Classically conditioned tail flexion in rats: CR-contingent modification of US intensity as a test of the preparatory response hypothesis

RALPH R. MILLER
State University of New York, Binghamton, New York 13901

and

CAROLYN GRECO and MICHAEL VIGORITO
University of Massachusetts, Amherst, Massachusetts 01002

A classically conditioned tail flexion in rats with a white noise as the conditioned stimulus and a tailshock as the unconditioned stimulus is shown to arise as a result of contingent presentation of the two stimuli rather than from sensitization or pseudoconditioning. After achieving an asymptote for conditioned tail flexion, different groups received response-contingent tailshock increment, decrement, or omission. None of these treatments appreciably altered the probability of a conditioned response. Evidence is presented demonstrating that the response was sensitive to changes in the relationship between the stimuli and that the subjects could differentiate the various shock levels. The present data are viewed as inconsistent with the preparatory response hypothesis, which posits that classically conditioned behavior depends upon intrinsic reinforcement of components of the conditioned response syndrome. The possibility is discussed that classically conditioned responses observed in the laboratory are often only part of a larger, perhaps more clearly instrumental, set of behaviors that would occur in the unrestrained animal.

Traditional discussions of classical conditioning (e.g., Kimble, 1961) are curiously silent concerning its adaptive value. Although there is apparent evolutionary value in a few classically conditioned responses (CRs), such as conditioned eye blink in anticipation of an air puff and conditioned salivation in anticipation of food delivery, the frequent lack of easily identifiable survival- and reproduction-enhancing consequences of classically conditioned responses stands in stark contrast with the obvious benefit resulting from most instrumentally learned responses. In fact, the lack of apparent function in classical conditioned behavior is one of the primary distinctions between classical conditioning and instrumental learning.

It is entirely possible that the capacity for classical conditioning evolved due to its contribution to in-strumental learning, as suggested by two-factor theory, or that it evolved as an epiphenomenal process. However, neo-Darwinian considerations and a desire for parsimony, that is, to minimize the differences between classical conditioning and instrumental learning, have prompted us to seek evidence of direct beneficial consequences of classical conditioning in situations in which they are not obvious. Classical conditioning by definition excludes the possibility of a CR's modifying the physical characteristics of the immediately subsequent unconditioned stimulus (US). However, it is conceivable that an internal component of the CR complex modifies the state of the organism, thereby rendering an appetitive US more beneficial or an aversive US less detrimental. Supportive of this view are the observations that tolerance to pain can be increased by internal preparation (e.g., Scott & Barber, 1977), that unconditioned responses (URs) to aversive USs, presumably indicative of the aversiveness of the US, decrease as a result of conditioning (e.g., Kimble & Ost, 1961; Kimmel, 1966; Kimmel & Burns, 1975), and that peak CR ordinarily occurs at the time of US onset (e.g., Martin & Levey, 1969). Historically, Pavlov (1927) alluded to the adaptive consequences of a CR without integrating them into his theoretical schema, whereas Schlosberg (1937) was more specific about

the nature of the adaptation and hypothesized that instrumental reinforcement of some aspect of the CR was the mechanism responsible for the maintenance of classical conditioning. In more recent times, the functional view of classical conditioning was reintroduced into psychological theorizing by Perkins (1955, 1968) as the preparatory response (PR) hypothesis and by Lykken and Tellegen (1974) as the preception hypothesis. The potentially preparatory nature of some classical conditioning preparations, such as eye blink and salivation, are relatively obvious, but whether the PR hypothesis can be applied to most classical conditioning preparations is open to question. (A few failures would be tolerable since there are occasional examples of dysfunctional instrumental learning, e.g., vicious circle behavior and negative automaintenance.)

Recently, Coleman and Gormezano (1979), in a detailed analysis of the applicability of the PR hypothesis to classical conditioning, concluded that despite considerable supportive evidence there are a number of major problems facing the PR hypothesis. However, their argument was embedded in a Thorndikean law of effect framework, which posits that reinforcement is necessary for acquisition of an association, rather than for responding given an association based largely upon contiguity. In order to avoid many of the problems discussed by Coleman and Gormezano (e.g., initial CR occurrence)—problems that exist for the application of the law of effect to instrumental learning as well as to classical conditioning—we prefer to view the PR hypothesis as concerning response generation rather than the formation of associations. A full discussion of this distinction would be too lengthy to include here, but it is an important distinction for a complete evaluation of the PR hypothesis.

