Classical Conditioning of Attack Behavior

in Squirrel Monkeys

by

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ABSTRACT

A review of the literature on classical conditioning of pain-elicited attack suggested that the use of a bite-tube as a CS should produce strong conditioned attack in Squirrel monkeys. In Experiment I, however, it was found that backward-pairings of shock and the bite-tube produced conditioned attack more reliably than forward-pairings. Experiment II demonstrated that forward-pairings could in fact produce strong conditioned attack but that such attack was independent of the duration of postshock attack. Experiment III showed that conditioning via the forward-pairing procedure did not depend upon the occurrence of shock-free periods. These data were compatible with the Pavlovian stimulus-substitution analysis of conditioning. Experiment IV found that conditioning via the backward-pairing procedure depended upon the presentation of trials on a fixed-time schedule. When trials were randomly distributed in time, very few attacks occurred. These data suggested that under the fixed-time schedule attack was elicited by the safety-signal properties of the bite-tube. A detailed examination of the data from all experiments suggested that neither the stimulus-substitution analysis nor the safety-signal analysis provided a consistent interpretation of the data. Finally, an opponent-process model of motivational phenomena recently proposed by Solomon and Corbit (1974) provided a consistent description of the present data and led to a number of testable predictions.

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CHAPTER I

Classical conditioning of pain-elicited aggression

In 1939, O'Kelly and Steckle discovered that fighting in a group
of rats could be induced by exposing the subjects to a series of high-
intensity electric shocks. Ulrich and Azrin (1962) were the first to
undertake a systematic investigation of this phenomenon, which they
termed "pain-elicited aggression". In their study, pairs of rats were
placed in a small chamber and given a series of electric shocks on
their feet. Soon after the shock series began, the rats faced each
other, assumed upright postures on their hindlegs, and bit or struck
each other immediately following each shock. The rate of fighting
was a monotonic function of both shock intensity (.5 ma to 5 ma) and
shock frequency (.1 shock/min to 38 shocks/min). Rats would also at-
tack hamsters, guinea pigs and dead rats (if the latter were moved
about the chamber on a stick). Ulrich and Azrin (1962) concluded that
attack by rats was an unconditioned reflexive response (UCR) to the
pain caused by the shocks.

More recent research has found that pain-elicited attacks can be
produced in a wide variety of animals and directed at an equally wide
variety of targets, both animate and inanimate (see reviews by
Hutchinson, 1973 and by Ulrich, Hutchinson & Azrin, 1965). But Squirrel

monkeys have been most extensively used as subjects in studies of
pain-elicited agression because of their readiness to attack in-
animate objects, which facilitates the quantitative measurement of
attack behavior. In the typical procedure employed by Azrin,
Hutchinson and their colleagues (Azrin, Hutchinson & McLaughlin,
1965; Azrin, Hutchinson & Sallery, 1964; Hutchinson, Azrin & Renfrew,
1968) a monkey is seated in a restraining chair facing a pneumatical-
ly-operated rubber bite-tube located at eye level a few inches away
from its face, and given a series of shocks to its tail.

Both Azrin et al. (1964) and Hutchinson et al. (1968) found
that the probability of postshock attack increased with increases in
shock intensity (50v - 400v) and that it decreased as a function of
time since shock delivery. Higher intensities or longer durations of
shock produced longer lasting attack episodes; but generally, attacks
did not persist for more than 15 sec after shock. Azrin et al. (1965)
reported a similar postshock time-course for a chain-pulling response
which gave access to an attack object. These investigators speculated
that the aggressive motivation aroused by shock was transient and that
a constant input of aversive stimulation would be required to maintain
attack.

The consistency in the results of research on pain-elicited at-
tack has led many investigators to regard the phenomenon as a simple
UCR to aversive stimulation (Azrin et al., 1963, 1964, 1965; Creer,
Hitzing & Schaeffer, 1966; Hutchinson, 1973; Ulrich & Azrin, 1962).

Thus, it has been assumed that attack is elicited by pain in the same manner that eyeblinking is elicited by a puff of air to an eye, salivation is elicited by meat powder on the tongue, and leg-flexion is elicited by shock to a leg.

Despite the magnitude and reliability of postshock agressive behavior in rats and monkeys, experiments which have attempted to demonstrate classical conditioning of pain-elicited attack have had surprisingly little success. For example, Vernon and Ulrich (1966) presented to pairs of rats a tone CS (1320 Hz, 1 sec) which preceded and overlapped a shock UCS(2 ma, .5 sec). Trials occurred every 10 sec over 1000 CS-only presentations, 1000 UCS-only presentations and 2000 CS-UCS pairings. Although postshock fighting occurred on 70%-90% of shock trials, CS-controlled fighting reached only 30%-50% levels after 2000 trials.

Creer, Hitzing and Schaeffer (1966) performed an experiment which was very similar in design and results to that by Vernon and Ulrich (1966). Pairs of rats were first exposed to random presentations of .5 sec shocks and .5 sec tones (for an unstated number of trials). They were then given 1810 tone-shock pairings over 6 sessions. On test trials, in which the CS was presented alone, the subjects displayed the stereotyped upright posture (Ulrich & Azrin, 1962) but they did not engage in striking or biting. When the intensity of the CS was increased to 80 dB and the procedure repeated, 4 pairs of rats pro-

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duced 1-8 fighting responses in total over 10 test trials interspersed among 200 CS-UCS pairings.

The preconditioning procedures employed in both of these studies may have interfered with conditioning. Two aspects of Vernon and Ulrich's procedure could have been expected to reduce conditioning. First, repeatedly presenting the CS alone may have produced latent inhibition (Lubow & Moore, 1959) which reduces the rate of subsequent conditioning to a preexposed CS. Second, presenting the UCS alone would have increased the likelihood that apparatus cues would be associated with shock, thereby reducing the probability that the CS would subsequently be associated with the UCS (Rescorla & Wagner, 1972). In the study by Creer et al. (1966) preexposing subjects to random presentations of the CS and UCS may have substantially interfered with conditioning. Mackintosh (1973) has shown that rats given random presentations of a CS and a UCS before conditioning subsequently learned to associate these stimuli more slowly than animals given either CS-only, UCS-only or no preexposure. Thus, both of the experiments suffer from serious defects in design which make them less than satisfactory demonstrations of classical conditioning of attack.

A more recent experiment by Lyon and Ozolins (1970) indicates that the extremely low levels of conditioned fighting obtained in the previous two studies cannot be entirely explained by interfering effects of CS or UCS preexposure. These investigators did not preexpose either the CS or the UCS before conditioning sessions, but they ob-

tained conditioned fighting in only 5 of 16 pairs of rats. Moreover, the levels of conditioned fighting obtained after 750-1500 trials were quite low (36%-50%). A number of combinations of CS duration and intershock interval were employed, but conditioned fighting on at least 35% of the trials (experimenter's criterion) occurred only when the CS was 16 sec and the intershock interval was 64 sec. Longer or shorter CSs using the 64 sec intershock interval produced no conditioned fighting at all. While direct comparison of the Lyon and Ozolins (1970) study with those by Vernon and Ulrich (1966) and Creer et al. (1966) is impossible because of procedural differences, the overwhelming impression made by all three studies is that classical conditioning of pain-elicited attack is very difficult.

Pain-elicited attack in Squirrel monkeys seems to be more amenable to classical conditioning procedures. Hutchinson, Renfrew and Young (1971) presented a tone or a light CS 10 sec before the delivery of a tail-shock to monkeys seated in front of a rubber bite-tube. Conditioned attack was obtained in all subjects in a median of 145 trials. As training progressed, however, response rates during the CS decreased in all subjects. Furthermore, in some subjects the rate of biting during the intertrial interval equalled, and at times exceeded, the rate during the CS. Further still, in all subjects, once the tone CS controlled attack, reversal training was ineffective: making the tone CS- and the light CS+ resulted in no extinction of responding to the tone and no conditioning of attack to the

light. On the whole, the difficulties encountered in classical conditioning of pain-elicited attack contrast sharply with the ease of eliciting attack by shock. The general purpose of the present research was thus to investigate some factors which may be important in classical conditioning of pain-elicited attack behavior.

Myer (1971) has argued that an animal's skeletal behavior can be either activated or inhibited by aversive CSs depending upon the subject's natural reaction to the CS rather than upon its reaction to the UCS. Novel or intense auditory and visual "distal" stimuli are assumed to inhibit behavior, whereas "proximal" stimuli such as electric shock, air blasts, or immersion in water activate behavior (Myer, 1971, p. 481). According to these assumptions, classical conditioning procedures should be most effective when the CS and the UCS both activate or both inhibit behavior, and be least effective when the response elicited by the CS is opposite to the response elicited by the UCS. Thus, the use of auditory and visual CSs in classical conditioning of attack should work against positive results because these stimuli inhibit behavior while shock activates it. Indeed, Myer concluded that the meager positive results obtained by Vernon and Ulrich (1966) and by Creer et al. (1966) were sensitization effects rather than true classical conditioning. Myer went on to suggest that the use of more traditional conditioning parameters, such as longer durations of the CS and fewer trials per session, would have produced fear of the CS and thereby have inhibited attack. The poor results of the study by Lyon and Ozolins (1970) might be due to this factor.

Although Myer's (1971) analysis might adequately account for some of the failures to classically condition attack, it suffers from at least one major flaw. His analysis concerns itself with general activation and inhibition of behavior: it does not predict what CSs might be effective in conditioning attack behavior specifically. The use of a tactile CS paired with shock might activate rather than inhibit behavior as Myer suggests (1971, p. 504), but one can imagine that some of the specific responses activated might be compatible with attack while others might compete with attack behavior. Hence, one cannot use a general activation concept to predict the outcome of procedures designed to condition specific responses.

The literature contains a number of examples which indicate that a variety of postshock responses may be elicited from animals (see review by Segal, 1972). These studies suggest that the precise topography of the UCR depends upon concurrent environmental stimulation rather than upon a general mechanism of activation and inhibition of behavior. For example, Caggiula (1972) has demonstrated that shock-induced attack in male rats depends upon the use of male rats as targets. If female rats serve as targets, shock elicits copulation rather than attack. Further, if opportunities to escape the shock are provided, rats will learn an escape response even though a male target rat is present (Azrin, Hutchinson & Hake, 1967). Also, Galef (1970) has shown that wild rats will attack a wooden ball when they are shocked only if the ball is novel. If the rats have as little as

5 min of exposure to the ball before being shocked, escape behavior rather than attack will be elicited by shock. Thus, the response elicited by shock depends at least partly upon the type of objects in the environment, the opportunities for alternative responses, and prior experience in the environment.

If the nature of the postshock behavior depends upon the nature of environmental stimulation concurring with the UCS, it seems plausible that the nature of the CS employed in classical conditioning experiments might likewise affect the nature of the CR obtained. The phenomenon of autoshaping in pigeons provides an illustration of this possibility.

Autoshaping was discovered by Brown and Jenkins (1968), who reported that repeatedly pairing illumination of a response key with delivery of grain would cause pigeons to approach and peck the lighted key. Moore (1973) pointed out that the use of classical conditioning procedures did not guarantee that autoshaping was due to Pavlovian processes. However, Jenkins and Moore (1973) demonstrated that the topography of the conditioned keypecks was identical to the topography of the consummatory response elicited by the reinforcer. Pigeons emitted eating responses toward CSs paired with food, and drinking responses toward CSs paired with water. Further, Rackham (1971) similarly demonstrated that courting behavior in male pigeons could be controlled by a keylight paired with access to a female pigeon. In both of these studies the topography of the CR was determined by the UCS.

