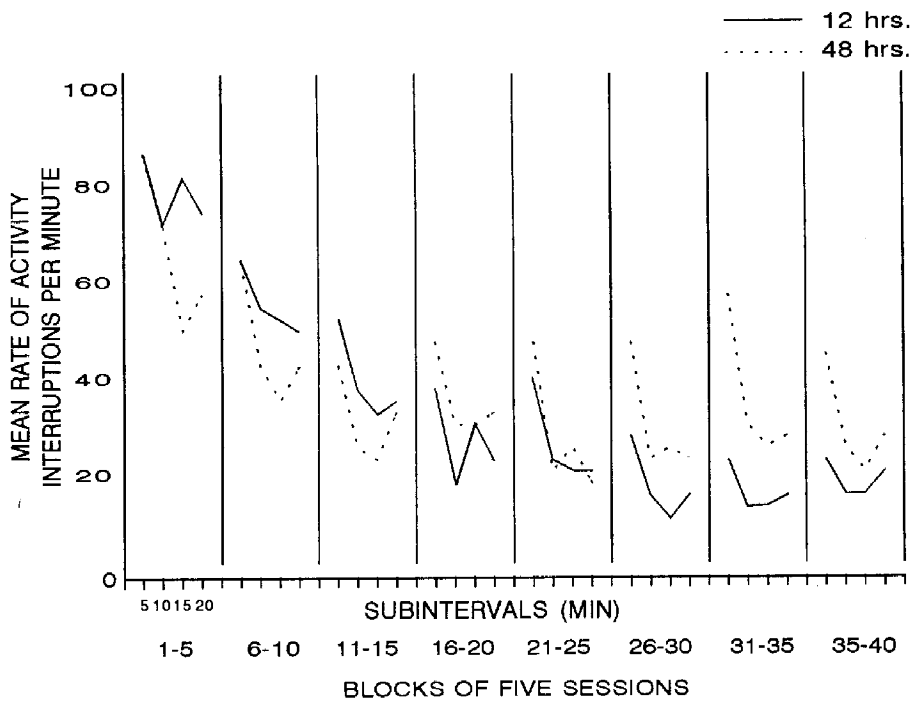

Figure 3. Mean activity distributed across four 5-min subintervals of the swimming session. Each panel of the figure shows these data as an average of 5 sessions. The solid line represents the mean of the two rats subjected to 12-hour intersession interval while the discontinuous line shows the mean of the two rats that swam on sessions separated by 48 hours. From Effects of session duration and intersession interval on the activity of rats in a swimming situation, by C. A. Bruner and I. Vargas, 1992, *Revista Mexicana de Psicología, 9*, p. 96. Copyright 1992 by Sociedad Mexicana de Psicología. Adapted with permission.

Figure 3 shows that activity decreased within -as well as between-sessions as a function of repeated exposures to the swimming situation. In addition, Figure 3 shows that activity decreased faster for the rats exposed to sessions separated by 12 hours than for the rats exposed to sessions separated by 48 hours.

Discussion

The results of this experiment replicated the findings of the preceding experiment concerning a within -and between- session improvement in the rat's chances of surviving. In addition the fact that activity decreased faster with frequent exposure to the swimming situation suggested that such improvement in the rat's life expectancy covaried with the extinction of an emotional, fear response elicited by the swimming situation.

Experiment 4. Life Expectancy in the Swimming Situation Depends on Rescue Schedule

As mentioned before, Richter (1957) noted that if the rats were taken out of the water and left to rest briefly, when forced to swim again, even under adverse circumstances (such as under a jet of water that prevented their floating), the rats survived for as long as 80 hours. Richter speculated that possibly, such rescue generated "hope" and encouraged the rat to resist such a long time. Leaving the concept of "hope" aside, it should be noted that the swimming sessions necessarily terminate when the rat is taken out of the water. Therefore, rescuing the rat is confounded with exposure to the swimming situation. Could a positive ending to each swimming session account for the results reported above? Bruner and Vargas (1991) performed the following experiment.

Purpose

To observe activity under a fixed-time and a variable-time rescue schedule.

Experimental Variables

Subjects and response: Eight five-month old, female rats at their *ad libitum* weight; swimming.

Independent Variable: The fixed-time rescue schedule consisted in taking the rat out of the water after swimming sessions that lasted 20-min. The variable-time rescue schedule consisted in subjecting the rats to swimming sessions of variable duration (2, 5, 13, 20, 27, 35 or 38 min), but which according to blocks of seven sessions, also averaged 20-min.

Dependent Variable: Activity (rate of beam interruptions).

