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Effects of duration of feedback on signaled avoidance

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Two experiments were carried out to study vertical jumping avoidance learning in rats. In particular, we examined the effects of the duration of a feedback stimulus and of the interval between the end of the feedback stimulus and the start of the next trial on acquisition and extinction of avoidance. In Experiment 1, the duration of feedback was manipulated while intertrial interval (feedback plus no-feedback) was held constant. Animals with feedback lasting more than 1 sec needed fewer trials to reach the acquisition criteria than did animals with no feedback or with 1-sec feedback. No differences were observed in extinction. In Experiment 2, the durations of both feedback and no-feedback were manipulated. Animals without feedback needed more trials to reach the acquisition criterion than did animals with feedback, but the performance of the feedback animals did not differ as a function of feedback duration, no-feedback duration, or total intertrial interval. Again, no differences were observed in extinction. These results indicate that the presentation of feedback improves the acquisition of vertical jumping avoidance, but that this effect is independent of the temporal characteristics of feedback.

Numerous studies have shown that the presence of feedback contingent on an avoidance response improves learning (Bolles & Grossen, 1969; Bower, Starr, & Lazarovitz, 1965; Cicala & Owen, 1976; D'Amato, Fazarro, & Etkin, 1968; Keehn & Nakkash, 1959; Owen, Cicala, & Herdegen, 1978) and slows extinction (Jacobs, Moot, & Harris, 1983). The mechanism by which feedback brings about these effects is a subject of debate at present.

According to the safety signal theory, feedback contingent on the response inhibits fear and therefore acts as a positive reinforcer of the response (Dinsmoor, 1977; Morris, 1974, 1975; Rescorla, 1968, 1969; Rescorla & LoLordo, 1965; Rescorla & Solomon, 1967; Weisman & Litner, 1971, 1972). Thus, Cicala and Owen (1976) and Owen et al. (1978) maintain that the end of the warning signal acts as negative reinforcement, causing fear to subside passively, and that feedback acts as positive reinforcement that actively reduces fear. Both mechanisms contribute to the acquisition and maintenance of the avoidance response. It is thought that the reinforcing mechanism of feedback is the same as that which underlies the reinforcing power of remaining in a safe place—that is, relaxation and counterconditioning (Bolles & Grossen, 1969; Denny, 1971). Therefore, it is assumed that the longer the duration of feedback, the greater the effect on the avoidance response, as occurs when time spent in a safe compartment is increased (Cándido, Catena, & Maldonado, 1984b; Cándido, Maldonado, & Vila, 1989; Denny, 1971).

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Other authors (Galvani & Twitty, 1978) have suggested that feedback has both motivational and informative characteristics, and that these characteristics are affected differentially by feedback duration. According to this view, if feedback signals that electric shock has been avoided and a shock-free period is to follow, then the amount of stimulus change, but not its duration, is important. However, if the feedback has motivational properties, then varying its duration should bring about differences in performance. Galvani and Twitty (1978), using the two-way shuttle response with an intertrial interval (ITI) of 30 sec, exposed their subjects to feedback of different durations (2, 5, or 10 sec) and to no feedback. They observed differences in performance only between the feedback groups and the no-feedback group; the groups with varying feedback durations did not differ significantly from one another. Therefore, the presence of feedback facilitated avoidance training, but its duration did not seem to be critical (e.g., 2 sec of feedback were as effective as 5 or 10 sec).

However, the temporal manipulation of feedback in Galvani and Twitty's (1978) study was very limited, because the assumed reinforcement mechanism (relaxation) may require a longer period of time than that employed by these researchers. Denny (1971) suggested that relaxation requires about 150 sec in a safe compartment, although Cándido et al. (1989) found reliable effects from 15 sec. Bearing this in mind, we devised an experiment to assess the effects of manipulating feedback duration on the acquisition, maintenance, and extinction of avoidance learning in a wider context than that used by

Galvani and Twitty (1978). We used the vertical jumping response as a measure of avoidance learning (Cándido, 1987; Cándido, Catena, & Maldonado, 1984a; Cándido, Maldonado, & Vila, 1988; Catena & Maldonado, 1983). With this response, contextual changes are less pronounced than those produced by other avoidance responses (i.e., one- or two-way responses). Therefore, this response facilitates the study of the influence of feedback without contamination by other contextual changes.