Moore (1973) has argued that autoshaping can be adequately explained by the Pavlovian stimulus-substitution principle: pairing the CS with the UCS causes the subject to behave toward the CS as it would toward the UCS. According to this principle subjects learn a stimulus-stimulus association rather than a stimulus-response association. It is not necessary that the subject perform the UCR during conditioning in order for a CR to be acquired. For example, Zentall and Hogan (1975) found that conditioned keypecking in pigeons could be generated and maintained for a short time by pairing a keylight with presentation of inaccessible grain. This finding provides strong support for the operation of stimulus-substitution in autoshaping.

Bindra (1974) has recently proposed essentially the same analysis of both classical and instrumental learning processes. However, Bindra makes a distinction between the motivational arousal controlled by a CS-US association, which may be relatively nonspecific in its behavioral effects, and the ability of the CS to elicit specific behavioral components of the UCR. This distinction applied to the stimulus-substitution analysis suggests that the response which emerges as the CR will depend upon the ability of the CS to support the topography of the conditioned consummatory response.

There is some experimental support for this suggestion. Schwartz (1973) used multiple VT/EXT schedules to examine the control of keypecking by stimuli lying on different sensory dimensions. Visual stimuli projected on the response key generated keypecking when cor-

related with the schedule of food delivery. But when an auditory stimulus was associated with food delivery it was incapable of such control, unless it had accompanied a predictive visual stimulus before being made the unique predictor of food. Very similar results have been obtained by Wasserman and McHaney (unpublished). These investigators, moreover, reported that the ability of a predictive auditory stimulus to control keypecking depended critically upon the concurrent presence of the previously predictive keylight as the target to be pecked. Thus it appears critical to the stimulus-substitution analysis of the autoshaping phenomenon that the CS be a localized stimulus toward which the behavior elicited by the UCS can be directed.

Given such data, it is not surprising that classical conditioning of attack behavior has been so elusive. In all of the attempts to classically condition attack either auditory or visual CSs were employed. The results of these experiments, though unimpressive, might be attributed simply to the concurrent presence of a target to attack, just as in the Wasserman and McHaney study the control of keypecking by an auditory stimulus depended upon the presence of a lighted key which had previously served as a target. In the study by Hutchinson et al. (1971) the localized visual stimulus appeared to be a less effective CS than the tone. It is possible that the subjects may have in fact directed their attacks toward the light CS and thereby reduced the number of attacks recorded on the bite-tube. The apparent superi-

ority of the auditory CS thus may have been an artifact of comparing localized (visual) and diffuse (auditory) CSs.

Extending the stimulus-substitution analysis to pain-elicited attack offers an interesting alternative to Myer's (1971) suggestions. It can be argued that auditory and diffuse visual stimuli are ineffective CSs not because they inhibit behavior, but because they do not provide a target for attack. It follows that strong classical conditioning of attack behavior in Squirrel monkeys might be obtained if a bite-tube were used as the CS. The first experiment examines this possibility.

CHAPTER II

The Experiments

General Methods

Subjects

In all experiments, the subjects were experimentally naive, feral adult male Squirrel monkeys (Saimiri sciureus) which were obtained from Connaught Laboratories, Willowdale, Ontario. The monkeys were maintained on a diet of Purina Monkey Chow biscuits given 2-3 times daily, and water ad libitum.

Upon arrival in the laboratory, the subjects were individually housed in the monkey colony room for 12-14 days. Two days before the start of an experiment, the monkeys were transferred to their running boxes and subsequently housed for the duration of the experiment in a temporary housing room adjacent to a room containing the experimental apparatus. The temperature of the housing and running rooms was maintained at approximately 24°C. A 12 hr day/12 hr night cycle was maintained throughout the experiments. The subjects were always run during the day portion of the cycle.

Apparatus

The running boxes measured 36 cm x 47 cm x 36 cm. They had stainless steel walls and grid floor, and a clear Plexiglas ceiling to per-

mit observation via overhead closed-circuit television. The front wall of each chamber contained a slot, 150 mm x 35 mm located 21 cm above the floor, through which a retractable latex bite-tube could be inserted and withdrawn. Located on the wall below the tube-slot, a panel of 8 stainless steel electrodes, each 20 cm x 2.5 cm, helped to insure that a subject could not avoid shock or reduce shock intensity by climbing onto the bite-tube and placing his feet against the front wall. The back wall of each chamber contained a food hopper and a water bottle to which access was blocked during experimental sessions.

The bite-tube was a length of 2 cm diam latex tubing bent into a semicircular configuration. When completely inserted the tube was 14.5 cm long and protruded a maximum of 6.5 cm into the chamber. The bite-tube was inserted and withdrawn by a motor and cam mechanism. A complete excursion of the tube took 4 sec, but the tube was present in the chamber during the last 2 sec of insertion and the first 2 sec of withdrawal. When the tube was fully retracted it was still visible to the subject and could be reached with the forearm, though it could not be attacked.

An air pressure switch (Tapeswitch model AW) was connected to the bite-tube so that displacement of the air by bites activated the switch and the recording apparatus in the control room. The sensitivity of the switch was adjusted so that bites, but not other forms of contact with the tube, would reliably activate the switch.

Procedure

In each experiment, there were 6 conditioning sessions followed by a test session. During conditioning sessions subjects received either 10 conditioning trials or 9 such trials plus a no-shock test trial. The test session consisted of 1 shock trial followed by 9 test trials.

The conditioned stimulus (CS) was the presentation of the bite-tube for 20 sec. The noise of the motor-cam mechanism accompanied all CS presentations.

The unconditioned stimulus (UCS) was scrambled electric shock delivered through the grid floor and the walls of the chamber via a Grason-Stadler E1064 shock generator set at 5 ma and .5 sec.

All trials were presented according to either fixed-time (FT) 4 min or variable-time (VT) 4 min schedules. The distribution of intervals on the VT schedule was chosen so that shocks would be randomly distributed in time with no minimum shock-free interval. Intervals used in the present experiments, however, ranged from 7 sec to 1150 sec, which gave an average interval of 215 sec. This interval was 25 sec shorter than the 240 sec interval used in the FT schedule.

Session durations varied with the schedule of trial presentations. Using the FT schedule the sessions were 40 min long, while under the VT schedule sessions ranged from 15 min to 70 min.

Throughout all experiments a trained observer monitored the behavior of the subjects via closed-circuit TV. Observations of the duration of attack episodes and of the frequency and duration of both approach-withdrawal from the tube and non-aggressive contact with the tube were made in most experiments. Six observers in total were employed in the course of the experiments. All were kept unaware of the specific rationale of the various experiments, and of the expected outcome.

Where statistical analyses were appropriate, they were carried out using Rodger's method (Rodger, 1974). This method allows unlimited post-hoc data-snooping at known error rates for Type I and Type II errors, provided a set of $\nu_1 = j-1$ mutually orthogonal contrasts of the j group means is asserted. Among the decision set $r = F/F[E\alpha: \nu_1 \ \nu_2] \leq \nu_1$ null contrasts are rejected and ν_1-r retained. Type I error rate, expressed as $E\alpha$, is the expected proportion of false rejections of true null contrasts when all contrasts are true nulls. In the present experiments $E\alpha$ was set at a conventional .05 level. A second parameter, called $E\beta$, controls the rate at which detection of true non-null contrasts occurs for a specified non-central parameter. $E\beta$ is principally governed by the size of the sample population and by the size of the non-null effects sought. In the present experiments the size of the non-null effects was assumed to be 1.0. Since $\underline{N}$s were small ($2 \leq \underline{N} \leq 6$), $E\beta$ ranged from .50 to .65. The basic implication of such low power is that only relatively large differences between groups will be reliably detected.

Rodger's method may be used to greater or lesser degrees of sophistication. In the present research, analyses proceeded only as far as determining whether groups differed and in what direction. In reporting the results of statistical tests the number of reject-able null contrasts per decision set, r, is given in place of the traditional p values. Rodger (1974) has recently published a cogent exposition of his method.

Experiment I

Classical conditioning of attack using a bite-tube CS

These traditional conditioning procedures were employed using the retractable latex bite-tube as the CS. The basic experimental group received forward-pairings of the bite-tube and shock (CS precedes UCS). The stimulus-substitution analysis predicts that strong conditioned attack will be produced in this group because the CS provides a target for attack behavior. Backward-pairings, in which the CS follows the UCS, were given to a second group to monitor elicited attack. No conditioned attack is expected in this group because the literature suggests that backward-pairings produce conditioned inhibition of the motivational state aroused by shock (Barlow, 1956; Moscovitch & LoLordo, 1968; Rescorla, 1967; Siegel & Domjan, 1971). Finally, as a control for possible sensitization effects, random presentations of shock and the bite-tube were given to a third group (Rescorla, 1967).

Method

Subjects and Apparatus

Eighteen (18) Squirrel monkeys served as subjects. They were housed and maintained as described in the General Methods section. The apparatus was previously described.

Procedure

Subjects were divided into 3 groups of equal size. In group FP

(forward-pairings) the bite-tube was presented for 20 sec prior to the onset of the shock. Withdrawal of the tube began with shock off-set. In group BP (backward-pairings) the CS was inserted immediately following each shock and remained in the chamber for 20 sec. This group was run to monitor elicited attack. Subjects in groups FP and BP received 9 conditioning trials and 1 test trial per session. The test trial was always the 5th trial in a session. Trials were sche-duled according to a FT 4 min schedule. In group Random the subjects received 10 CS and 9 UCS presentations per session according to iden-tical, independent VT 4 min schedules.

Following 6 conditioning sessions, a test session was run in which the subjects in groups FP and BP received 1 conditioning trial followed by 9 presentations of the CS alone. Subjects in group Random received 10 presentations of the CS alone during this session.

Results and Discussion

The data of primary interest are the performances of subjects during test trials. Figure 1-1 shows the average number of bites per trial during the daily test trial over sessions 1-6. Figure 1-2 presents the results of the test session (session 7).

Unexpectedly, test trial biting developed in 4 of the 6 subjects in group BP by the second conditioning session. A mean asymptote of 7 bites/trial was reached on the third session and was maintained throughout the remaining sessions. By comparison, the performance of