To date, two of the principle approaches to testing the PR hypothesis have been omission training and preference for signaled shock (PSS). [For psychophysical approaches to the PR hypothesis, see the extensive work of Furedy and his associates with humans (e.g., Furedy & Murray, 1976) and the recent research of Miller, Greco, Vigorito, and Marlin with rats, Note 1.] The PSS phenomenon consists of an animal's electing to be forewarned of an impending shock that is unavoidable and ostensibly unmodifiable. This preference is seen even when fixed electrodes are used to administer the shock (e.g., Miller, Marlin, & Berk, 1977). In essence, the animal is choosing to be conditioned rather than not conditioned. Viewing the preference in this way suggests that the animal benefits from being conditioned, presumably by the shock's being rendered less detrimental as a result of some element of the CR. Alternative explanations of the PSS effect include the information-seeking hypothesis (Berlyne, 1960) and the signaled-safety hypothesis (Seligman, 1968). Recently, Marlin,

Sullivan, Berk, and Miller (1979), using a modified version of the PSS preparation, reported that a preference remained after differences in signaled safety had been eliminated as contributing factors and information-seeking had been rejected on the particulars of the data. Their results were consistent with those of D'Amato and Safarjan (1979), and Fanselow's (1979) observation that naloxone attenuates PSS in rats suggests that part of the PR may include the release of endogenous opiates. As a consequence of observing this preference in a situation in which two of the three traditional explanations of the PSS effect could be discounted, Marlin et al. (1979) concluded that preparatory responding at least contributed to the ordinary PSS effect. However, this conclusion rested not on a confirmation of PRs, but on proving the incompleteness of the two other explanations. As D'Amato and Safarjan (1979) have pointed out, their data and those of Marlin et al. (1979) can be explained without recourse to PRs by using the Rescorla-Wagner (1972) model to compute differential acquired aversiveness of the warning signals (also see Fanselow, 1980). Consequently, these two reports cannot be regarded as compelling evidence of the generality of PRs.

Attempts to test the PR hypothesis using omission training paradigms were predicated on the following logic. If the preparatory role of CRs is fundamental to classical conditioning, withholding the US whenever a CR occurs is potentially equivalent to adding an extrinsic instrumental contingency to the intrinsic modulation of reinforcement attributed to the CR syndrome by the PR hypothesis. In principle, any extrinsic instrumental reinforcement resulting from the omission contingency should summate with any existing intrinsic instrumental reinforcement underlying classical conditioning; therefore, conditioning with an aversive US should be enhanced and conditioning with an appetitive US should be attenuated. The traditional alternatives to reinforcement explanations of classical conditioning are (pure) contiguity theory and expectancy theory. As both of these positions predict that associative strength will depend upon the probability of a US given a CS (assuming no USs without a CS), omission training with both appetitive and aversive USs would be expected to impair performance. These predictions distinguish themselves from the PR hypothesis in the aversive but not the appetitive situation. Consequently, omission studies using aversive USs (operationally, active avoidance) are potentially more illuminating than those using appetitive USs in contrasting the PR view with alternative theories of classical conditioning. Enhanced response strength due to the CR-dependent omission of an aversive US would *not* definitively establish the existence of PRs in the given situation. Such an outcome could result from a summation at the response generation stage with separate mechanisms under-

lying classical conditioning and instrumental learning, or alternatively could arise from the extrinsic instrumental contingency overshadowing any detrimental consequences of the omission procedure upon classical conditioning. However, a failure to observe the predicted enhancement with the response-contingent omission of an aversive US would serve as strong evidence that classical conditioning is impervious to extrinsic reinforcement and, by extrapolation, also refractory to intrinsic reinforcement.

Consistent with the PR hypothesis, many studies of omission training using an aversion US have found enhanced responding (e.g., Bolles, Stokes, & Younger, 1966; Brogden, Lipman, & Culler, 1938; Holland, 1979; Kamin, 1956, 1957; Wahlsten & Cole, 1972), but in some instances responding was unchanged or deteriorated (e.g., Holland, 1979; Schlosberg, 1934). Moreover, Mackintosh (1974) argues that a microanalysis of the data indicating enhanced responding tends not to support a reinforcement interpretation of classical conditioning; for example, local CR enhancement is not seen immediately following the omission of an aversive US.

A major problem with the use of omission training to evaluate the role of reinforcement in aversive conditioning is that withholding the US, while potentially reinforcing responding, dilutes the CS-US contingency. Effectively, omission training could be equivalent to placing an animal on a classical conditioning partial reinforcement schedule, which rarely enhances classical conditioning and has often been reported to impair responding (e.g., Brogden, 1939; Wagner, Siegel, Thomas, & Ellison, 1964). To study the effects of superimposing CR-contingent US omission upon a classically conditioning relationship without radically altering the CS-US contingency on omission trials, a modified procedure was developed by Coleman (1975) and Gormezano and Coleman (1973) and applied to the shock-induced nictitating membrane response of the rabbit. In addition to the conventional omission training group, other animals were run for whom shock intensity was decreased, but nonzero, provided a CR occurred. Contrary to expectation based on the PR hypothesis, rabbits receiving US shock reduction on those trials during which they produced a CR failed to display superior conditioning relative to those animals lacking the omission contingency. Thus, despite the paradigm avoiding gross differences in information delivered to the subject as a result of attempted extrinsic reinforcement of CRs, extrinsic CR-contingent decrements of the US failed to enhance performance. In a second study, Gormezano and Coleman (1973) increased intensity of the aversive US whenever a CR occurred, but failed to see any attenuation in performance as would be predicted by a PR analysis of classical conditioning. More recently, Clark and Prokasy (1976) have obtained similar data using a