In the vertical jumping response, temporal manipulation of the stimulus contingent on the response (feedback) allows contextual differentiation of ITI only in terms of presence as opposed to absence of feedback, where ITI is defined as the time that elapses between the last response and the next warning signal. In Experiment 2, we attempted to ascertain whether the effect of feedback on the subject is due to the feedback itself or to the time that passes between the end of the feedback and the start of the warning signal.

EXPERIMENT 1

Our primary objective in Experiment 1 was to find out whether the addition of exteroceptive feedback after the vertical jumping response would improve avoidance learning, and whether the temporal manipulation of this feedback would affect the rate of acquisition and resistance to extinction, under both lax and strict criteria.

Method

Subjects

Forty female Wistar rats, 90–120 days old at the start of the experiment, from the University of Granada experimental stock were used. They were kept at a constant 20° C on a 12:12-h light:dark cycle. Training took place in the light phase.

Apparatus

The experimental apparatus consisted of a modified rat operant conditioning chamber (LETICA LI-200) made of four walls: two opposing walls, 31 cm high by 28 cm long, were of transparent plastic; the other walls, 31 cm high by 23.5 cm long, were of opaque plastic and modular aluminum plates, respectively. The floor was formed by a grid of 19 stainless steel rods 4 mm in diameter and positioned 2 cm center-to-center; these were connected in series to a LETICA LI 2700 shock-source module designed to produce continuous scrambled current between 0 and 3.5 mA. Five photoelectric cells were mounted at 5-cm intervals 25 cm above the grid, beginning 5 cm from the aluminum wall. Corresponding lights (5 mm in diameter) were mounted in the opposite wall. Lights and cells formed an electrical circuit connected to a response recorder. A vertical jump interrupted the circuit and recorded a response (Cándido et al., 1984a; Cándido et al., 1988). A buzzer, producing 88 dB SPL at 24 V, was used as the warning signal. It was installed in the center of the aluminum wall at a height of 2.5 cm. The chamber was placed in a sound-attenuating box 70 cm long, 53.5 cm high, and 46 cm wide; an exhaust fan produced a background noise of 70 dB SPL, measured, like the warning signal, from within the chamber.

A 24-V white light that served as feedback after each avoidance or escape response was situated at the center of the aluminum wall, 10 cm above the floor and 3 cm above the warning buzzer. The light was controlled by a LETICA LI-2200 module.

Table 1
Duration (in seconds) of Feedback (FB), Nonfeedback (No FB), and Total Intertrial Interval (ITI) for Each Group

Groups	FB	No FB	ITI
NFB	0	70	70
1FB	1	69	70
15FB	15	55	70
30FB	30	40	70
60FB	60	10	70

Note—Duration of warning signal was fixed (5 sec) for all the groups and was independent of the manipulation of nonfeedback time.

Avoidance and escape latencies were measured by a LETICA LE 130/100 digital chronometer, accurate to .1 sec. The temporal sequence of the events was controlled by the LI 2700 module.

Procedure

Acquisition and maintenance. Each rat was put into the chamber and allowed 5 min to explore it without interference (the fan was on) before the trials began. A trial consisted of a warning signal followed 5 sec later by a 2-mA electric shock. Both continued for 30 sec or until the rat broke the photocell beam by jumping.

The rats were divided at random into five groups (n = 8), each group having feedback of different duration as is shown in Table 1. The total ITI for each group was fixed at 70 sec. The group designation refers to feedback (light) duration. ITIs without feedback elapsed in darkness and ended with the warning signal (see Table 1).