Figure 1-1

Average bites/test trial over sessions 1-6.
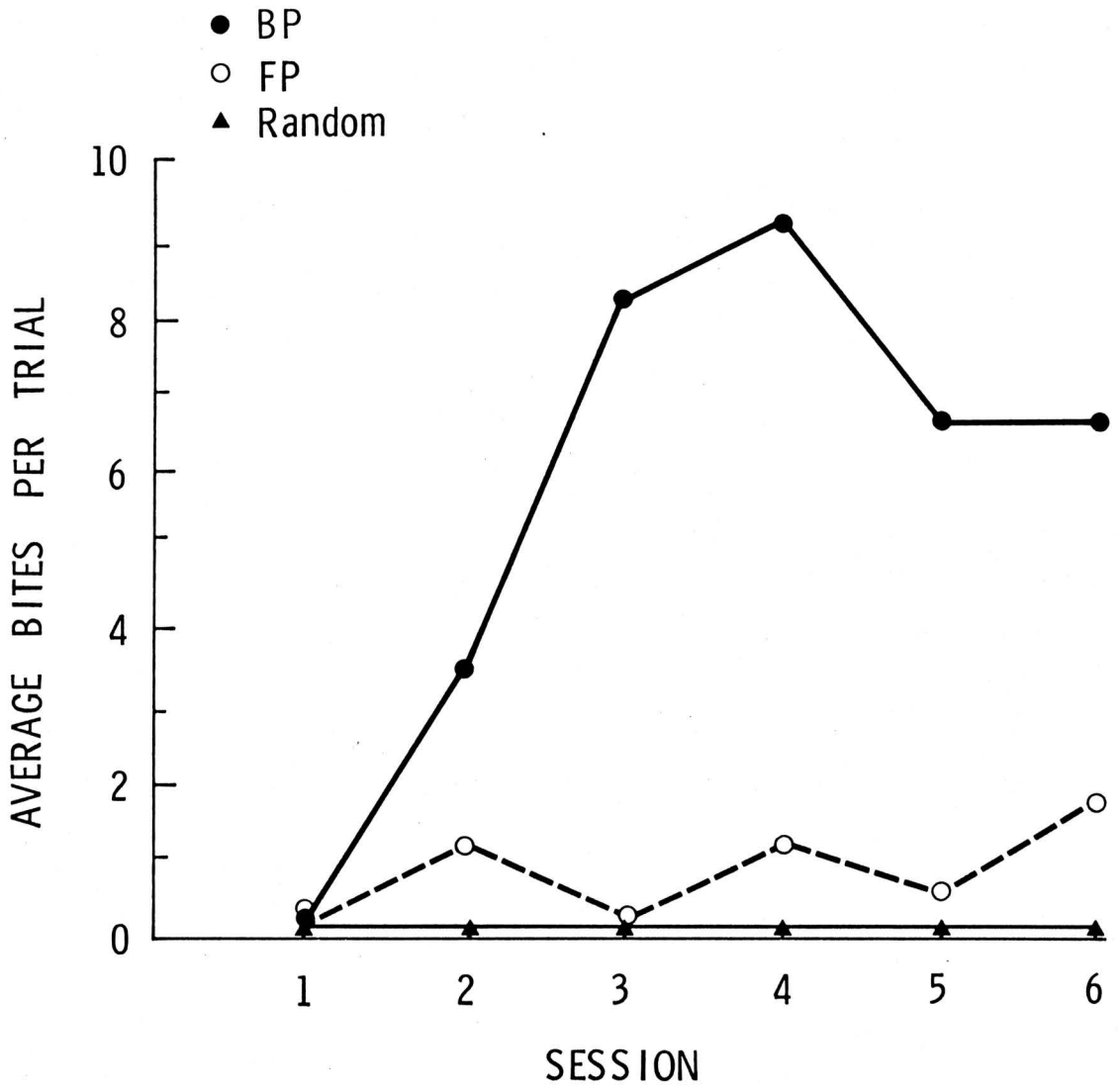
Figure 1-2

Average bites/trial across the test session (Session 7). Trial 1 was
a shock trial. Trials 2-10 were no-shock test trials.
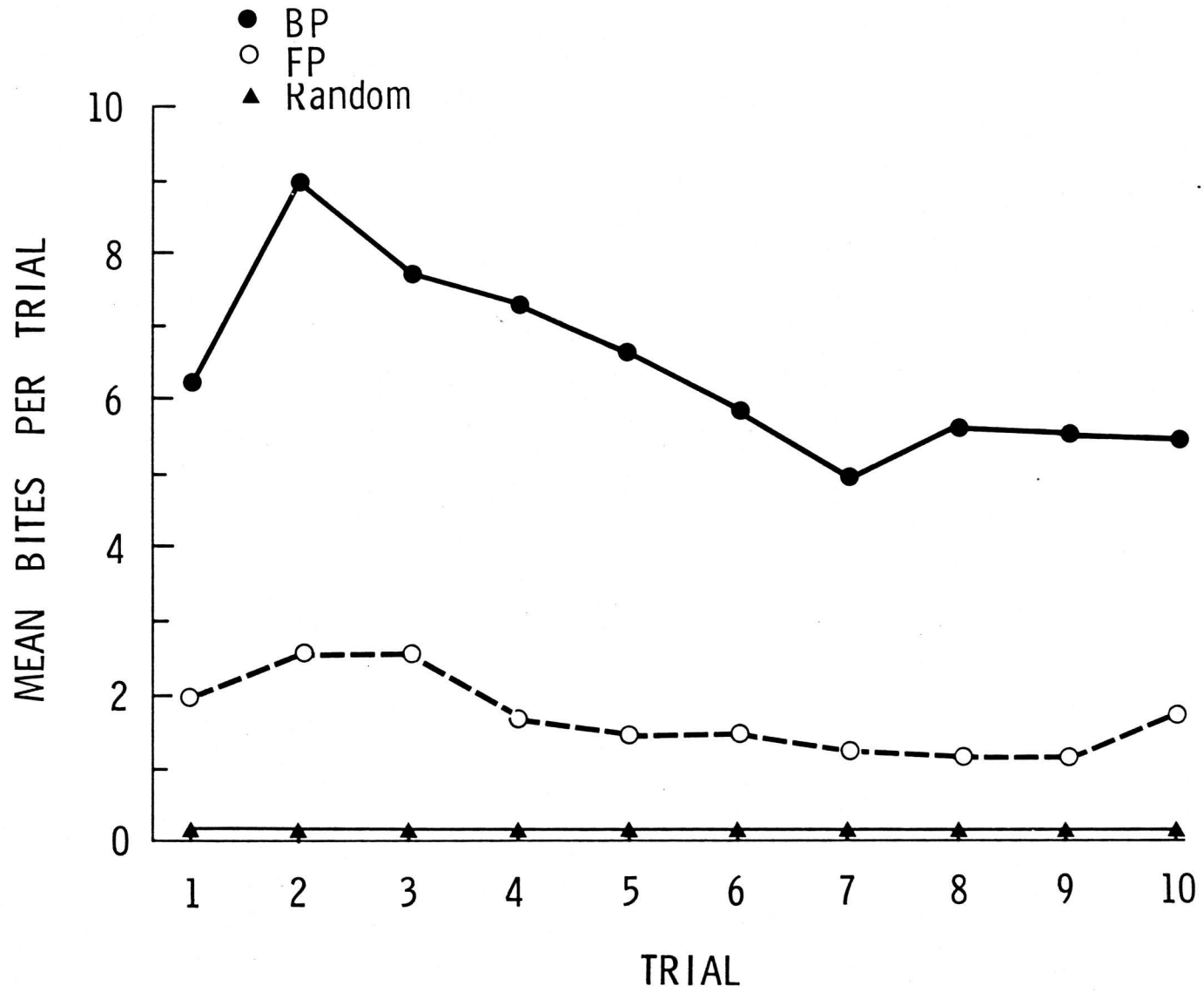
group FP was feeble. Throughout conditioning and testing the mean level of biting was very low--about 1.5 bites per trial. Incidentally, this performance compares unfavorably with the results of Hutchinson et al. (1971). This is particularly surprising since an inspection of the data from individual subjects revealed that a single subject was responsible for all conditioned attack in group FP. Conditioned attack by this subject was on a level with that of group BP. Finally, subjects in group Random displayed virtually no biting at any time. In fact, there were only 11 bites in total made by the subjects in this group.

Measures of the amount of time the animals spent in the front half of the chamber (which contained the bite-tube) during the CS and the ITI periods are shown in Figure 1-3. In the ITI periods the subjects in groups BP and FP spent more time in the front of the chamber than group Random, but the former 2 groups did not differ from each other ($\underline{F}$ = 3.00, $\underline{df}$ = 2/15, $\underline{r}$ = 1).

It can be seen in Figure 1-3 that during the CS periods the subjects in group FP tended to withdraw from the bite-tube into the rear of the chamber, while the subjects in group BP tended to remain in the front half. Subjects in group BP spent a significantly greater proportion of the CS periods in the front half of the chamber than either group FP or group Random. Also, group FP spent marginally more time in the front than group Random ($\underline{F}$ = 7.00, $\underline{df}$ = 2/15, $\underline{r}$ = 1). The data on this measure from individual subjects can be found in the Appendix.

Figure 1-3

Average proportion of CS and ITI periods spent in the front half of the

chamber.
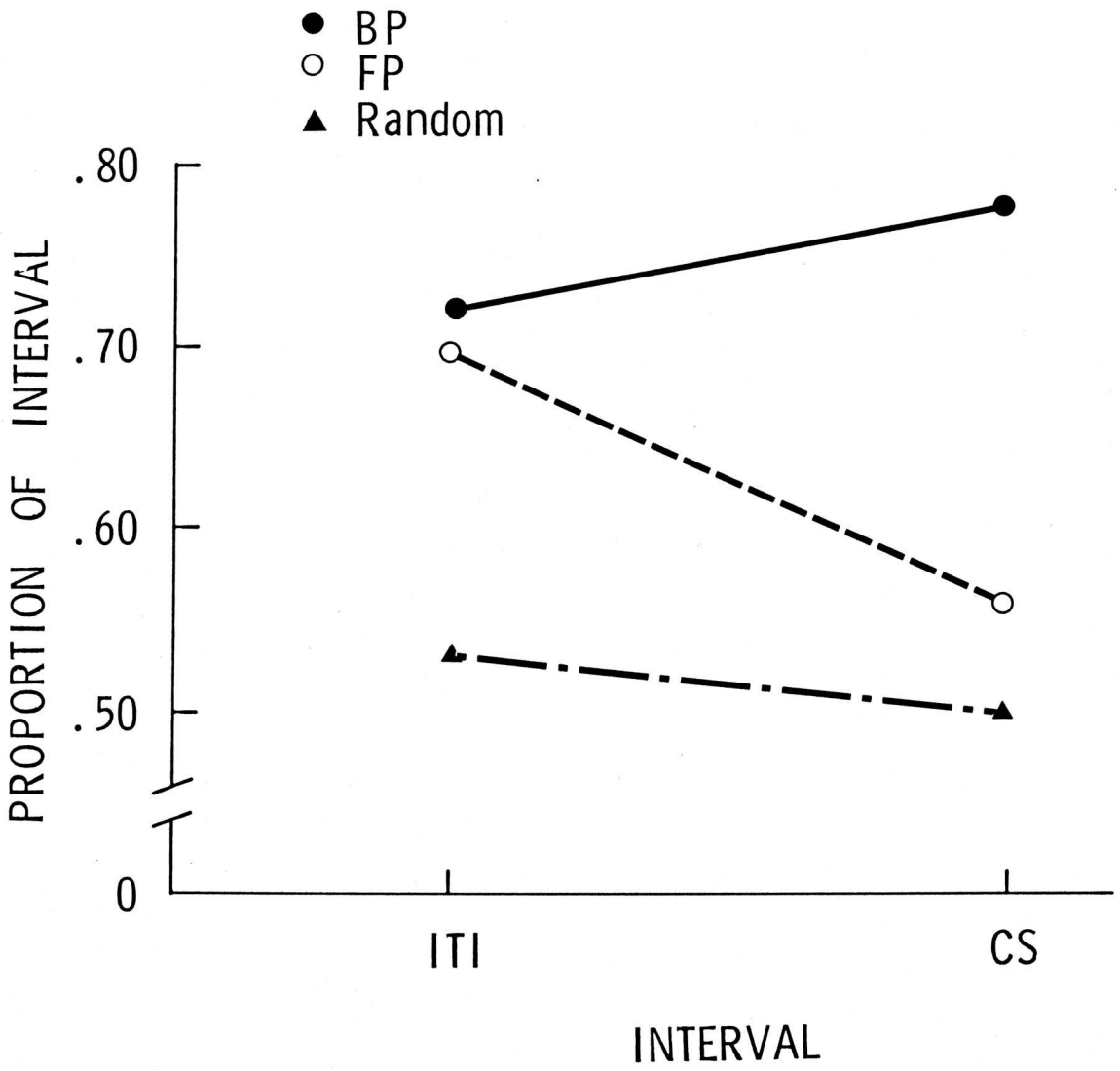
The results of Experiment I pose two distinct though related problems for experimental analysis. Clearly, the most curious problem is the analysis of conditioned attack obtained by backward-pairings of shock and the bite-tube. Conditioning with the backward pairing procedure appears to be by definition an example of backward excitatory conditioning. That is, the UCR--attack--was controlled by the CS alone. However, an alternative to such an analysis exists.