Method

Four subjects were subjected to the fixed-time rescue schedule and the other four subjects were subjected to the variable-time rescue schedule. The eight rats swam during 35 daily sessions, conducted seven days a week and at the same time every day. Thus, both groups swam for the same 700 minutes and were rescued the same 35 times. The only difference between these two groups was the rescue schedule. The soiled water was replaced after each individual session and initially set at 36°C.

Findings

Figure 4 shows the mean rate of activity for the rats subjected to the fixed- and variable-time rescue schedules as a function of five blocks of seven sessions each. The dotted lines in each group show fitted regression slopes. For both groups, mean activity decreased gradually across sessions. However, activity decreased faster for the group rescued after a fixed-time rescue schedule. The difference between the regression slopes fitted to both functions is statistically significant ($F(1,36) = 4.84$, $p < .05$).

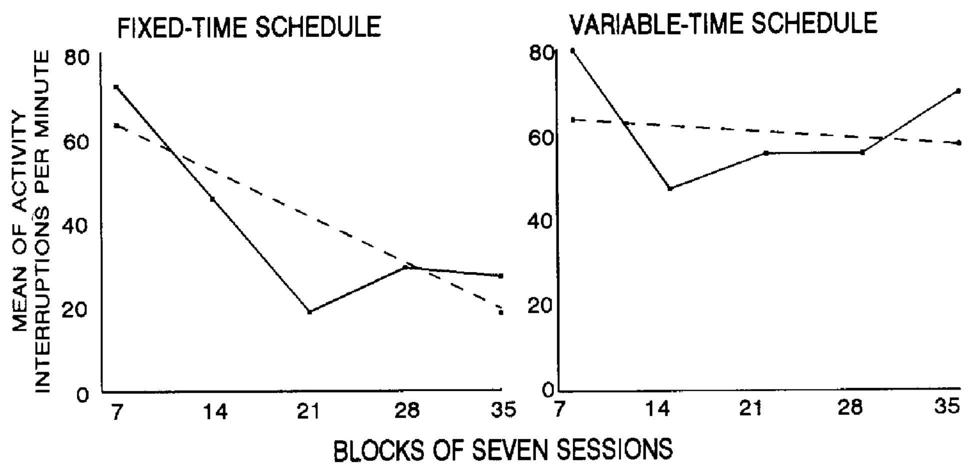

Figure 4. Mean activity as a function of five blocks of seven sessions each. The graph on the left shows the four-rat means under the fixed-time rescue schedule while the graph on the right show the same data for the four subjects exposed to the variable-time schedule. From El efecto de dos programas de rescate sobre la actividad de la rata en una situaci6n de nado, by C. A. Bruner and I. Vargas, 1991, *Revista Interamericana de Psicología, 25*, p. 167. Copyright 1991 by Sociedad Interamericana de Psicología. Adapted with permission.

Discussion

Given that the rat's activity in the water estimates its life expectancy, the fixed-time rescue schedule improved the rat's chances of survival significantly more than the variable time schedule. In addition, the idea that rescuing the rat from the water may be a positive reinforcer and therefore produce elation fits well the fear-extinction hypothesis of decreased activity. If the emotion caused by the rescue operation is "pleasurable", such emotion may have contributed to the Pavlovian counterconditioning of the fear response (e.g., Wolpe, 1958).

CONCLUSION

To turn life expectancy into an amenable subject for a conditioner, some conceptual maneuvers had to occur. Following Cannon's description of "voodoo" dead, Richter showed that sudden death also occurs in rats subjected to the swimming situation. Although Richter concentrated on the rat's demise, implicit in his original report, was the fact that life expectancy in such situation varied orderly. Subsequent research on the sudden death of swimming rats brought to the forefront the role of environmental variables in determining life duration. Thus, a problem was posed for a conditioner: to translate the different procedures used by sudden death researchers into the framework of behavior analysis. Given that the rat's life expectancy in the swimming situation is not long, such reduced life expectancy could be used as a baseline in the analysis of survival.