Training lasted until the rat reached the acquisition criterion of 20 consecutive avoidance responses. An avoidance response was one that occurred within 5 sec of onset of the warning signal.

Extinction. Once a subject had performed 20 consecutive avoidance responses, the extinction stage commenced. Training consisted of exactly the same procedure as that for acquisition, except that there was no electric shock. Trials continued until the rats reached the extinction criterion of 10 consecutive failures to make an avoidance response. A no-avoidance response was deemed to have occurred when the rat failed to jump during the 5-sec warning signal. Thereupon the warning signal ended, no feedback was given, and the countdown to the next trial began.

The number of trials needed to reach each criterion of acquisition (5, 10, 15, and 20 consecutive avoidance responses) or extinction (1, 5, and 10 consecutive no-avoidance responses) was taken as the dependent variable. Each criterion was taken as met on the first of each consecutive sequence of responses in the acquisition phase or the first of each consecutive sequence of avoidance failures in the extinction phase. This eliminated the possibility of counting trials more than once when more than one criterion was reached in a single faultless sequence (Cándido et al., 1988; Cándido et al., 1989). Thus, if a subject made 20 consecutive correct responses starting with the 12th trial, the number of trials taken to reach each criterion was the same (i.e., 12 trials).

Results

Acquisition

Figure 1 represents the number of trials taken by each group during avoidance training, depending on acquisition criteria. It should be observed that the no-feedback and minimal feedback groups (NFB and 1FB) took more trials than did the other groups.

We first conducted a multivariate analysis of variance (MANOVA), because the covariance matrix does not follow a sphericity pattern (Mauchley sphericity test, $W = .443$, $p < .001$). The scores were analyzed with

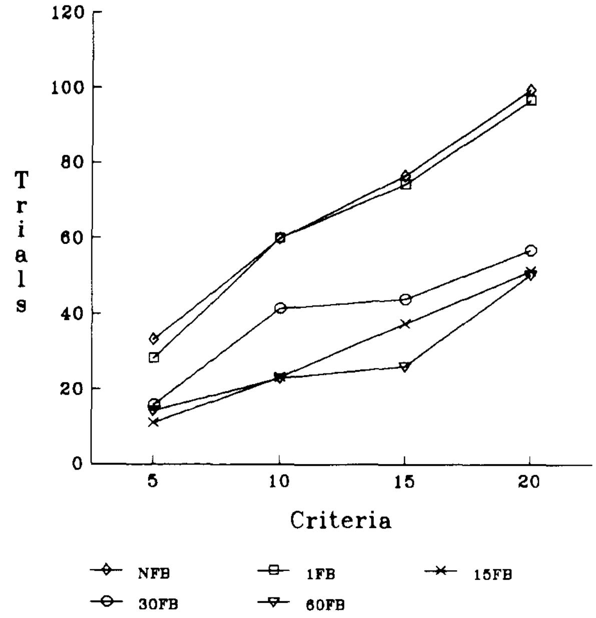

Figure 1. Mean number of trials needed by each feedback group to reach the successive acquisition criteria. The number of each group refers to duration of feedback in seconds.

a 5×4 MANOVA, the first factor being the five groups and the second (repeated measures) factor being the four acquisition criteria. The criterion for statistical significance of at least $p < .05$ was adopted in all the analyses.

The results showed a significant effect of groups [$F(4,35) = 3.923$] and acquisition criteria [Hotelling $t(3,33) = 2.315$, approximate $F(3,33) = 25.456$]; however, the interaction was not significant.

A later analysis done with Student's *t* test showed differences between the NFB group and the 15FB, 30FB, and 60FB groups, and between the 1FB group and the 15FB, 30FB, and 60FB groups.

Extinction

Figure 2 shows the total number of trials taken by each group during the extinction stage. Because the covariance matrix was singular, the scores were subjected to a 5×3 ANOVA (groups × extinction criteria). Only a significant effect of the extinction criteria was observed [$F(2,70) = 11.072$].