In a review of punishment theory, Dunham (1971) suggested that behavior elicited by shock under fixed-time schedules might be subject to control by what he called an "implicit avoidance contingency". That is, the response which most frequently and immediately follows shock offset has the unique property of predicting the absence of shock for a longer period than any other response in the animal's reper-toire. As a result of repeatedly participating in this fortuitous response-stimulus relationship the response may be strengthened. Thus, in the case of backward-pairings, the bite-tube may function as a dis-criminative stimulus for the implicit avoidance response--attack--not as a Pavlovian excitatory CS.

The second general problem is to account for conditioning, or its absence, in the forward-pairing procedure. The stimulus-substitution analysis led to the prediction that the use of the bite-tube as a CS would be a powerful conditioning procedure. However, only one subject in group FP displayed conditioned attack. There are two possible ex-planations for the ineffectiveness of this procedure.

One possibility is that the forward-pairing procedure may be primarily a fear conditioning situation. If so, the subjects would be afraid of the bite-tube and thus would be expected to withdraw from the tube rather than to approach and attack it. Wasserman, Franklin and Hearst (1974) have shown that pigeons will withdraw from localized stimuli which predict the absence of food. Similarly, Bindra (1974) has argued that animals will tend to withdraw from or avoid contact with aversive stimuli in conditioning situations. The fact that the subjects in group FP tended to withdraw from the tube during CS periods is consistent with such a competing response analysis.

Informal observations of the subjects in group FP revealed a variety of reactions to CS presentations: circling the perimeter of the chamber, somersaulting, and jumping from front to rear. Clearly, the forward-pairing procedure did not uniquely select attack as the response to the CS, unlike the BP procedure. It has been reported that monkeys allowed unrestricted access to a bite-tube and other manipulanda in a unsignalled shock situation display low probabilities of attack relative to non-aggressive lever-pressing or chain-pulling before shock delivery. However, after shock delivery these probabilities are reversed (Hutchinson & Emley, 1973; Hutchinson et al. 1971). It seems reasonable to speculate that conditioned attack might be more readily obtained if the relative probability of attack before shock delivery could somehow be increased.

The second variable operating in the forward-pairing procedure may have been the fact that the bite-tube was retracted immediately upon shock delivery and thus limited postshock attack to less than 2 sec. Zentall and Hogan (1975) reported that preventing pigeons from eating grain which was presented following illumination of a keylight produced short-lived and relatively low levels of autoshaped keypecking. If some minimum duration of unconditioned responding is necessary for a response to become conditioned to a CS, allowing monkeys more time to bite the CS after shock should lead to more reliable conditioned attack.

The results of Experiment I raised a number of questions about the stimulus-substitution principle, the implicit avoidance contingency and the role of postshock attack. The next experiment focuses on the possible role of postshock attack in the forward-pairing procedure.

Experiment II

The role of postshock attack in forward conditioning

In Experiment I it was suggested that the general failure to obtain conditioned attack in group FP might have been because the immediate withdrawal of the bite-tube after shock effectively limited postshock attack. Conditioning in the forward-pairing procedure might depend directly on the probability or duration of the postshock UCR. If the bite-tube CS were to remain in the chamber for a short period after shock, one might expect to find conditioned attack in proportion to the duration of the UCR permitted. The same prediction can be derived from the implicit avoidance hypothesis: The extent to which postshock attack samples and is reinforced by the implicit avoidance contingency should also increase the probability of attack before shock.

The present experiment was designed to assess the degree to which the duration of the opportunity to attack the bite-tube after shock contributes to conditioning in the forward-pairing procedure.

Method

Subjects & Apparatus

Eighteen (18) Squirrel monkeys served as subjects. All details of maintenance and apparatus were described in the General Methods section.

Procedure

Subjects were divided into 3 groups of equal size. All subjects were given 10 CS-shock trials per session for 6 sessions. Group PS-0 received training identical to group FP in Experiment I. Groups PS-10 and PS-30 received the same forward-pairings of CS and shock as group PS-0, but the bite-tube remained in the chamber after shock for 10 sec or 30 sec respectively. For all groups, the intershock interval was 240 sec. Following 6 conditioning sessions a test session was run in which one conditioning trial was followed by 9 shock-free test trials.

Results and Discussion

Reliable preshock attack developed in 11 of the 18 subjects by the 6th conditioning session. There were no differences between the groups in the rates at which conditioned attack developed (F < 1.0, df = 2/15, r = 0). Conditioned attack began after an average of 20.8 trials in group PS-0, 35.3 trials in group PS-10, and 21.7 trials in group PS-30. Figures 2-1 and 2-2 display the average number of bites per trial and the average duration of attack per trial across all sessions. There were no statistically significant differences between the groups on either the biting or duration measure over all 6 conditioning sessions taken together, over session 6 taken alone, or within session 7 (the test session) (all Fs < 1.0, df = 2/15, r = 0).

Postshock attack developed in groups PS-10 and PS-30 in much the

Figure 2-1

Average bites/trial across all trials and all sessions.
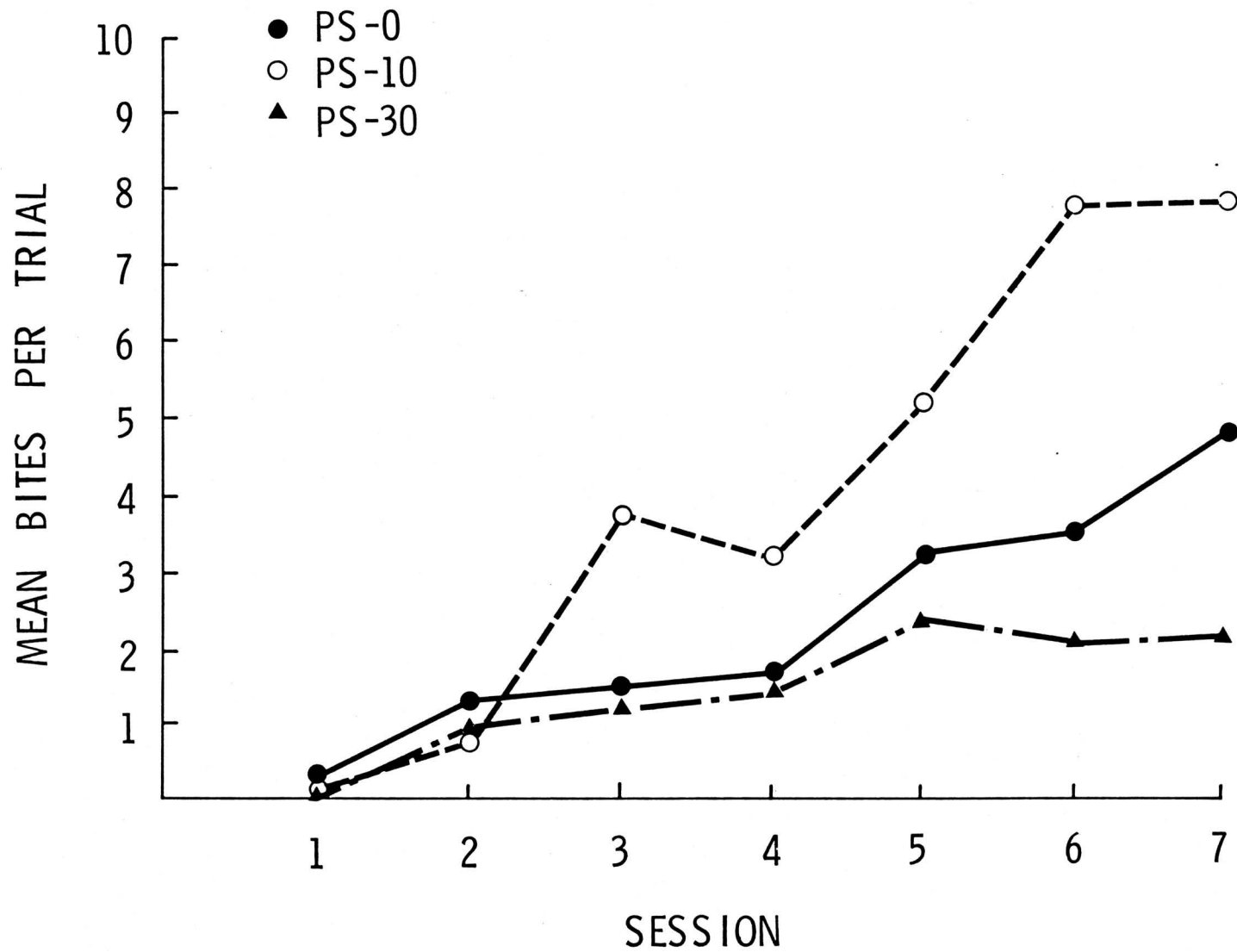
Figure 2-2

Average duration of attack/trial across all trials and all sessions
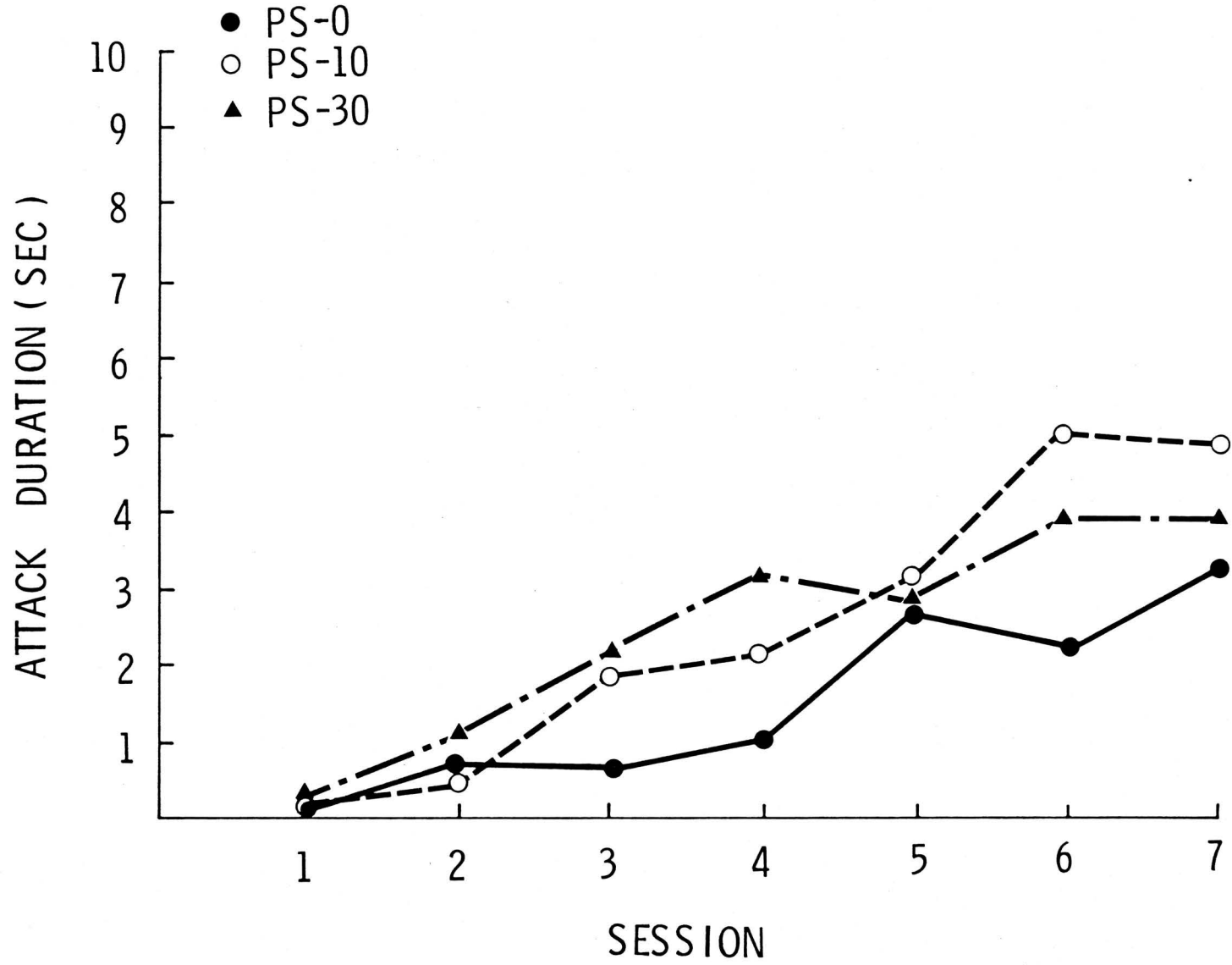
same way as it had in the backward-pairing group in Experiment I. Biting was initiated after an average of 21.5 shock trials and reached an asymptote of 6 bites per trial by the 6th session (see Figure 2-3). Although group PS-30 consistently displayed longer durations of post-shock attack than group PS-10 (see Figures 2-3 and 2-4), the difference was not significant (F < 4.97, df = 1/10, r = 0).