human eyelid preparation. Jointly, these studies pose problems for the PR hypothesis because, if classical conditioning is motivated by intrinsic reinforcement, surely it should be responsive to the extrinsic reinforcement potentially available in CR-contingent aversive US reduction. As ingenious as these studies were, we could not accept their conclusions without reservation. The PR hypothesis appeared to explain the results of too many other studies to be quickly discarded. Moreover, the increases and decreases in US intensity in the above-cited studies were possibly so great as to support more or less classical conditioning, respectively, thereby potentially overshadowing any effect of the CR-contingent US modification. Therefore, in an effort to evaluate the validity and generality of Gormezano and Coleman's rejection of the PR hypothesis, the present research used the same CR-contingent US increment and decrement paradigms, but applied them to rats in a tail flexion preparation similar to that of Schlosberg (1934).

The research plan first called for a series of pilot studies to determine appropriate parameters that would yield consistent acquisition of a conditioned tail flexion with a response asymptote sufficiently far from either a performance ceiling or floor that any later enhancement or attenuation in responding could be detected. Experiment 1 established that our preparation was sensitive to conditioning rather than to some nonassociative phenomenon such as sensitization or pseudoconditioning. Moreover, since our ultimate goal was to attempt to reinforce CRs by changing tailshock intensity, Experiment 2 demonstrated that animals trained just with the intended, punishing higher intensity and just with the intended, rewarding lower intensity were equivalent in asymptotic CR frequency, a condition necessary to assure that any shifts in responding seen later were due to the response contingency per se rather than to mere changes in classical conditioning arising from different US intensities. Experiment 3, the last in the series, modified US intensity on trials during which conditioned tail flexions occurred.

Limited control equipment necessitated our testing different experimental groups serially, rather than in parallel as we would have preferred. Therefore, in both the pilot and formal experiments, considerable attention was paid to the between-groups uniformity of acquisition under equivalent conditions. As will be evident from the similarity of the acquisition curves of each group prior to differential treatment, the preparation was sufficiently consistent to prevent sequential effects from appearing across groups. In order to obtain potentially equivalent acquisition curves that could be used to assess sequential effects, CRs served as the basis for US modification only after an asymptote was achieved through traditional response-independent classical conditioning.

EXPERIMENT 1: EVIDENCE FOR ASSOCIATIVE CONTROL OF TAIL FLEXION

The first experiment was designed to demonstrate acquisition of a classically conditioned tail flexion in our preparation and to establish that it was not an artifact of some nonassociative process such as sensitization or pseudoconditioning. Therefore, in addition to the basic CS-US group, the present experiment included a truly random control group (Rescorla, 1967) for which CSs and USs were administered independently. Moreover, to determine how sensitive asymptotic responding under the present parameters was to changes in contingencies, the conditioned tail flexion of the paired CS-US group was extinguished with a series of CS-only presentations.

Method

Subjects. Twelve male rats of the Sprague-Dawley strain (Charles River CD, Wilmington, Mass.), weighing 285-360 g, were assigned randomly to one of two groups (n = 6). The subjects were acclimated to the animal colony and to handling for at least 10 days before the beginning of the experiment. All animals were housed in individual wire-mesh cages in a continuously illuminated colony. In the home cage, water was available ad lib and food was restricted to 15 g/day of Purina powdered chow in order to prevent the animals from increasing in size so rapidly as to outgrow the conditioning apparatus. The limited food ration was in force for at least 7 days prior to the experiment. On experimental days, the animals received their daily ration 1-3 h after conditioning.