Discussion

In light of the results obtained in this experiment, we may conclude that the differences encountered among our groups cannot be attributed to the ITI, since the same interval (70 sec) was given to all groups.

Secondly, it would seem that the effect of feedback in this task manifests itself between extreme values—that is, between minimal or no feedback (1FB and NFB groups) and feedback lasting for a reasonable length of time (15FB, 30FB, and 60FB groups). Therefore, beyond a minimal duration, the effect of feedback duration on the vertical jumping response is negligible. These results seem to indicate that the effect of feedback duration on the avoidance response is asymptotic at rather short durations. This is in line with the results and conclusions of Galvani and Twitty (1978), who used another kind of response.

As far as extinction is concerned, the most noteworthy conclusion is that the differences among our groups are not statistically significant. These data would at first glance appear to contradict the existing literature on the subject (Jacobs et al., 1983). However, Jacobs et al. used a Sidman avoidance procedure, presenting feedback only during the response-shock interval, and, what is more important, they did not use a performance criterion of acquisition. In their experiment, extinction began in the second day of training after 45 min. The different results in these studies could be due to these procedural differences. Indeed, they could be explained by the fact that our groups all reached the same strict acquisition criterion of 20 consecutive avoidance responses. Since the subjects had been matched on the same strict acquisition criterion before the extinction stage, they would tend to be similar in their extinction rates (see also Cándido et al., 1989).

In Experiment 1, we found statistically significant differences among groups exposed to different feedback/no-feedback durations, with a fixed ITI (70 sec). Our results therefore could be due to the length of either feedback time or no-feedback time. Experiment 1 does not permit one to distinguish whether the effect on the subjects' performance was due to the increase in feedback time or the decrease in no-feedback time.

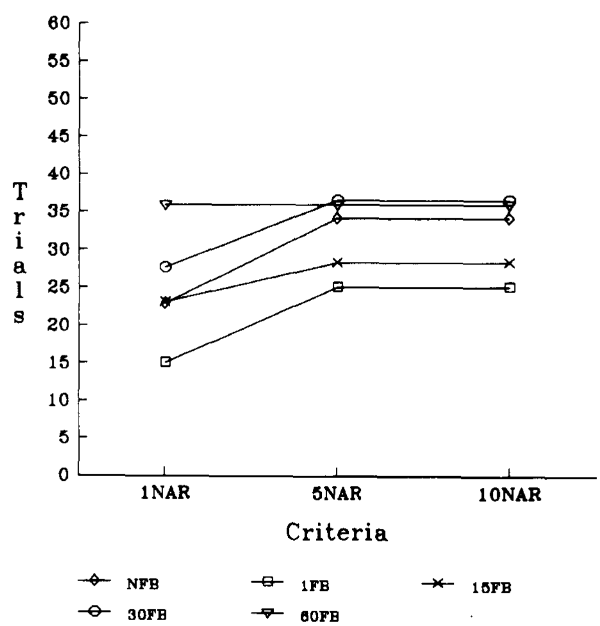

Figure 2. Mean number of trials needed by each feedback group to reach the successive extinction criteria.

This is remarkable, considering that the effect of feedback or a safety signal is influenced by the duration of other stimuli present in the situation. For example, Weisman and Litner (1971) found that in a wheel-turning task, the magnitude of the inhibitory effect of a CS1, conditioned through classical differential conditioning, depended on the duration of this in relation to another CS2, which also signaled a shock-free interval. Weisman and Litner (1971) concluded that inhibition brought about by a stimulus is, in part, a function of the inhibition elicited by another stimulus present in the situation. Moreover, Cándido et al. (1989), using a one-way response, found that the supposed reinforcing power of the time spent in the safety compartment depended on the time spent in the danger compartment (see also Denny, 1971; Modaresi, 1975, 1984). It may be that the reinforcing power of feedback does not depend on its absolute duration, but rather on its duration in relation to the danger-free period that follows—that is, the time without feedback before the start of the warning signal. In other words, it depends on the duration of the feedback, relative to the whole ITI. Experiment 2 was designed to clarify whether the effect of feedback depends on the time without feedback or on ITI.