Clearly, the forward-pairing procedure was not as ineffective as suggested by Experiment I. However, its effectiveness did not depend on the duration of postshock attack. Thus, even when postshock attack samples the implicit avoidance contingency, no increase in preshock attack results.

Not all subjects in any group met the conditioning criterion of a minimum of 10 sec of attack during session 6. In both groups PS-0 and PS-10, 3 subjects met the criterion, while 5 subjects in group PS-30 were successfully conditioned. Among the subjects not meeting the criterion there were two patterns of results. In each group there was 1 subject which met the criterion before session 6 but extinguished as the sessions progressed. The remaining subjects never met the criterion; indeed, only 1 of these subjects ever bit the tube (3 bites total). It should be noted that the subjects which did not meet the conditioning criterion also failed to meet the same criterion in postshock attack. This suggests that postshock attack, regardless of its duration, might be necessary for conditioning. However, in 4

Figure 2-3

Average postshock bites/trial across all shock trials for groups PS-10 and PS-30.
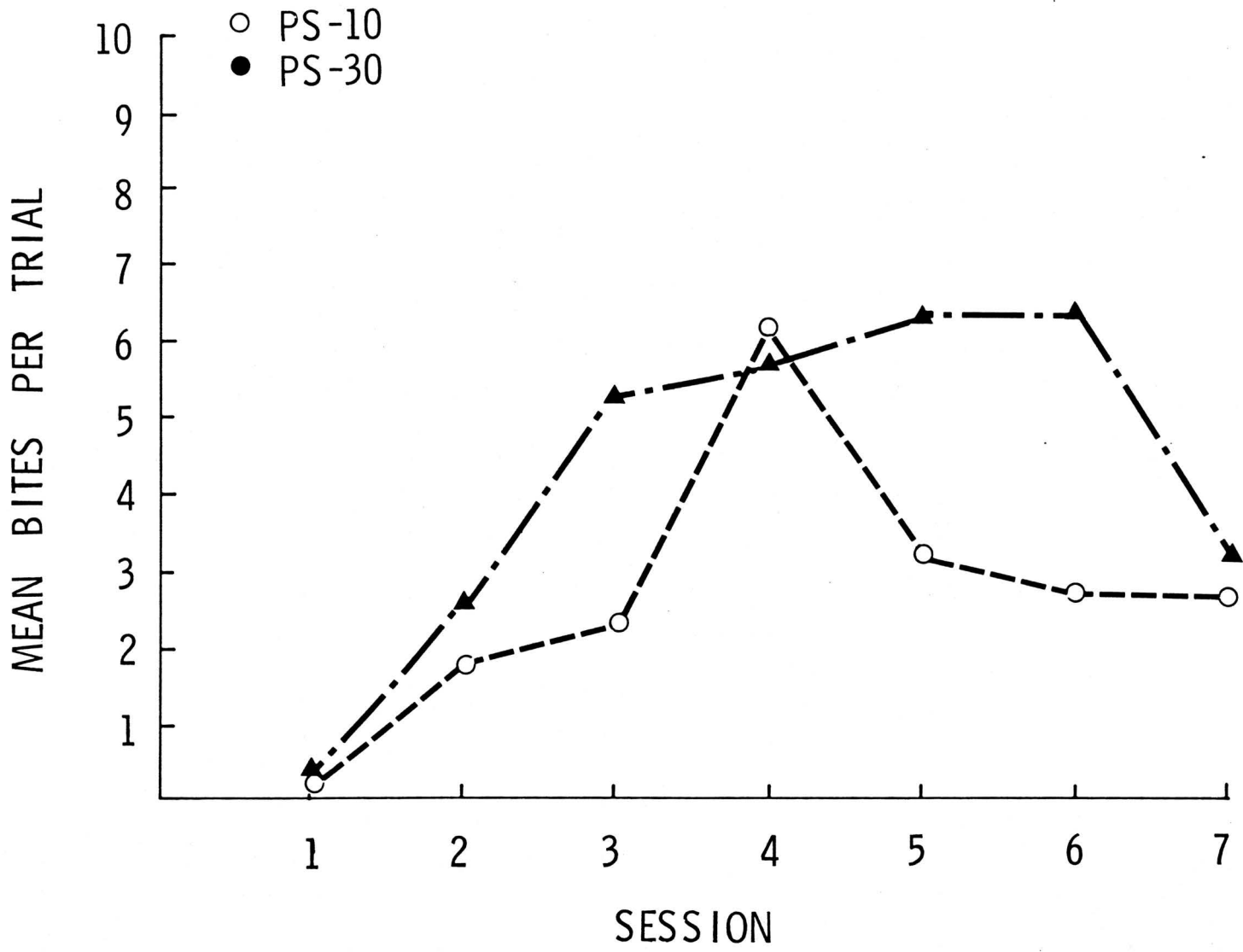
Figure 2-4

Average duration of postshock attack/trial across all shock trials

for groups PS-10 and PS-30.
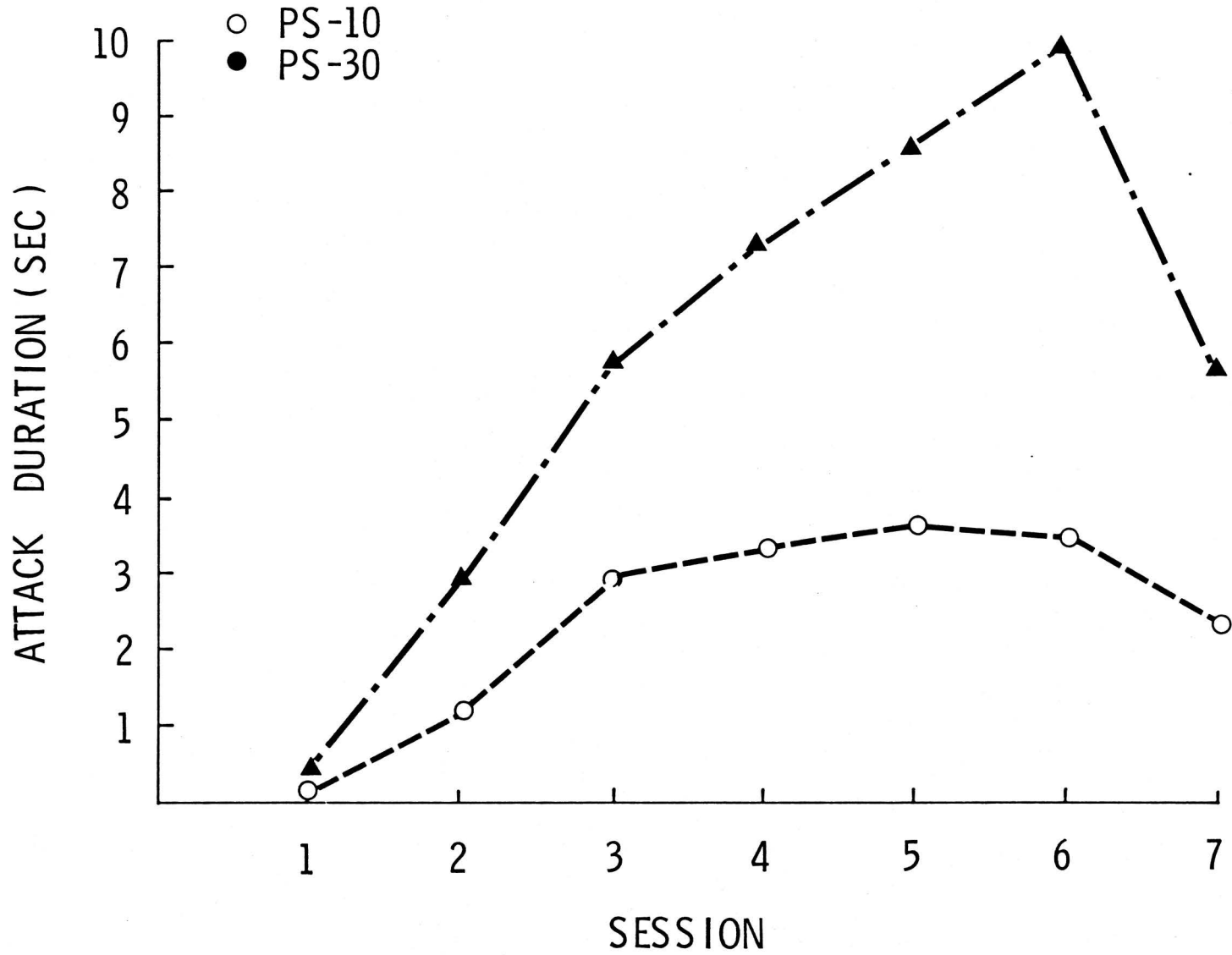
Figure 2-5

Average proportion of CS and ITI periods spent in the front half of the chamber across all sessions for biters and nonbiters.

of the subjects, preshock attack emerged before postshock attack--
suggesting to the contrary that postshock attack need not precede
the emergence of preshock attack.

The possibility remains that the failure to condition attack
stemmed from competition among other responses elicited by shock,
such as withdrawal from the tube. To examine the suggestion, three
additional measures were used to compare the behavior of biters
($N = 11$) and non-biters ($N = 7$) in this experiment: (a) position in
the chamber; (b) rate of entering the front of the chamber; and (c)
rate of touching the bite-tube without biting it.

Measure (a) revealed, as expected, that the biters spent a
greater proportion of the CS than the ITI in the front half of the
chamber ($F = 34.0$, $df = 1/20$, $r = 1$). However, the non-biters clear-
ly did not simply withdraw from the tube during CS periods. Although
the proportions of CS and ITI periods spent in the front of the cham-
ber were statistically equal ($F = 1.0$, $df = 1/12$, $r = 0$), the non-
biters tended to spend more time in front during the CS than during
the ITI. These data are displayed in Figure 2-5.