Apparatus. Six semicylindrical Plexiglas restraining cages (Fisher No. 1-280-10) were used to hold the animals. Each restraining cage was suspended inside a well-ventilated, sound-attenuating, dimly illuminated environmental chamber containing an 82±2 dB masking noise composed primarily of 10/sec "clicks." The tail of each animal was suspended horizontally backwards with support from a Plexiglas disk through which the last 3 cm of the tail passed. Several turns of adhesive tape on the distal side of the disk prevented the animal from retracting its tail. The disk was suspended from the ceiling and floor by three rubber bands that permitted the disk to be easily displaced but tended to restore it to its equilibrium position. Three centimeters proximal to the supporting disk, a freely rotating loop of nylon thread was passed around the tail with transverse slippage prevented by a turn of adhesive tape. Clipped around the tail, 5±1 cm proximal to the nylon thread, was a Littelfuse fuseholder (National Tel-Tronics No. 410, Meadville, Pa.) with one prong of each of its two electrodes covered with insulation. Both the spring constant of the electrodes and adhesive tape held the exposed part of each electrode flush against the bottom of the animal's tail.

Tail movement was monitored through a cylindrical magnet (.7 cm long × .6 cm diam) hanging from the tail by the nylon thread. The magnet was suspended inside a coil that was connected to an activity monitor (Lafayette No. 86010). The coil consisted of two coaxially aligned pickups from a pair of activity platforms (also Lafayette No. 86010), and the magnet was derived from the same piece of equipment.

The CS was a 1-sec burst of white noise 10±2 dB above background, the background masking "clicks" being off for the duration of the CS. The US, which immediately followed CS termination, consisted of a 60-Hz, constant current tailshock of .5 sec duration.

Procedure. On the day prior to the initiation of conditioning, each animal was adapted to one of the apparatuses for 2 h. Adaptation was identical to treatment on the conditioning days except for the lack of both the CS and US. Animals struggled against the restraining apparatus for the first 5-15 min and then remained motionless except for an occasional postural adjustment or bout of struggling that lasted no more than a few seconds. The primary consequence of the adaptation session was that, on conditioning days, the animals were almost totally quiescent in the restraining cage except for CRs and URs.

A daily conditioning session lasted 3 h and consisted of approximately 360 successive intervals of 30 sec each. A probability gate set at 30% determined whether a CS-US pairing would occur at the initiation of each interval. Pairings in a particular session were terminated after 100 had occurred. A pre-CS measure of tail activity was taken for .9 sec, starting 1.0 sec prior to CS onset. Tail motion was also monitored during the last .9 sec of the 1.0-sec CS presentation. An animal was judged to have emitted a CR if its activity monitor produced more pulses during the CS than immediately prior to it. Attempts were made to equate the sensitivity of the six monitors; however, the ultimate assurance that differences in sensitivity between apparatuses did not systematically influence the data was that throughout the entire series of experiments the sensitivity of each apparatus was held constant and groups were counterbalanced across apparatuses.

The conditioning group received the CS paired with the US on the previously described random schedule until 100 pairings/day had occurred. For both groups, the US was a 1.6-mA tailshock, the intensity we planned to deliver in later studies when shock intensity was not modified, that is, when there was no CR. The control group experienced the CS on the same schedule, but received the US during a random 26% of approximately 415 26-sec intervals until 100 tailshocks had been administered. Treatment continued until asymptotic performance was observed in both groups. Asymptote was defined as at least 3 consecutive days with daily mean scores that did not differ from one another within groups by more than 10%. After both groups had reached asymptote, the control group was terminated and the conditioned group was subjected to a CS-alone extinction procedure. Extinction was identical to conditioning except for the omission of any US presentations. The random relationship between the CS and US for the control group permitted occasional pairings, but the influence of these pairings upon asymptotic performance, given the anticipated large number of preasymptotic CS and US presentations, was assumed to be small (Kremer, 1971).

Results and Discussion

The daily performance of each group is illustrated in Figure 1. At the conditioning asymptote, Days 9-11, the CS-US paired group responded more frequently than the truly random group. The performance asymptote following extinction of the CS-US paired group was below that of both the conditioning group and the truly random group.

After 11 days of paired or truly random stimuli presentations, performance had stabilized. Using pooled scores from Days 9-11 to define asymptote performance, a comparison between the CS-US paired group and the truly random group proved significant [t(10) = 2.33, p < .05]. Extinction of tail flexion, begun on Day 12, achieved an asymptote and was terminated on Day 20. Individual means from Days 18-20 were used to determine the group mean extinction asymptote. Comparison between this extinction asymptote and the acquisition asymptote of Days 9-11 proved significant [t(5) = 3.39, p < .02]. The extinction asymptote was also reliably lower than that of the truly random group [t(10) = 2.25, p < .05].
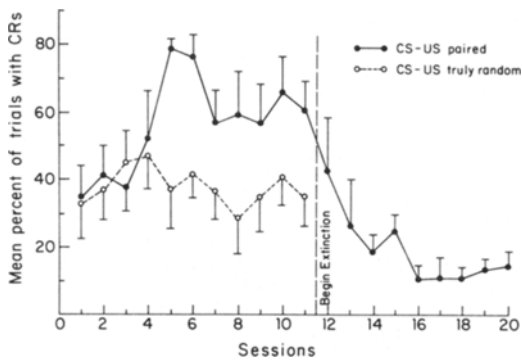
Figure 1. Acquisition curves as a function of the relationship between CS and US (n = 6). Each session contained 100 trials. Brackets indicate standard errors. The CS-US paired group was conditioned to asymptote with a 1.6-mA US, after which the US was omitted on all trials (extinction). The truly random group was run for the duration of conditioning of the paired group.

