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The effects of frustration induced by discontinuation of reinforcement on force of response and magnitude of the skin conductance response

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If frustration is an aversive emotion in humans, then the behavioral increment in vigor of response following discontinuation of a positively reinforced force-contingent leverpress (frustration effect) might reasonably be expected to be accompanied by a gross physiological response such as an increase in skin conductance. The present study tested this hypothesis by means of a double-lever force-contingent reinforcement apparatus in which subjects received a small monetary reward if they pressed the first lever (reward lever) with an amount of force that was greater than 1.5 kg but less than 3.0 kg. Presses on the second lever, designated as a reset lever required for reactivation of the reinforcement mechanism and subsequent presses on the reward lever, were never reinforced, but force of response was measured. Following this procedure, any changes in force on the reset lever could not be attributed to associative strategies gained through familiarity with the reward lever. The results indicated a significant increase in force on the reset lever (frustration effect) following discontinuation of reinforcement on the reward lever (first extinction trial) accompanied by a significant increase in the skin conductance response, evidence that suggests that frustration is an emotion with a physiological basis as well as a behavioral effect. Increases in force of response on the reset lever and correlated increases in the magnitude of the skin conductance response were inversely related to the time of delay between the reward leverpress and the reset leverpress.

Miller and Stevenson (1936) and Skinner (1938) were among the first experimenters to note the emotional consequences (increase in force of response) that occur during the first few extinction trials of a barpress response (frustration effect), and Marzocco (1951) may have been the first to demonstrate quantitatively the frustration effect by comparing the force that rats exerted on the bar immediately following discontinuation of reinforcement with the force exerted immediately prior to discontinuation of reinforcement. In subsequent research on human subjects, Blixt and Ley (1969) demonstrated the frustration effect following positive reinforcement of a force-contingent barpress, and Ditkoff and Ley (1974) demonstrated the frustration effect following both positive and negative reinforcement of a force-contingent barpress.

Although Brown and Farber (1951) and Amsel (1958, 1962, 1967) have put forth theories that address the motivational properties of frustration, Amsel's theory of fractional anticipatory frustration is more analogous to the conditioned aversive emotion of acquired fear (Miller, 1951). However, unlike fear, in which physiological effects have been measured directly, the aversive emotional effects of frustration have been limited to indirect effects on instrumental behavior (e.g., Daly, 1974). The present article addresses the issue of frustration as an emotion with direct physiological consequences.

If frustration is an aversive emotion in human subjects, then the behavioral increment in vigor of response following discontinuation of a positively reinforced force-contingent leverpress might reasonably be expected to be accompanied by a gross physiological response such as an increase in skin conductance. The purpose of the present study was to test this hypothesis using the same procedures as those used by Ditkoff and Ley (1974), that is, a double-lever force-contingent reinforcement apparatus in which subjects successively pressed each of two levers (a reward lever and a reset lever) on each trial. Correct reward lever responses (presses within a 1.5-3.0 kg force band) were positively reinforced by a cumulative counter that indicated that 5¢ had been awarded for each press within the required force band. Presses on the reset lever, designated as a mechanism required for subsequent presses on the reward lever, were never reinforced. In this way, any increase in force on the reset lever could not be attributed to associative strategies gained through familiarity with the reward lever and would, therefore, reflect the effects of frustration independent of prior reinforcement on the reward lever.

Since frustration is relatively labile with sudden onset and brief duration, its effect on the vigor of the reset lever

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response would be expected to be inversely related to times of delay. Thus, weak frustration during intermediary delays of 10 sec or the complete dissipation of frustration following relatively long delays of 20 sec would be expected to produce little or no increase in force of response on the reset lever and little or no increase in the magnitude of the skin conductance response, whereas strong frustration following a relatively brief delay of 5 sec would be expected to produce a significant increase both in force of response and in magnitude of skin conductance response. For the purpose of testing these hypotheses, three different time-delay intervals (5, 10, and 20 sec) between presses on the reward lever (the force-contingent reinforcement lever) and the reset lever were instituted.

METHOD

Subjects

The subjects were 24 undergraduate students enrolled at the State University of New York at Albany.