Measure (b) revealed that both the biters and the non-biters
entered the front of the chamber more frequently during the CS than
during the ITI periods ($F = 61.6$, $df = 1/20$, $r = 1$; $F = 14.2$, $df = 1/12$,
$r = 1$). There was no difference between biters and non-biters on this
measure ($F = 1.0$, $df = 1/16$, $r = 0$). Figure 2-6 displays these data.
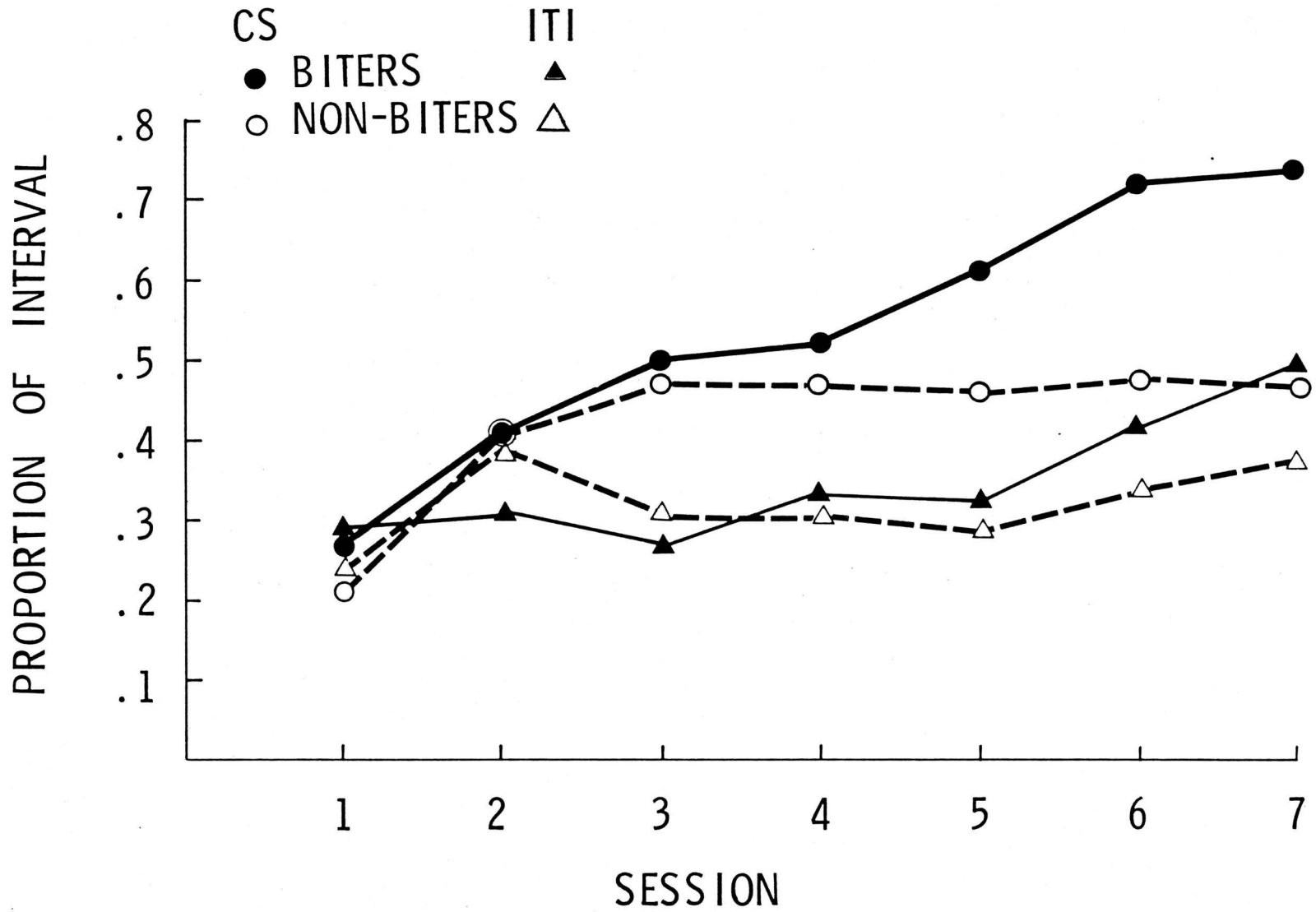
Figure 2-6

Rate (per 20 sec) of entering the front of the chamber during CS and
ITI periods for biters and nonbiters.
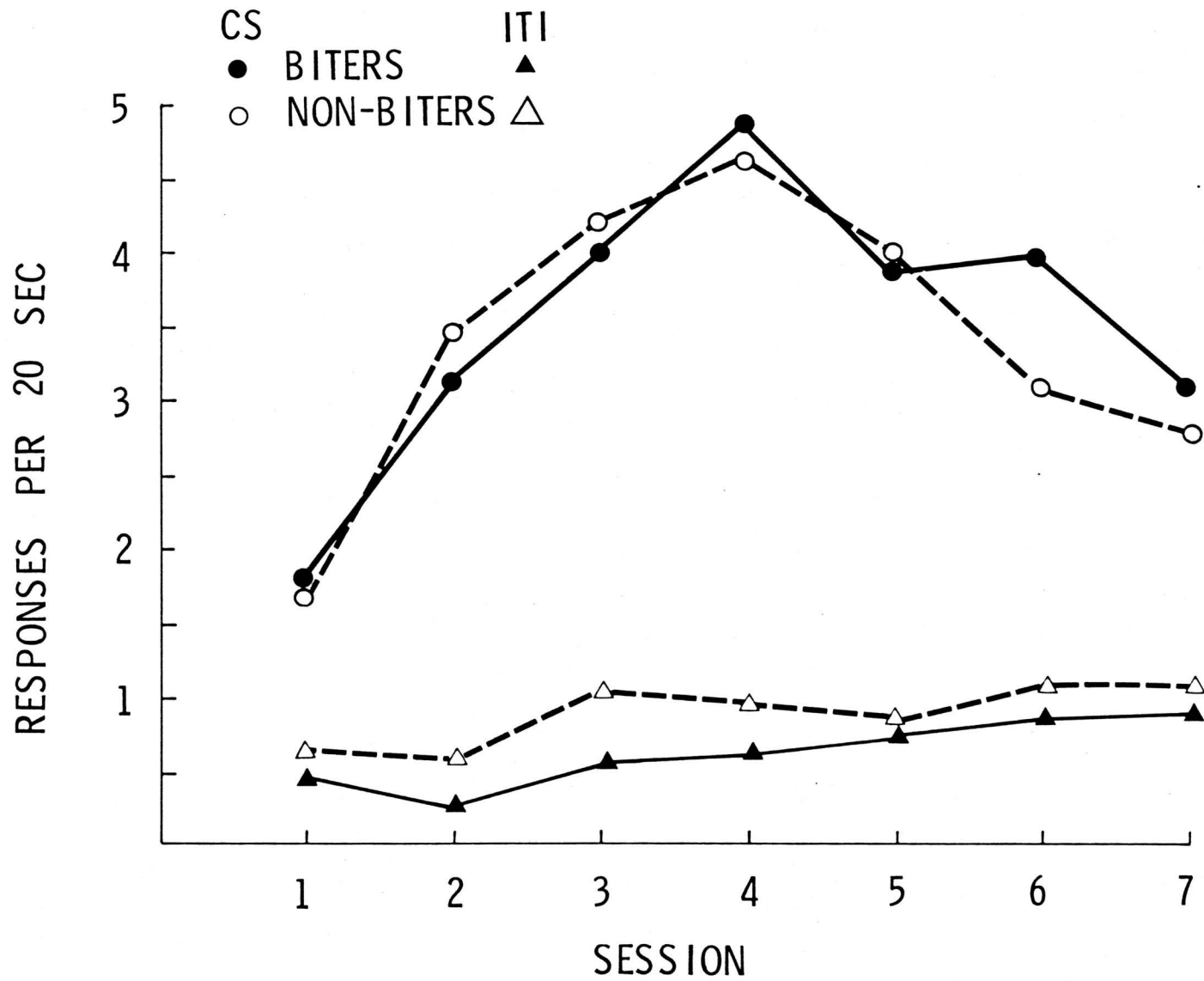
On the whole, measure (b) indicated that subjects did not simply ap-
proach and attack the tube during CS periods: They became generally
more active and made several approach/withdrawal movements. During
the ITI, however, they became less active and tended to remain in
either the front or rear of the chamber.

Not all the approaches to the tube by biters were accompanied by
attack. Figure 2-7 shows measure (c), the rate (per 20 sec) of touch-
ing the tube without biting during both CS and ITI periods for biters
and non-biters. It can be seen that after the third conditioning ses-
sion the biters achieved a higher rate of touching the tube during the
CS than had the non-biters (F = 4.94, df = 1/16, r = 1). Most inter-
estingly, the rate for the non-biters during the CS was significantly
higher than during the ITI periods (F = 16.7, df = 1/12, r = 1). Thus,
subjects which did not develop conditioned attack nevertheless con-
sistently approached the bite-tube and made contact with it during the
CS periods. It is implausible therefore to argue that the behavior of
the non-biters was simply incompatible with tube-biting.

Contrary to the results of Experiment I, the present experiment
supports the stimulus-substitution analysis of conditioned attack.
Providing opportunities for subjects to engage in postshock attack did
produce substantial levels of postshock attack, but the amount of this
behavior had no effect on conditioning. Furthermore, observations of
the non-biters failed to yield any evidence that these subjects engaged
in behavior which was incompatible with tube-biting. It appears that

Figure 2-7

Rate (per 20 sec) of nonaggressive contact with the tube across all
sessions for biters and nonbiters.
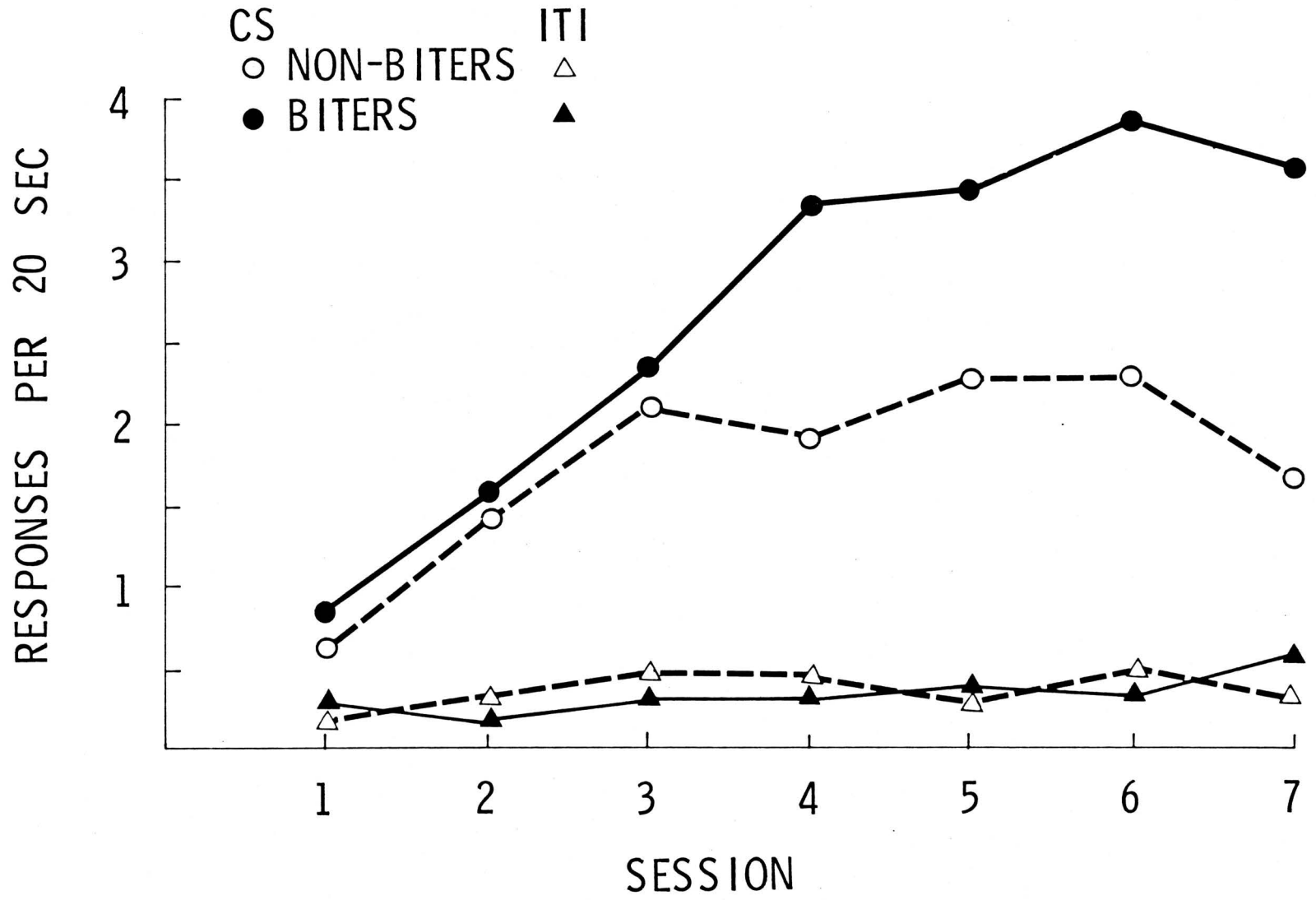
the Pavlovian stimulus-substitution principle is sufficient to account for conditioned attack in the forward-pairing procedure.