The observed difference between the two groups on Days 9-11 stands as evidence that the CS-US pairings yielded associative conditioning in addition to any sensitization or pseudoconditioning that may have also been present. The more frequent responding seen in the truly random group on Days 9-11 compared with the extinction asymptote of the CS-US paired group on Days 18-20 suggests either that some nonassociative effects of the US presentations were contributing to the overall performance of both groups prior to Day 12 or that chance CS-US pairings had given the CS some excitatory strength in the truly random group (e.g., Kremer, 1971). The fact that the paired group reached an extinction asymptote in 5 days of CS-only treatment indicates that animals at an acquisition asymptote supported by a 1.6-mA US are sensitive to changes in the prevailing contingencies and respond to the change relatively rapidly. This implies that any changes in associative strength due to response-contingent modification of the US should be evident in similarly trained animals.

EXPERIMENT 2: ACQUISITION OF TAIL FLEXION AS A FUNCTION OF US INTENSITY

Since the key experiment in this series was to investigate the consequences of response-contingent increases and decreases in US intensity, in Experiment 2 groups of animals that consistently received these higher and lower tailshock intensities were examined in order to establish that both the lower and higher intensities were aversive as indicated by the unabated elicitation of a UR and, further, that all three intensities of tailshock were differentially aversive, as indicated by the amplitudes of the resultant URs. The aversiveness of both low and high intensities would assure that the trials on which CR-contingent US modification would occur in later experiments would not be, effectively, extinction trials, and differential

aversiveness of the three intensities was necessary if we were to regard response-contingent substitution of one shock by another as being extrinsically reinforcing. Furthermore, because we wished to observe any effects of the extrinsic reinforcement contingency to be imposed in later experiments, it was necessary to demonstrate that the magnitudes of aversiveness of the three tailshock intensities were not so disparate as to yield appreciably different degrees of classical conditioning, an effect that would reduce the sensitivity of the later experiments to instrumental contingencies. In addition to demonstrating equivalent conditioning, we hoped to achieve an intermediate performance asymptote that would be maximally sensitive to later manipulation.

Method

Subjects and Apparatus. Eighteen male rats of the Sprague-Dawley strain (Charles River CD, Wilmington, Mass.), weighing 300-410 g, were assigned randomly to one of three groups (n = 6). The subjects were acclimated to the colony, maintained, and handled as in Experiment 1. The apparatus, subject preparation, stimuli, and response monitoring were all the same as they were for the CS-US paired group in Experiment 1, except that the tailshock intensity differed among groups.

Procedure. On the day prior to the initiation of stimuli presentations, each animal was adapted to one of the apparatuses for 2 h, exactly as in the previous experiment. The conditioning procedure for all three groups was the same as that for the CS-US paired group in Experiment 1. For one group, the US was a 1.6-mA tailshock, identical to that of the CS-US paired group in the last study. Another group received a .6-mA US, and the third group received a 2.5-mA US. The latter two values were selected on the basis of pilot studies indicating that .6 mA was clearly above the aversive threshold, that 2.5 mA was not so painful as to produce a UR that lasted more than 15 sec, and that both .6 and 2.5 mA produced URs that could be distinguished from the UR elicited by 1.6 mA. The animals were observed at both the beginning and the end of the present experiment to check the validity of the pilot data concerning UR differences as a function of US intensity. Conditioning sessions continued until asymptotic performance was achieved for all three groups. Asymptote for a group was defined as in Experiment 1, that is, at least 3 consecutive days with daily mean scores that did not differ within groups by more than 10%.

Results

As can be seen in Figure 2, no significant differences among groups was observed when average performance on the last 3 days of conditioning (Days 10-12) was used to determine asymptotic frequency of CRs [F(2,15) = 1.49, p > .25].