Apparatus

The apparatus was a modification of that designed by Blixt and Ley (1969). It consisted of two vertically mounted 48.26-cm-high steel levers equipped with bicycle handlebar grips at their tops. They were mounted side by side (30.5 cm apart) with the left-hand lever (reward lever) painted red and the right-hand lever (reset lever) painted green. The two levers were fastened to a tabletop in such a manner that there was no discernible movement in the levers when force was applied. At the exact middle of each lever—front and rear—were two bonded strain gauges (SR-4, Type FA-50-35, 350-ohm resistance, manufactured by Baldwin-Lima-Hamilton, powered by a variable power supply delivering 6V) that, in a manner similar to a Wheatstone bridge circuit, measured the amount of force applied to the levers. The output from the bridge circuit was adjusted to zero voltage when no force was applied to the levers. The bridge developed a small signal voltage when it became unbalanced because of pressure on the levers. This signal, when routed through a Carrier amplifier to a Brush 8-channel pen recorder (Model RD-1682-30), caused a pen deflection on a moving graphical tape. Each lever was wired to a separate pen so that the force of response on either lever could be determined.

Two cuelights (one red and one green to correspond to the left and right levers, respectively) were mounted on a bracket approximately 51 cm high, fastened to a desktop. The cuelights were directly behind their correspondingly colored levers and appeared approximately 5 cm above them. The levers were color coded with the cuelights. The sequence of the response-delay intervals (5, 10, or 20 sec) was randomly determined. Each interval occurred 13 times in the program. The intervals initially selected were those used by Marzocco (1951) of 10, 20, and 40 sec. However, it was found in a pilot study that these were too long to demonstrate the frustration effect and maintain the subjects' interest in the task. Hence, each of Marzocco's original intervals was halved; that is, 5-, 10-, and 20-sec intervals were used.

When the red light was on, the subjects pressed the corresponding lever. The force applied to the lever was then routed through a strain-gauge amplifier and was graphically recorded. The appropriate light circuit (i.e., the red light) also activated and reset the force-band discriminator. The force-band discriminator was also monitored by the recorder and the subject by way of the digital reward counter (Lafayette Model 5707-B). The force between 1.5 and 3.0 kg (selected on the rationale of the Blixt & Ley, 1969, criteria) was the appropriate criterion force band and was monitored by the discriminator according to the voltage output from the strain gauge generated by the subject's leverpress.

The measurement of skin conductance changes was monitored by a Lafayette Instrument Company Model 7601A AC-DC psychogalvanometer. The skin conductance electrodes were attached to the forefinger and little finger of each subject's nonpreferred hand (i.e., the hand the subject did not use to press the levers). The signal from the meter was routed to the Brush pen recorder.

Each subject was seated in a desk-chair, the desk portion of which had been modified such that the top was constructed of a 76-cm square, 2-cm thick piece of plywood. The levers were mounted approximately 10 cm from the edge of the desktop nearest the subject and approximately 8 cm from the sides of the desktop. The reward indicator counter was mounted directly between the two signal lights, on the same bracket. During the experiment proper all electrical apparatus was shielded from the subjects' view by a screen.

Procedure

On arrival at the experimental setting, each subject was randomly assigned to one of three experimental groups (three different time intervals during extinction trials) with the requirement that there be an equal number of subjects in each group.

The recorder and apparatus were checked each day for proper calibration of the 1.5-3.0-kg force band prior to running the subjects. The experimenter then spent approximately 5-10 min familiarizing each subject with the experimental setting and apparatus.

The subjects were instructed to press the lever repeatedly with an approximately equivalent amount of force. Each subject was instructed to grasp the handle grip of the red reward lever and to press forward with his/her preferred hand, using a "light" force, and then immediately to release the lever. If, on this first trial, a subject pushed the lever beyond the 1.5-3.0-kg force band (as noted by the pen recorder), the subject was asked to "push again but this time a little bit lighter." If a subject did not push hard enough, the subject was requested to "push and release again but this time a little bit harder." This procedure was continued until the subject pressed within the required force band. The subject was then told: "That's just right. Now try to push again with the same amount of force." This pretraining process continued with the experimenter giving feedback (e.g., "That's a little too much," or "That's not quite hard enough") until each subject was responding fairly consistently (i.e., three successive correct response trials) within the required force band. It is important to point out that the subjects were told following each pretraining trial that they were to press the green reset lever in a similar fashion following each reward leverpress "in order to reset the apparatus." If a subject inquired as to whether to press the reset lever with the same amount of force as the reward lever, the subject was told: "Press the green lever in the same manner you pressed the red lever."

Following this training session, the subjects were told that they could earn 5¢ for each correct response (i.e., pushing the lever "just right"). The subjects were then instructed as follows: "Directly in front of you are two lights. The red one on the left corresponds to the red lever on the left and the green light on the right corresponds to the green lever on the right. Your task is to push the red lever the same way (i.e., with the same amount of force) you have just been doing when the red light comes on and then to release the lever immediately after you have made your response. Remember, press and then release. If you have pressed with the correct amount of force the counter in front of you will advance showing a number. For each correct response recorded on the counter you will be paid a nickel. After a varying interval of time following the flash of the red light, the green light will come on. Some of the intervals will be short, while others will be much longer. As soon as the green light comes on you are to press the green reset lever in the same manner as the red reward lever and then release immediately. This will reset the mechanism for the next reward leverpress."