Contrary to the prediction of the implicit avoidance hypothesis, there was no graded effect on conditioning of the duration of postshock attack. This finding does not completely rule out the implicit avoidance hypothesis since the implicit avoidance contingency was equally present for all groups. However, it can be concluded that differential opportunities to sample the contingency do not have differential effects on conditioning.

There is a discrepancy in the results of forward-pairings between Experiments I and II. The discrepancy lies in the responses of non-biters to CS presentations. In Experiment II non-biters approached and made contact with the bite-tube, but in Experiment I non-biters apparently withdrew from the CS. Two possible explanations can be offered. The first concerns procedural differences between the two experiments. In Experiment I only the amount of time spent in the front half of the chamber was recorded, while in Experiment II the frequencies of entering the front and of contacts with the tube were also recorded. It is possible that the non-biting subjects in Experiment I did approach and make contact with the tube during CS periods, but that these responses went unrecorded. Thus, the discrepancy may be only quantitative not qualitative. The second possibility has greater theoretical importance. In any classical conditioning procedure, the experimenter does not have precise control of the subject's response to the UCS. In the present

experiments the FP procedure may be a fear conditioning situation for some subjects, who consequently withdraw from the bite-tube. For others the same procedure elicits anger which results in conditioned attack, or approximations to attack such as approaching and touching the bite-tube. While the stimulus-substitution principle can explain both results post-hoc the principle cannot predict a priori which response will be conditioned. It could be that the qualitative difference between fear and anger depends ultimately upon quantitative differences in the subjects' reactions to shock. But even so, the basic problem is the same--to predict what a subject's CR will be. Thus, the discrepancy in results between the two experiments may point out a problem with which the stimulus-substitution principle must cope in situations in which more than one UCR is possible.

Experiment III

The forward-pairing procedure:

. Fixed-time vs variable-time schedules

In Experiment II it was found that the extent to which post-shock attack sampled the implicit avoidance contingency affected neither the rate of acquisition nor the magnitude of conditioned attack in the forward-pairing procedure. However, it cannot be concluded that the implicit avoidance contingency had no effect on the results. Although the groups differed in the amount of time allowed for postshock biting, the duration of the shock-free period sampled by biting was the same for all groups.

The purpose of the third experiment was to determine if the implicit avoidance contingency is necessary for conditioning in the forward-pairing procedure. If the implicit avoidance contingency contributes to the strength of conditioned attack by reinforcing post-shock attack, scheduling trials at random intervals should eliminate this contribution to the development of conditioned attack.

Method

Subjects and Apparatus

The subjects were 6 Squirrel monkeys. Housing conditions were as described earlier. The apparatus was unchanged from the previous experiments.

Procedure

Two groups of 3 monkeys were trained on the FP procedure. That is, the bite-tube was presented for 20 sec immediately preceding the delivery of shock. The tube was withdrawn upon shock offset. One group, FP-FT, received conditioning trials according to a FT 4 min schedule. The other group, FP-VT, received conditioning trials randomly distributed throughout a session by the use of the VT 4 min schedule employed in Random in Experiment I.

All subjects received 10 conditioning trials per session for 6 sessions. The test session, in which a single conditioning trial was followed by 9 CS-only test trials, followed the conditioning sessions.

Results and Discussion

The development of conditioned attack across all sessions is shown in Figures 3-1 and 3-2. It is evident that both groups achieved equal levels of conditioned attack--about 5 bites per trial. No significant differences between the groups were found in the number of bites during training or testing ($Fs < 1.0$, $df = 1/4$, $r = 0$). One subject in each group failed to develop reliable conditioned attack.

The implicit avoidance contingency does not contribute to response strength in this procedure. Hence, forward-pairings of the bite-tube and shock alone are sufficient to establish conditioned attack.

Figure 3-1

Average bites/trial across all trials and all sessions.
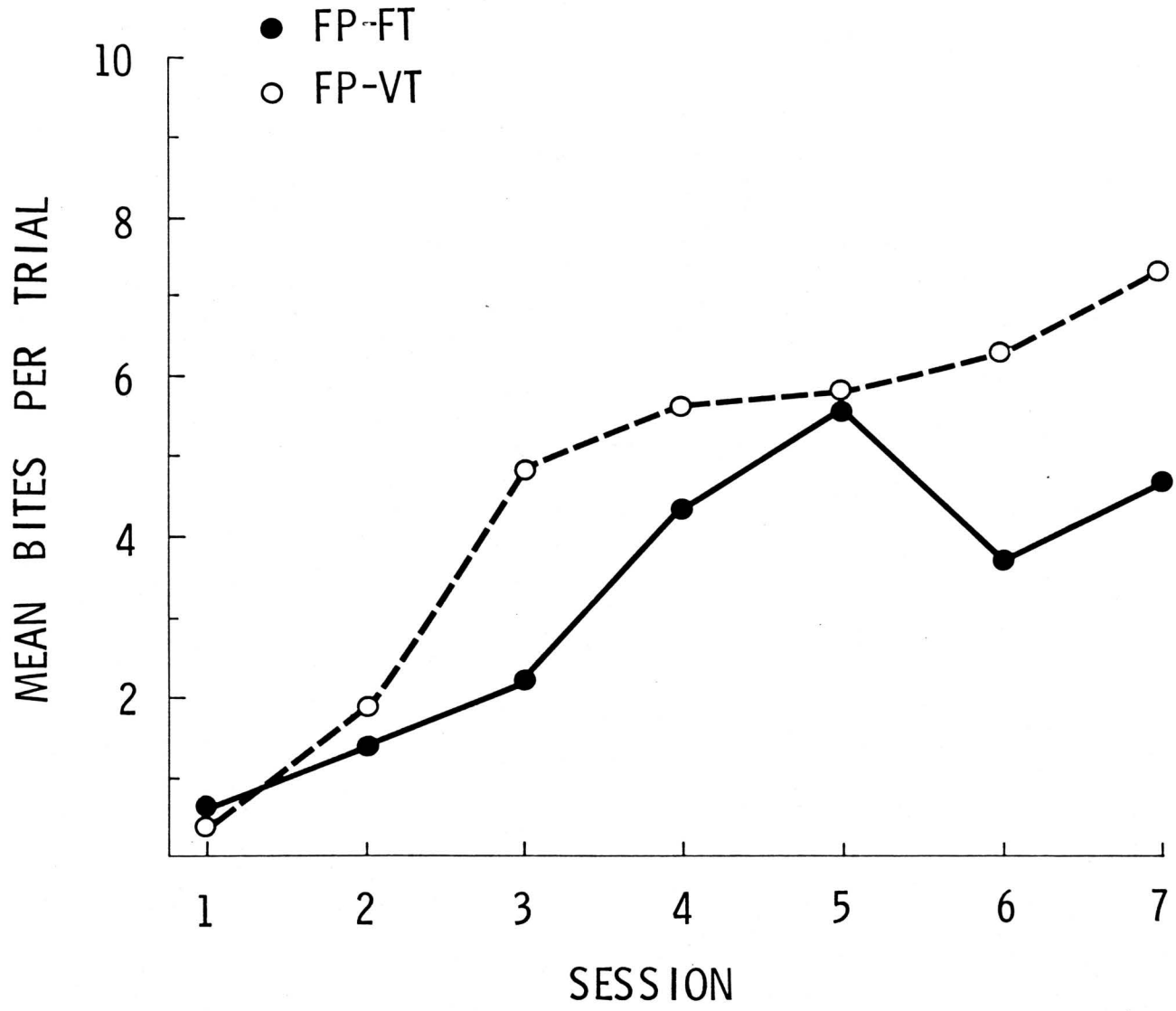
Figure 3-2

Average duration of attack/trial across all trials and all sessions.
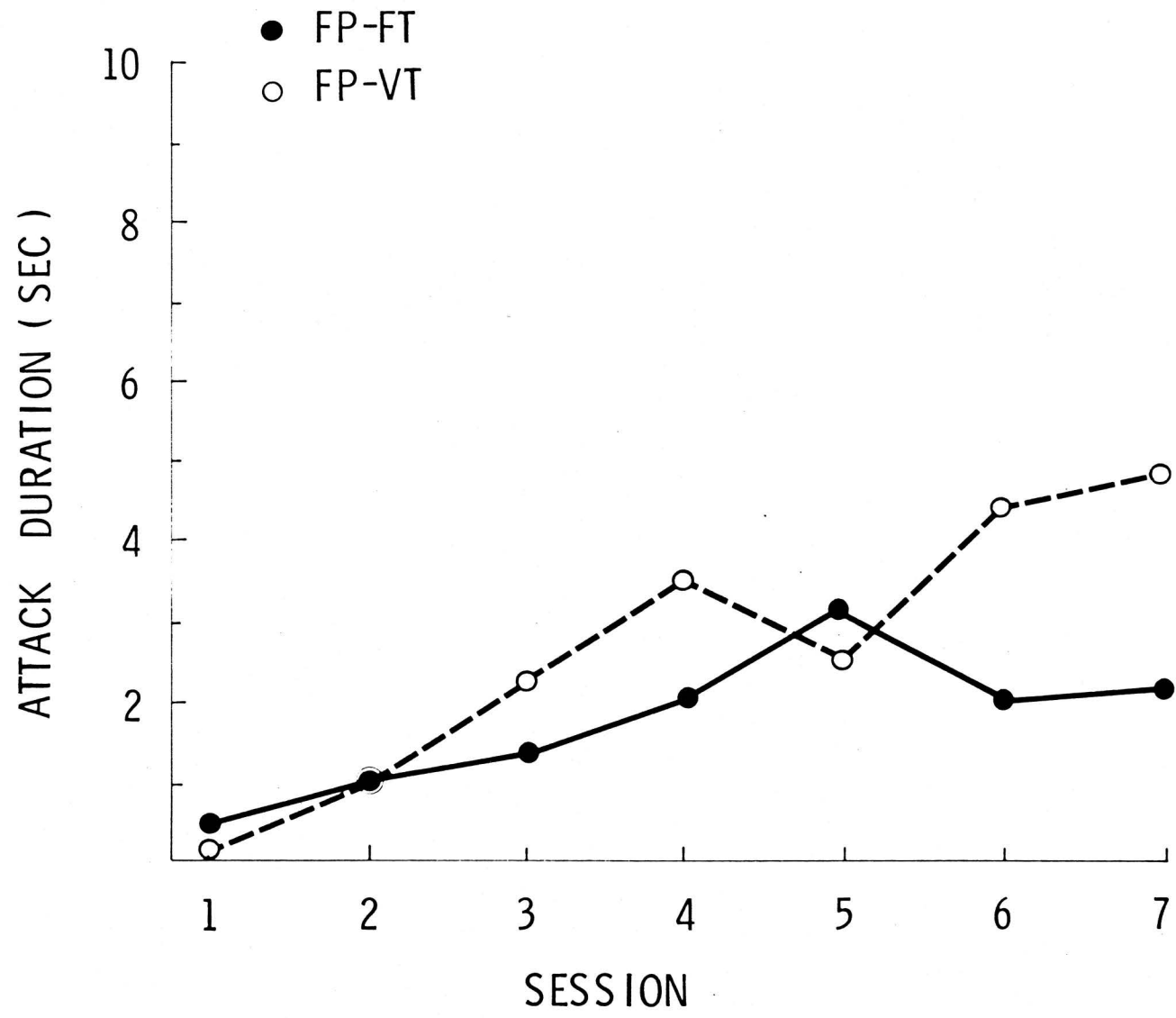
Experiment IV

The backward-pairing procedure:

Fixed-time vs variable-time schedules

The most interesting result of Experiment I was conditioned attack obtained via backward-pairings of shock and bite-tube. Two alternative explanations of this finding were suggested. One was the possibility of backward-excitatory conditioning. This interpretation assumes that contiguity of shock and the bite-tube is sufficient for the tube to acquire control of shock-elicited attack by the stimulus-substitution principle (see Heth & Rescorla, 1973). The second possibility was that pain-elicited attack might become conditioned through participation in an "implicit avoidance contingency" (Dunham, 1971). This explanation assumes that conditioning depends on the safety-predictive properties of elicited attack which arise when trials are scheduled at relatively long fixed time periods.