EXPERIMENT 2

Our aim in Experiment 2 was to examine the effect of manipulating feedback and no-feedback durations on acquisition and extinction of avoidance performance, using the vertical jumping response.

Method

Subjects and Apparatus

The subjects were 60 female rats similar to those described in Experiment 1. The apparatus was also the same.

Procedure

Acquisition. The procedure was identical to that employed in Experiment 1, except in the manipulation of the feedback duration to which each group was exposed (see Table 2).

The 60 rats were assigned at random to six groups (n = 10). Three groups differed in the time with feedback (0, 3, and 20 sec) and maintained a constant time without feedback (55 sec). These groups were designated 0-55, 3-55, and 20-55, where the first number indicates feedback duration and the second indicates no-feedback time up to the start of the warning signal.

The remaining three groups maintained constant time with feedback (55 sec) while time without feedback differed (0, 3, or 20 sec).

Table 2
Duration (in seconds) of Feedback (FB), Nonfeedback (No FB), and Total Intertrial Interval (ITI) for Each Group

Groups	FB	No FB	ITI
0-55	0	55	55
3-55	3	55	58
20-55	20	55	75
55-0	55	0	55
55-3	55	3	58
55-20	55	20	75

Note—Duration of warning signal was fixed (5 sec) for all the groups and was independent of the manipulation of nonfeedback time.

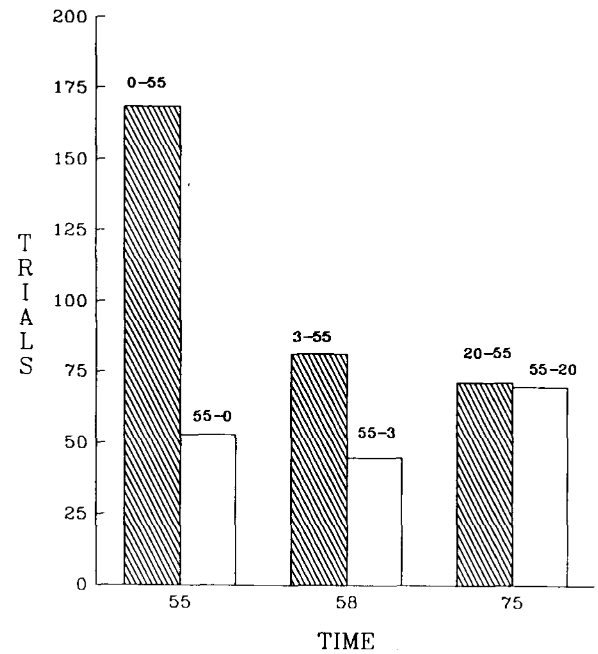

Figure 3. Mean number of trials needed by each group to reach the acquisition criterion (20 consecutive avoidance responses). In the group designations, the first number of each pair refers to duration of feedback in seconds. The second number of the pair refers to duration of nonfeedback in seconds. The abscissa indicates the duration of the total ITI.

These groups were designated 55-0, 55-3, and 55-20. Again, the first number indicates feedback duration and the second indicates no-feedback time up to the start of the warning signal.

Therefore we had two conditions; the first was the manipulation of feedback duration, and the second was the manipulation of no-feedback time up to the start of the warning signal.

All rats were trained until they reached 20 consecutive avoidance responses.

Extinction. Once 20 consecutive avoidance responses had been reached, the extinction stage began. This consisted of the same procedure as that for acquisition, except that this time there was no electric shock. Trials continued until rats reached 10 consecutive failures to make an avoidance response.

The criterion for considering an avoidance response as such was the same as it was for Experiment 1.