Indicative of the reliability of the data, the performance of Group 1.6 in this study was quite similar to that of the equivalently treated group in Experiment 1, that is, the CS-US paired group. Session 1 behavior was found to be an unacceptable measure of preconditioning baseline responding due to a strong tendency toward increased CR frequency seen over trials within Session 1. However, only 2 of the 18 animals (11.1%)—one from Group .6 and one from Group 2.5—produced tail flexions during the first CR presentation of Session 1, that is, before ever having been shocked. Asymptotic CR frequencies of the
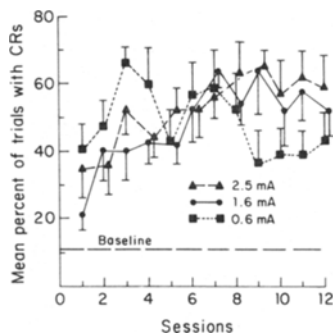
Figure 2. Acquisition curves as a function of US intensity (n = 6). Each session contained 100 CS-US pairings. Brackets indicate standard errors. Baseline reflects responding to the first CS in Session 1 (n = 18).

three groups were 41.1%, 55.7%, and 58.1% for Groups .6, 1.6, and 2.5, respectively, each of which contrasts sharply with the 11.1% baseline of Trial 1 on Day 1.

Direct observation of the animals found that all three shock intensities yielded URs indicative of aversive stimulation at both the beginning and end of training. Responses to tailshock consisted of tail flexions, vocalizing, and attempts to attack the source of distress and free their tails. These responses appeared to be of similar amplitude and duration within groups and different between groups. Duration of the longest lived element of the UR syndrome, usually struggling against the restraining cage, was the easiest of the measures to quantify. Weak tailshock (.6 mA) initiated 1-5 sec of responding, intermediate tailshock (1.6 mA) initiated 6-14 sec of responding, and strong tailshock (2.5 mA) initiated 15-30 sec of responding with better than 90% accuracy. Thus, tailshock intensities could be differentiated on the basis of UR duration. This relationship between tailshock intensity and UR duration held in both Session 1 and Session 12, although all subjects exhibited a tendency toward reduced URs in Session 12 relative to Session 1.

Discussion

All three tailshock intensities appeared able to support and maintain conditioning of a tail flexion. This is consistent with the observation that the aversiveness of each intensity contained throughout the experiment, a conclusion that is also supported by the observed URs. The comparison of CRs across groups proved nonsignificant. The similarity of the three asymptotes suggests that differences in classical conditioning as a function of these three shock intensities were negligible. This was desirable as future experiments would be looking for enhanced responding due to response-contingent attenuation of shock and decreased responding due to response-contingent augmentation of shock; reduced classical conditioning with lower shock intensities could possibly counter

any such consequences of the intended instrumental contingencies. On the one hand, we did not want different levels of classical conditioning to result from the different tailshock intensities, since that would influence responding independent of any extrinsic instrumental contingency. On the other hand, it was essential to our intention of reinforcing tail flexions with changes in shock intensity that the different intensities be both discriminable and differentially aversive. The observed difference in UR duration as a function of shock intensity argues for the different intensities' being discriminable and differentially aversive. Moreover, a previous study by Marlin et al. (1979), using the identical tail electrode preparation in a shuttlebox, found that differences in tailshock intensities smaller than the present ones yielded a decided preference for the lower intensity. Hence, the present differences in shock intensity are clearly able to support at least certain types of instrumental behavior.

As can be seen in Figure 2, asymptote performance levels were sufficiently far from either 0% or 100% responding to make it unlikely that either floor or ceiling effects would obscure any change in response frequency resulting from the response-contingent increments in shock intensity that were planned for subsequent studies.

The original plan for this series of experiments had been to examine the effect of a response-contingent modification of shock intensity upon classical conditioning. Whether this could best be done during acquisition or after an asymptote for conditioning had been achieved was regarded as an empirical issue. Consistent with our pilot data, the present study indicates that between-day performance during acquisition is highly variable compared with asymptotic performance, probably too variable to see any consequences of a superimposed extrinsic instrumental contingency. Therefore, we decided to limit future manipulations to imposing response-dependent contingencies only after stable conditioning asymptotes had been reached.

EXPERIMENT 3: US MODIFICATION CONTINGENT UPON CONDITIONED TAIL FLEXIONS

Having established that we could obtain conditioned tail flexions that were truly associative and that asymptotic responding was relatively responsive to changes in classical contingencies, we proceeded to examine the effects upon responding of a response-contingent modification in tailshock intensity. All groups were conditioned to asymptotic performance. Then, whenever a CR occurred, shock was decreased for one group, increased for another, omitted for a third, and unchanged for a fourth. A fifth group served as a quasi-yoked control.

Method

Subjects and Apparatus. Thirty male rats of the Sprague-Dawley strain (Charles River CD, Wilmington, Mass.), weighing 295-380 g, were assigned randomly to one of five groups (n = 6). The subjects were acclimated to the colony, maintained, and handled as in Experiments 1 and 2. The apparatus, subject preparation, response monitoring, and stimuli, except for US intensity, were all the same as in Experiments 1 and 2.