The purpose of the skin conductance electrodes was then explained to each subject. The experimenter explained that he was interested in determining if there were any changes in autonomic nervous system reactivity during performance of the task and that this apparatus would enable him to make measurements to determine this. The subjects were assured that there was nothing about the electrodes that would hurt or disturb them in any way.

All subjects were reinforced for every correct response (reinforcement indicated via the reward counter). After a sequence of 30 leverpress trials, reinforcement was terminated and a constant response-delay interval (5, 10, or 20 sec) was instituted depending on the interval group to which the subjects had been assigned. That is, during the extinction period, 8 randomly assigned subjects had a constant 5-sec delay, a second 8 had a constant 10-sec delay, and the final 8 had a constant 20-sec delay. The extinction period continued for 5 trials.

Hypotheses

On the basis of both theory and the previously discussed research, it was expected that the force of response on the reset lever following the first nonreinforced press on the reward lever would be significantly greater than the force on the reset lever following the prior trial in which the reward leverpress was reinforced. It was also expected that the increase in force on the reset lever following nonreinforcement on the reward lever would be inversely related to the time of delay between the reward leverpress and the reset leverpress.

Furthermore, if the skin conductance response is an index of physiological changes underlying frustration, then changes in skin conductance should parallel changes in force, that is, the skin conductance response should increase following nonreinforcement and the magnitude of increase should be inversely related to the time of delay between reward and reset leverpresses.

RESULTS AND DISCUSSION

Force of Response

The means and standard deviations of force of response on the reset lever following the last reinforced reward leverpress and first nonreinforced reward leverpress for each of the three response-delay intervals are given in Table 1. A mixed-factorial 3×2 analysis of variance (3 between-subject response-delay intervals × 2 within-subject trials) revealed that neither the main effect of response-delay interval [$F(2,21) = 0.85, p > .05$] nor the main effect of trials [$F(1,21) = 0.06, p > .05$] was significant. However, consistent with predictions, the response-delay interval × trials interaction was significant [$F(2,21) = 2.94, p < .05$, one-tailed test] (see Ley, 1979).

The nature of this interaction can be seen in Table 1, where the mean increase in force of response (i.e., the frustration effect) was inversely related to the time of delay between the first nonreinforced reward leverpress and the following reset leverpress. Although the increase of 0.64 kg for the 5-sec-delay group was statistically significant [$t(7) = 5.82, p < .001$], the increase of 0.30 kg for the 10-sec-delay group fell just short of statistical significance [$t(7) = 1.50, p < .10$] for a one-tailed test, and the increase of 0.03 kg for the 20-sec-delay group was not significant [$t(7) = 0.22, p > .05$]. Considering the lengthy delay for the 20-sec group, the absence of a significant increase suggests the ephemeral quality of frustration under experimental conditions such as those of the present study. Most important are (1) the strong frustration effect following the relatively brief 5-sec delay and (2) the inverse relationship between the magnitude of the frustration effect and the times of response delays.

Table 2
Means and Standard Deviations of Skin Conductance Response (in mhos) During Reset Leverpresses Following the Last Reinforced Reward Leverpress and First Nonreinforced Reward Leverpress for the 5-, 10-, and 20-Sec Response Delay Intervals

	Skin Conductance Response				
	After Last Reinforced Trial		After First Nonreinforced Trial		
Response-Delay Group (*ns* = 8)	*M*	*SD*	*M*	*SD*	Mean Difference
5 sec	.13	.11	.18	.16	.05
10 sec	.16	.12	.18	.11	.02
20 sec	.19	.08	.20	.12	.01

Electrodermal Response

The means and standard deviations of skin conductance responses during reset leverpresses following the last reinforced reward leverpress and the first nonreinforced reward leverpress for each of the three response-delay intervals are given in Table 2. Consistent with predictions, the mean increases in the magnitudes of the skin conductance response were exactly parallel with those of force. That is, the mean increase of 0.04 mhos for the 5-sec-delay group was statistically significant [$t(7) = 2.00, p < .05$] for a one-tailed test (see Ley, 1979) and 0.02 mhos greater than the significant mean increase of 0.02 mhos for the 10-sec-delay group [$t(7) = 5.00, p < .05$], which, in turn, was 0.01 mhos greater than the observed mean increase of .01 mhos for the 20-sec-delay group [$t(7) = 0.14, p > .05$].