Results

Acquisition

Figure 3 shows the number of trials taken by the six groups to reach the criterion of 20 consecutive avoidance responses. As can be seen, the feedback groups took fewer trials to reach criterion than did the one group without feedback.

A 2×3 (conditions × group) ANOVA showed significant effects of conditions [$F(1,54)$ = 11.184] and groups [$F(2,54)$ = 3.738] and a significant conditions × groups interaction [$F(2,54)$ = 4.829].

Analysis of the interaction showed significant differences in the feedback duration manipulation condition [$F(2,27)$ = 4.887] but not in the no-feedback duration

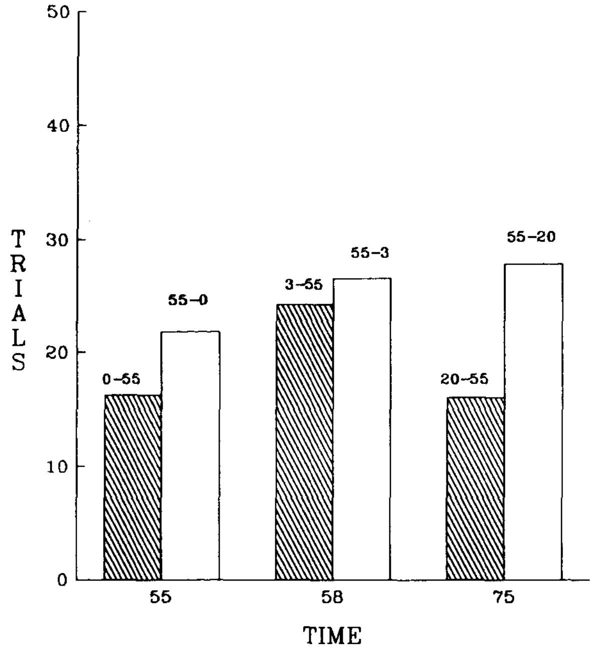

Figure 4. Mean number of trials needed by each group to reach the extinction criterion (10 consecutive failures).

manipulation condition. A later analysis done with Student's *t* test showed that the group without feedback (0–55) performed more poorly than all the other groups, which did not differ.

Extinction

Figure 4 represents the number of trials to extinction taken by the different groups in each condition.

A 2×3 (conditions × group) ANOVA showed no reliable differences.

Discussion

The most noteworthy conclusion of this experiment is that in acquisition a difference arose between the groups that were exposed to feedback and the one that was not, but not among the groups that were exposed to different feedback durations. The effect of the feedback would therefore seem to be independent of the feedback's duration, at least when the ITIs last between 55 and 75 sec. This pattern of results confirms those obtained by Galvani and Twitty (1978), and it leads us to assume that the reinforcing effect of feedback is due to its informational rather than its motivational value.

What is more, it seems that the feedback-duration effect is independent of the no-feedback duration, as is demonstrated by the absence of statistically significant differences among groups exposed to identical feedback durations but different no-feedback durations and ITIs. This contradicts the assumption that the feedback will be more effective if it signals a longer safe period (Bolles & Grossen, 1969; Morris, 1974) and that its effectiveness depends on the duration of other stimuli predicting a period of safety (Weisman & Litner, 1971). It is possible that feedback lasting for 55 sec has reached its asymptotic value of effectiveness, obscuring the influence of other kinds of temporal variables. However, this does not explain why we did not encounter differences between the groups with shorter feedback durations (3 or 20 sec) but with the same no-feedback duration (55 sec).

It appears that 3 sec of feedback are as effective on the vertical jumping avoidance response as are 20 or 55 sec, as long as the ITI is between 55 and 75 sec.

The absence of effects in the extinction stage may be due to the strict performance criterion (20 consecutive avoidance responses) used in the acquisition stage. Similar results were found with the vertical jumping response in Experiment 1, where subjects had equivalent resistance to extinction after reaching strict acquisition criteria, and such results have also been found for the one-way response (Cándido et al., 1989).