Procedure. All animals received 2 h of adaptation to the apparatus on the day prior to the initiation of conditioning. All animals were then given 100 daily pairings of the CS with a 1.6-mA tailshock until the group mean frequency of CRs did not vary by more than 10% over 3 successive days. Upon reaching this criterion tailshock intensity was decreased for Group .6 from 1.6 to .6 mA each time it produced a CR. Tailshock for Group 2.5 was increased to 2.5 mA whenever a CR occurred. Tailshock for Group 0 was omitted whenever a tail flexion occurred. Group 1.6 was a control group for which shock intensity was not modified. And Group .6-I had its tailshock reduced from 1.6 to .6 mA on a random 72% of its postacquisition trials independently of the occurrence or nonoccurrence of a CR. Intermittent attenuation on 72% of the trials was chosen after the response frequency of Group .6 was found to be uniform and to average 72% through the postacquisition phase of the study. After the postacquisition contingency went into effect, the running of each group was continued until the group mean again achieved 3 consecutive days with no more than 10% variation.

Results and Discussion

All groups displayed equivalent acquisition asymptotes. Postacquisition response-contingent changes in US intensity caused no group to differ from Group 1.6, the consistent US control group. These relationships are illustrated in Figure 3.
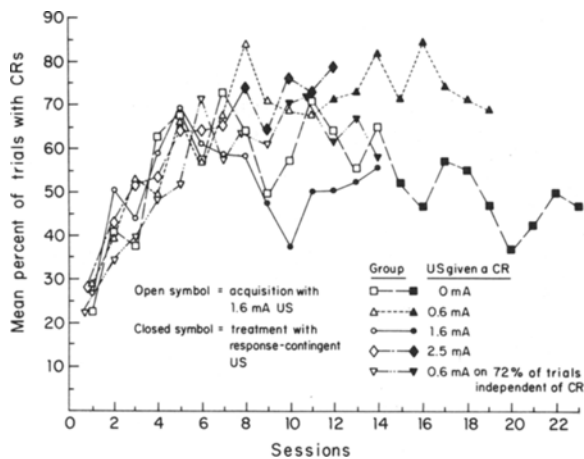
Figure 3. Performance as a function of postacquisition treatment (n = 6). All groups were initially trained to asymptote with a consistent 1.6-mA US. Following acquisition, tailshock intensity depended upon the occurrence of a CR, except for Group .6-I, which had a random 72% of its postacquisition USs reduced from .6 to .6 mA, thereby matching the overall daily shock experience of Group .6. If an animal in a response-contingent group did not produce a CR on a given trial, tailshock remained at the 1.6 mA used in acquisition. Owing to the large number of groups, standard error brackets, which were similar in magnitude to those illustrated in Figures 1 and 2, have been omitted.

Different groups achieved an initial asymptote at between 7 and 14 days. Acquisition with a uniform 1.6-mA US produced asymptotes ranging from an average of 59.3 CRs per day for Group 1.6 to an average of 68.8 for Group .6, a difference that proved to be highly nonsignificant [t(10) = .31, p > .5]. The similarity of initial acquisition asymptotes is consistent with the fact that all groups received identical treatment up to this time. It also provided a common starting point for differential treatments, thereby minimizing one potential source of bias.

When differential treatments were imposed following initial acquisition, the groups took from 5 (Groups 2.5 and .6-I) to 9 (Group 0) days to again achieve asymptote. Asymptotes following the initiation of differential treatments ranged from an average of 47.2 CRs per day (Group 0) to 76.2 (Group 2.5). This extreme difference proved significant by an ordinary t test [t(10) = 2.25, p < .05] but not by any range test that took into account the presence of five groups. Notably, no group differed significantly from the asymptote of 56.4 CRs per day achieved by Group 1.6, the constant US intensity control group (all ps > .2). Observation of subjects' response to USs using the same criteria as in Experiment 2 permitted proper identification of the shock intensity on over 90% of the observed trials in each group; therefore, it is unlikely that the animals were insensitive to the differences in shock intensity. In addition to shock intensities' being discriminable, each intensity was judged aversive as indicated by the nature of the URs and the struggling that followed all US presentations. Within-subject comparisons between initial acquisition asymptotes and differential treatment asymptotes failed to achieve significance in any of the five groups [all ts(5) ≤ 1.38, ps > .2].

The PR hypothesis predicts that CR-contingent increases in US intensity should have attenuated the CR frequency of Group 2.5 relative to that of Group 1.6, whereas CR-contingent decreases in US intensity should have enhanced the CR frequency of Group 0 relative to that of Group 1.6. On the other hand, a noninstrumental view of Pavlovian conditioning, such as contiguity theory, would predict that CR frequency would vary monotonically with US average intensity. The data are diametrically opposed to the PR hypothesis; however, interpretation of the observed difference between Groups 0 and 2.5 in the other direction must be qualified in light of Group .6's yielding a treatment asymptote of 72.0 CRs per day, closer to the 76.2 CRs of Group 2.5 than to the 47.2 CRs of Group 0. The exceptionally low treatment asymptote of Group 0 compared with the treatment asymptotes of the other groups may reflect both the effectively fewer CS-US pairings received by these animals during each treatment day and any extinction resulting from the omission trials.