Letting the rat to die in the water, as done in the earlier studies was neither, palatable for ethical reasons nor convenient to study independent variables that by their very nature, require repetition and demonstrations of reversibility of behavioral effects. Although substituting the behavioral categories of "victims" and "survivors" (Binik, Theriault and Shustack, 1977) was an improvement over actually sacrificing the rats, such a dependent variable was rather clumsy. In contrast to the dichotomous categories of "victim" and "survivor", observing the rat's activity in the water seemed a more sensible choice, not only because it was amenable for automatic recording, but also because it reflected intermediate degrees of the individual subject's chances of survival. In Experiment 1, activity was shown to be a valid dependent variable to estimate the rat's life expectancy. The subsequent three experiments in this paper describe attempts to improve the life expectancy of the rats, through the manipulation of environmental variables. In Experiment 2, the repetition of the swimming session increased the rat's life expectancy. In Experiment 3, the temporal distribution of the swimming sessions had a similar effect, with shorter intersession intervals improving the rat's chances to survive more than longer intersession intervals. In Experiment 4, the rescue operation was unconfounded from the subject's exposure to water. In addition, it was subjected to a schedule. In the latter experiment, a fixed-time rescue schedule was shown to increase life expectancy more than a variable-time rescue schedule.

The results described in the present paper suggest the following analysis of previous research. In a paper titled "Giving up on life", Seligman

(1974) stated the idea that sudden death in humans as well as in other animals (including cockroaches), is due to helplessness. That is, a pervasive state within the subjects, caused by their impotence to alter current circumstances, and that in turn produces effects on both, their overt and covert behavior. Among the noxious effects of such state are physiological disturbances that may lead to death. Although in the case of swimming rats, Seligman's theory may explain sudden death under extremely adverse circumstances (such as in Richter's pioneering experiments), the present research suggests a limit to his formulation. The results described here suggest that if the rats are treated gently and literally giving the opportunity to stay alive from one session to the next, far from being helpless, they adapt remarkably well to their circumstances. As described before, the rats main strategy consist in slowing down their activity and in general, behaving in a manner consonant with the behavioral category of "survivor". None of the rats used in the present experiments either died while swimming or showed any sign of physiological disturbance (e.g., weight loss). Therefore, whether the swimming situation is lethal or not, appears to depend on the intensity of the events added to the situation, which of course, stand in a continuum of aversiveness.

Concurring with Seligman's interpretation of the rat's sudden death in the swimming situation, Porsolt, LePichon and Jalfre (1977), theorized that if the rat does not die in the water, it at least becomes "depressed" after "realizing" that escape is impossible. Furthermore, such "depression" is said to manifest itself in a decreased mobility time (measured by an observer equipped with a stopwatch), from a first to a second exposure to the swimming situation. Thus, Porsolt, et al. have used the swimming situation as a model of "depression" in the rat and to test potential antidepressant substances. Some substance is administered to the rat and if mobility time increases, the substance is said to have antidepressant properties. Intriguingly such a model of "depression" prospered separately from the more recent research on sudden death and has rarely, if ever cited the latter literature (see Borsini and Melli, 1988 for a relatively recent review of this type of pharmacological research). The formulation by Porsolt et al. has, of course, been criticized on both logical (cf. Hawkins, Hicks, Phillips and Moore, 1978; Hughes and Lynch, 1978; Hughes, Stein and Lynch, 1978) and empirical grounds (e.g., Nishimura, Tsuda, Oguchi, Ida, and Tanaka, 1988 a; Nishimura, Tsuda, Ida and Tanaka, 1988 b). The data from the present research contradict the interpretation by Porsolt, et al. of decreased activity in the swimming situation. It is obvious that the present data, instead of suggesting a worsening in the rat's mood, suggest the adaptation of the rat to its circumstances and an improvement of its chances to survive.

One interpretation of the effects of the different manipulations described in the present paper is that these are simple elements of a swimming course for rats. This possibility seems unlikely for at least two reasons. One reason is that rats "naturally" swim and no rat has ever drowned (or for that matter died in the swimming situation) in this laboratory. The second reason is that, if death occurs while swimming, it is likely due to heart failure (similar to "voodoo" death in humans, see Richter, 1957). In contrast to the swimming-course-for-rats interpretation of the preceding experiments, the author believes that the different procedures described in this paper had effects that were not limited to the rat's ostensible swimming behavior, but included its entire organism. Such notion, of course, is being borrowed from Schoenfeld's (1971) concept of "conditioning the whole organism" and that states that since every part of the subject functions interdependently with other parts, stimulation has multiple effects, including those within the subject's internal *milieu*. Therefore, the environmental variables studied in the present experiments, in addition for allowing the "natural" reinforcement of adaptive movements in the water, must have conditioned simultaneously other segments of the rat's behavior. The same independent variables must have also created physiological regularities inside the subject's body. Although physiological variables were not recorded in the present research, some of these effects were evident, as when defecation and urination in the water decreased as the rats became more experienced with the swimming situation. Among such physiological changes, the simultaneous conditioning of the rat's heart rate (e.g., Notterman, Schoenfeld and Bersh, 1952), implicated in sudden death, possibly played a role in the rat's survival.

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