GENERAL DISCUSSION

The main conclusion drawn from the results of these studies is that subjects exposed to feedback lasting more than 1 sec acquired the vertical jumping response in a signaled avoidance procedure more rapidly than those with 1 sec of feedback or none at all; and that this effect was independent of feedback time, ITI, or no-feedback time, at least with the temporal parameters used in these experiments.

The data obtained in research on the effectiveness of presenting feedback contingent on the vertical jumping avoidance response are consistent with other studies on the presentation of feedback contingent on avoidance responses in other tasks (Bolles & Grossen, 1969; Bower et al., 1965; Cicala & Owen, 1976; D'Amato et al., 1968; Franchina, Kash, Reeder, & Sheets, 1978; Galvani & Twitty, 1978; Owen et al., 1978). Both this research and our own show that the presentation of exteroceptive feedback contingent on an avoidance or escape response facilitates its acquisition.

Our results are not incompatible with the safety signal theories which predict that feedback acts as positive reinforcement of the response (Morris, 1974, 1975; Rescorla & Solomon, 1967; Seligman & Binik, 1977; Weisman & Litner, 1971, 1972), if it is assumed that feedback reinforcement is independent of feedback duration.

Our results are also compatible with Bolles's theory (Bolles, 1970) of species-specific defense reactions (SSDR) when it is applied to slowly acquired avoidance responses. In this kind of response learning, Bolles assumes that the functional effectiveness of the avoidance response itself entails establishing safety signals that quell the SSDRs that compete with relaxation (Denny, 1971). Feedback is considered to be functionally equivalent to safety signals, and therefore it has a similar effect, accelerating the acquisition of the avoidance response.

However, the effect of feedback would seem to be due not as much to its possible incentive-motivational characteristics as to its informative value (Galvani & Twitty, 1978). If the effect of feedback on the subject's behavior were due exclusively to its incentive motivation, then lengthening its duration ought to increase its effectiveness. In our case, longer feedback should bring about more rapid acquisition. The results show the same facilitating effect of feedback on acquisition independently of its duration. Nor does the effectiveness of feedback seem to depend on the length of the shock-free period that follows (no-feedback time), at least when one uses moderate ITIs (55-75 sec) and the vertical jumping response. This is indicated by the fact that there were no significant differences in the speeds of acquisition of those groups that, while having the same feedback duration, differed in the no-feedback time that elapsed before the start of the warning signal. It is remarkable that in the one-way avoidance response task, there have been indeed variations among the groups that spent different lengths of time in the safe compartment (Cándido et al., 1984b; Denny, 1971) and among the groups that, in spite of remaining in the safe compartment for the same length of time, had varying lengths of time in the danger compartment before the start of the warning signal (Cándido, 1987; Cándido et al., 1989).

It is possible that to remain in a safe place has characteristics different from feedback or safety signals presented in a potentially dangerous place or context. The time spent in a safe place may have incentive-motivational characteristics whose value depends on the time spent in a dangerous place. However, the presence of a signal within a dangerous context announcing a period of safety may not have these incentive-motivational characteristics, but rather it may have informational value for the subject. Therefore, the changes in length of time, intensity, or salience relative to other stimuli will only render the signal more perceptible, but they will not modify its value. The effect of feedback on the avoidance response will not vary once it has been detected and its significance understood. The psychological aspects underlying the reinforcing power of this information are still open to question, but it has been suggested that they may be related to "control" (Averill, 1973) or "predictability" (Mineka, Cook, & Miller, 1984; Starr & Mineka, 1977).

From this perspective, the meaning or informational value of a feedback signal would tell the subject that the response was correct and that a safe, shock-free period was to follow. Therefore, feedback times lasting longer than would strictly be necessary to inform the subject of this state of affairs (approximately 2 or 3 sec) would only confirm the information but would not influence the subject's performance.

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