The observation that tailshock modification contingent upon production of conditioned tail flexions failed to alter the animals' frequency of responding to the CS in a fashion consistent with the instrumental contingency argues against the PR hypothesis. However, this conclusion must be qualified in light of the shock intensities used. In principle, it is possible that greater differences between the different tailshock intensities might have yielded an additive effect between the classical and instrumental contingencies. Unfortunately, larger differences in tailshock intensity were found, in pilot studies, to produce different classical conditioning baselines, a result that could have obscured any instrumentally induced change in response frequency. It should be remembered, however, that previously cited evidence indicated that the present differences in shock intensities were more than adequate to promote preferential behavior in a shuttlebox. This suggests that the present shock levels should have yielded a reinforcement effect if classical conditioning were subject to such additive factors.

One final caveat concerning the present conclusions arises from the assumption, based on Experiment 2, that the three different shock levels used did not support different degrees of classical conditioning, a factor that if present would tend to obscure any change in responding due to the extrinsic reinforcement value of the response-contingent US modulation. The demonstration in Experiment 2 of equivalent classical conditioning for the three tailshock intensities was between-subjects, whereas the present study exposed individual animals to two shock levels, thereby potentially generating contrast effects. Any occurring contrast effects would correspond to negative successive contrast in the case of Group 2.5 and positive successive contrast in the case of Group .6. However, Mackintosh (1974) has concluded that, although negative successive contrast sometimes does occur, there is no evidence to date to support the occurrence of positive successive contrast despite efforts to obtain such data. Thus, the generalization from the between-subjects data of Experiment 2 to the within-subjects data of the present experiment is possibly misleading in the case of CR-contingent US increments, but not likely so in the case of CR-contingent US decrements.

GENERAL DISCUSSION

The total lack of support for the PR hypothesis seen in the present data is entirely consonant with the conclusions of Gormezano and Coleman (1973) based on the same paradigm applied to a very different preparation. Moreover, our demonstration that the altered US intensities did not support levels of conditioning different from those of the initial US intensity (Experiment 2), which might have over-shadowed any evidence of extrinsic reinforcement, argues against one possible alternative explanation of their results. The consistency of the present results with those of Clark and Prokasy (1976) and those of Gormezano and Coleman (1973) argues for the generality of our common conclusions.

If the PR hypothesis is inapplicable to a large number of classical conditioning preparations, does this imply that classical conditioning has no adaptive value? Surely this question transcends our data, which bear only upon one possible form of adaptive value, that is, reinforcement of the CR. It appears implausible in the face of our present knowledge of evolution that classical conditioning is completely lacking in adaptive value. Among the functional alternatives to the PR hypothesis is two-factor theory, which posits that covert CRs mediate instrumental behavior by inducing an appropriate motivational state, such as fear in an animal. Two-factor theory has a long history and has proven viable in many, but not all, applicable situations (e.g., Mowrer, 1960; Rescorla & Solomon, 1967). Additionally, Moore (1973) has argued compellingly that simple instrumental responses might be no more than Pavlovian CRs.

Another alternative that may be particularly relevant to the interpretation of the present data and the data of Gormezano and Coleman (1973) has been suggested by Zener (1937). Zener noted that his dogs, when released from their conditioning harnesses, responded to the CS by approaching the food tray and generally behaving in a highly functional manner. He concluded that CRs in the laboratory were fragments of a larger response syndrome that animals would perform were it not for the restraining apparatus in which many classical conditioning studies with animals are performed. Human subjects in classical conditioning experiments are less apt to be physically restrained, but the demand characteristics of the situation are often as effective as a harness or a restraining cage. One may reasonably assume that the potential to be classically conditioned evolved in the natural habitat of animals, a set of situations in which bodily restraint is notably absent. Therefore, we see considerable merit in regarding a conditioned response as a small segment of the entire behavioral syndrome that would occur in an animal's natural habitat. This position makes any lack of adaptive function on the part of classically conditioned responses in laboratory settings seem less incongruous in respect to Darwinian theory, as evolutionary theory recognizes that adaptations are best suited to the ecological niche in which they arose. This is not to imply that the interrelationships of the traditional variables of classical conditioning studies cannot be profitably studied in preparations using restrained subjects; however, such preparations may be inappropriate for functional analyses of classical conditioning.

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