Relationship Between Force and the Electrodermal Response

Since the absolute magnitudes of the force of responses differed among the three delay groups, as did the absolute magnitudes of the skin conductance responses, a clearer picture of the parallel relationship between force on the reset lever following nonreinforcement on the reward lever (i.e., the frustration effect) and the magnitude of change in the skin conductance response on corresponding trials is shown in Figure 1. The scale for the force of response given on the ordinate on the left side of the

Table 1
Means and Standard Deviations of Force of Response (in kilograms) on the Reset Lever Following the Last Reinforced Reward Leverpress and First Nonreinforced Reward Leverpress for the 5-, 10-, and 20-Sec Response Delay Intervals

	Force on Reset Lever				
	After Last Reinforced Trial		After First Nonreinforced Trial		
Response-Delay Group (*ns* = 8)	*M*	*SD*	*M*	*SD*	Mean Difference
5 sec	1.28	.54	1.92	.37	.64
10 sec	1.94	1.05	2.24	.97	.30
20 sec	1.52	.71	1.55	.65	.03

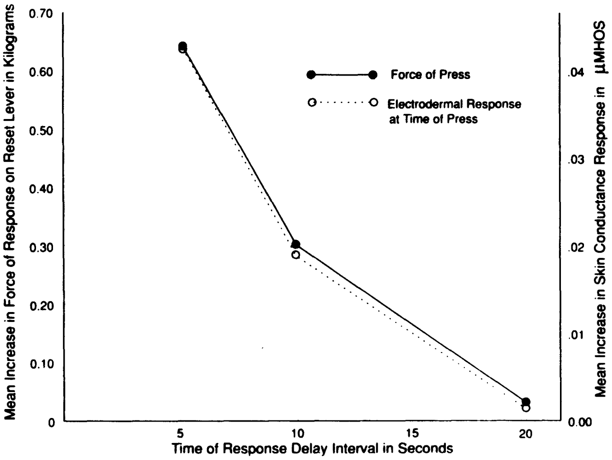

Figure 1. Mean increase in force of response on the reset lever and mean increase in the skin conductance response for the 5-sec, 10-sec, and 20-sec response-delay-interval groups.

figure was selected so that the mean force for the 5-sec-delay group would correspond to the mean magnitude of the skin conductance response, given on the ordinate on the right side of the figure, for the same group. Corresponding points for force and the skin conductance response for the 10-sec- and 20-sec-delay groups were the consequence of simple linear scaling of their respective measures. Although an insufficient number of response-delay intervals precludes the computation of a meaningful coefficient of correlation, the almost identical form of the two gradients supports the hypothesis that the frustration effect has a physiological basis in terms of the skin conductance response.

Some additional evidence to support this hypothesis can be found in correlations between force of response on the reset lever and corresponding amplitude of the skin conductance response on the frustration-effect trial for the 8 subjects in each of the three response-delay groups. That is, since the frustration effect was clearly demonstrated in the 5-sec-delay group, one might expect that the magnitude of force on the reset lever following the first nonreinforced trial would covary with the magnitude of the skin conductance response, whereas such covariation might not be expected on trials in which the frustration effect was not clearly demonstrated. To test this hypothesis, rank-order correlation coefficients were computed between force and the skin conductance response for the 8 subjects in the three response-delay groups on the frustration trial. Consistent with predictions, the correlation coefficient for the 5-sec-delay group was significant ($r = .77, p < .05$), whereas those for the 10-sec- and 20-sec-delay groups were not ($r = .27$ and $.60$, respectively).

With respect to the primary purpose of the present study, the overall pattern of results for the combined force measures and skin conductance response measures supports the hypothesis that the frustration effect, heretofore a behavioral phenomenon, may qualify as an emotion with a physiological base. In this connection, it may be important to note that the frustration effect produced by the force-contingent leverpress apparatus is consistent with that obtained by Blixt and Ley (1969) and Ditkoff and Ley (1974), thus contributing to the validity of this technique. Furthermore, in view of the direct connection between acute hyperventilation (i.e., a sudden increase in ventilation that leads to a sharp drop in pCO_2) and sudden increase in skin conductance response, pH, and heart rate (e.g., Ley, 1991, 1992), it is interesting to speculate on the possibility that ventilation may be a bridge between the psychological and physiological features of frustration. Perhaps the force-contingent leverpress apparatus provides a unique paradigm for studying the relationship between operant conditioning effects and physiological parameters of emotion.

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