A simple test of these two explanations involves maintaining the contiguity of UCS and CS while eliminating the implicit avoidance contingency through the use of a random intertrial interval (Moscovitch & LoLordo, 1968).

Method

Subjects and Apparatus

Twelve (12) Squirrel monkeys served as subjects. All details of the apparatus were the same as in Experiment I.

<u>Procedure</u>

Subjects were divided into two groups of equal size. Group BP-FT received backward-pairings of the shock UCS and the bite-tube CS on a FT 4 min schedule. This group was a replication of group BP in Experiment I. The second group, BP-VT, also received backward-pairings of the UCS and the CS, but trials were presented according to the variable-time schedule described in the General Methods section. Use of such a schedule eliminates the implict avoidance contingency because there is no predictable safe interval following shock, except the period during the presentation of the CS itself.

As in Experiment I, the subjects received nine conditioning trials and one shock-free trial per session for six sessions. On the seventh session, all subjects received 1 conditioning trial followed by 9 consecutive trials on which the CS was presented alone.

Results and Discussion

Figures 4-1 and 4-2 show the average number of bites per trial over sessions 1-7. Conditioned attack developed in group BP-FT during the first conditioning session and reached an asymptote of 5-6 bites per trial in the third session. During the test session, group BP-FT averaged 3-4 bites per trial. By contrast, very little conditioned attack was observed in group BP-VT, as can be seen in the Figures. Group BP-FT made significantly more bites per test trial than group BP-VT over sessions 1-6 ($\underline{F} = 5.74$, $\underline{df} = 1/10$, $\underline{r} = 1$), and on session 7 (trials 2-10; $\underline{F} = 5.20$, $\underline{df} = 1/10$, $\underline{r} = 1$).

Figure 4-1

Average bites/test trial across sessions 1-6.
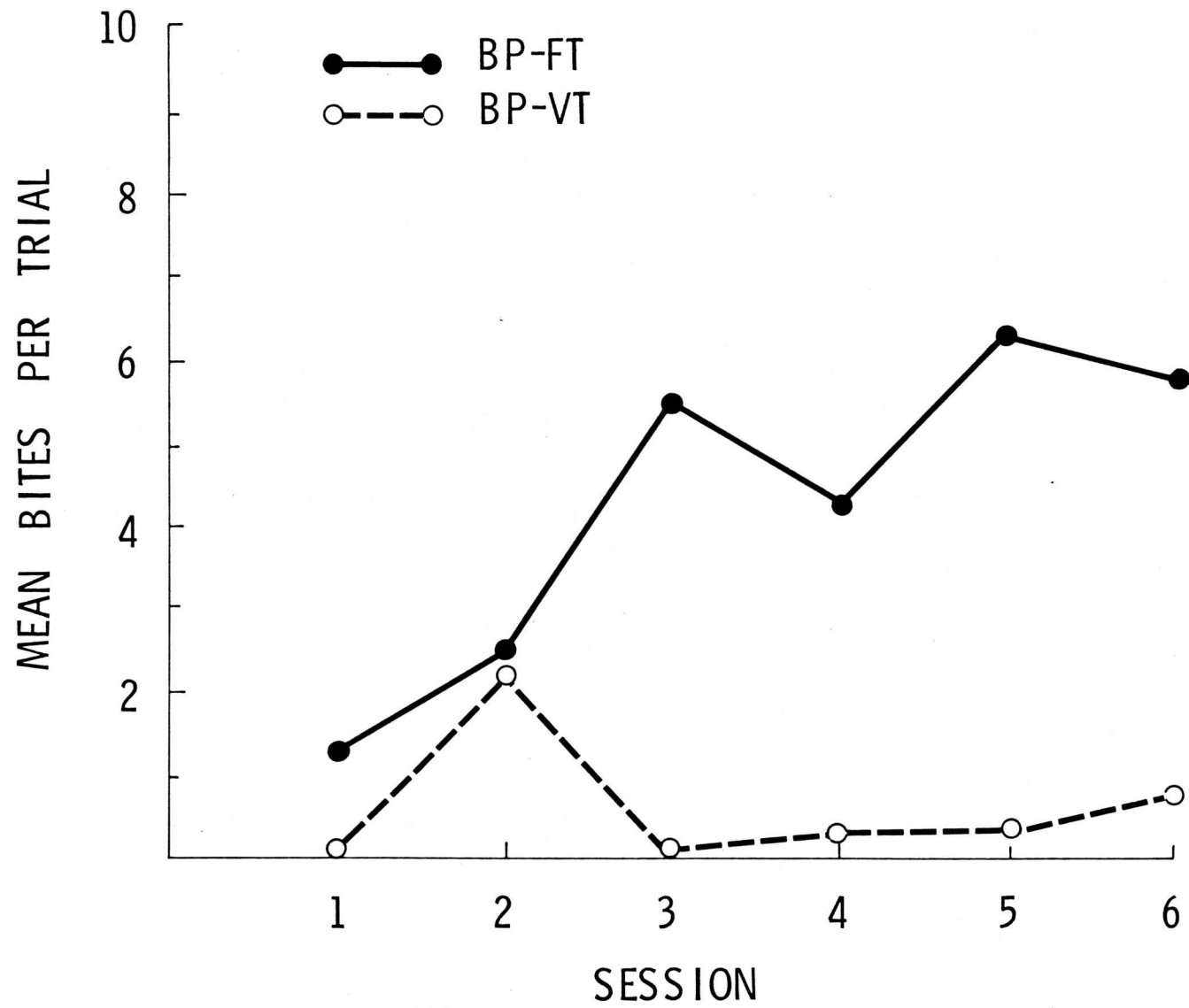
Figure 4-2

Average bites/trial across all trials in Session 7. Trial 1 was a

shock trial. Trials 2-10 were no-shock test trials.
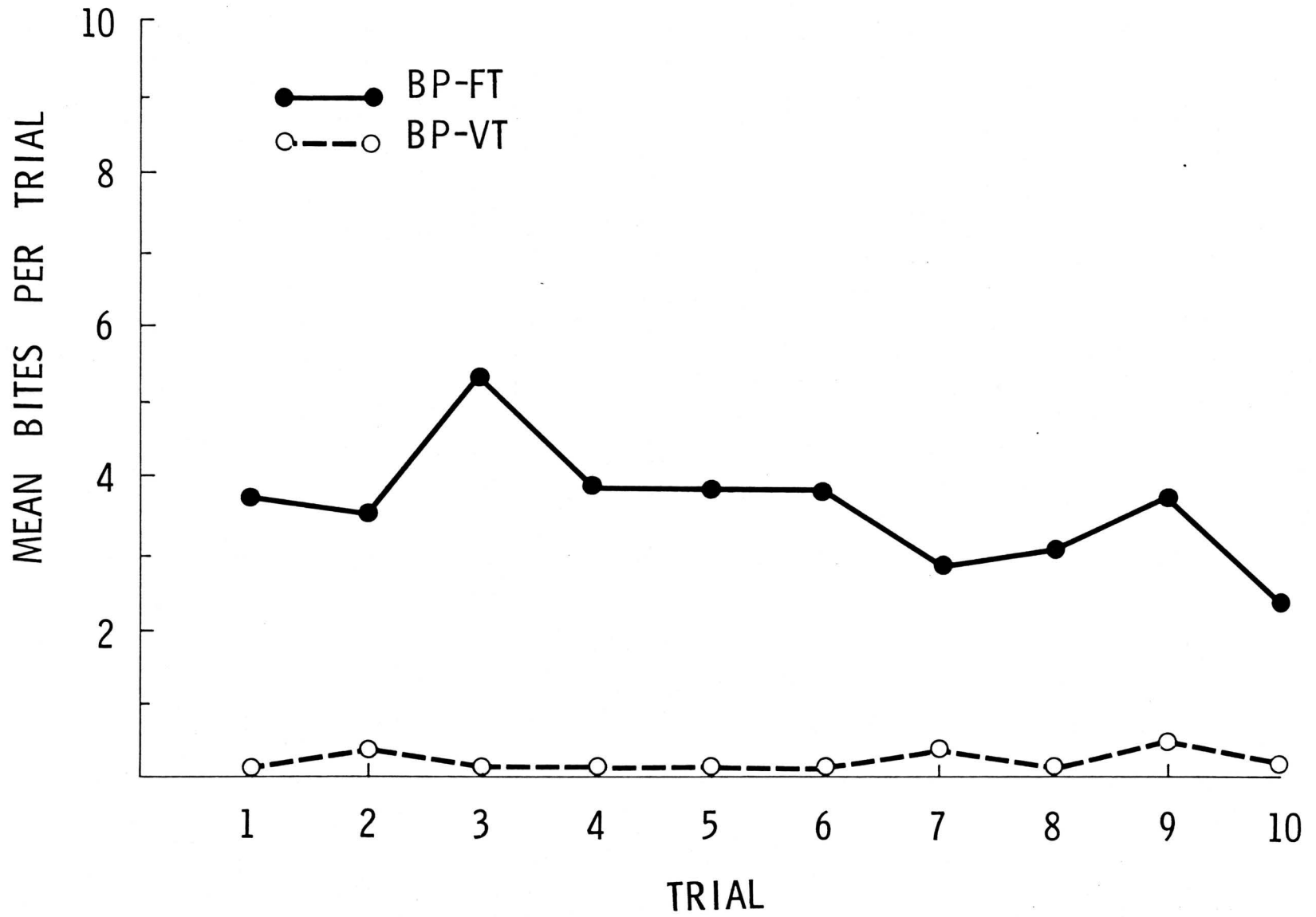
Postshock attack was also significantly greater in group BP-FT than in group BP-VT (F = 5.87, df = 1/10, r = 1). The average number of postshock bites per trial for both groups is shown in Figure 4-3. Subjects in group BP-FT developed postshock attack sooner (15 vs 46 trials) and made over five times more postshock bites in total than subjects in group BP-VT. This result in surprising because it indicates that postshock attack is not simply elicited by shock. Apparently, contiguity of the shock and the bite-tube is not sufficient to produce postshock attack.

Three of the subjects in group BP-VT did engage in postshock attack, primarily during sessions 5 and 6. These subjects averaged 4.6 bites per trial. The subjects in group BP-FT averaged 7.7 bites per trial. A t-test of this difference was almost significant (t_8 = 2.01, .05 < p < .10).

In general, group BP-VT differed from group BP-FT in four ways: 1) Fewer subjects engaged in postshock attack (3 vs 6); 2) The onset of postshock attack was delayed (46 vs 15 trials); 3) The magnitude of postshock attack per trial was marginally reduced; and 4) There was very little conditioned attack (26 bites total vs 348 bites over all test trials).

The proportion of the ITI periods which subjects spent in the front half of the chamber did not differ between the groups (F = 1.0, df = 1/10, r = 0). Figure 4-4 displays for each group the mean pro-

Figure 4-3

Average postshock bites/trial across all shock trials in sessions 1-6.
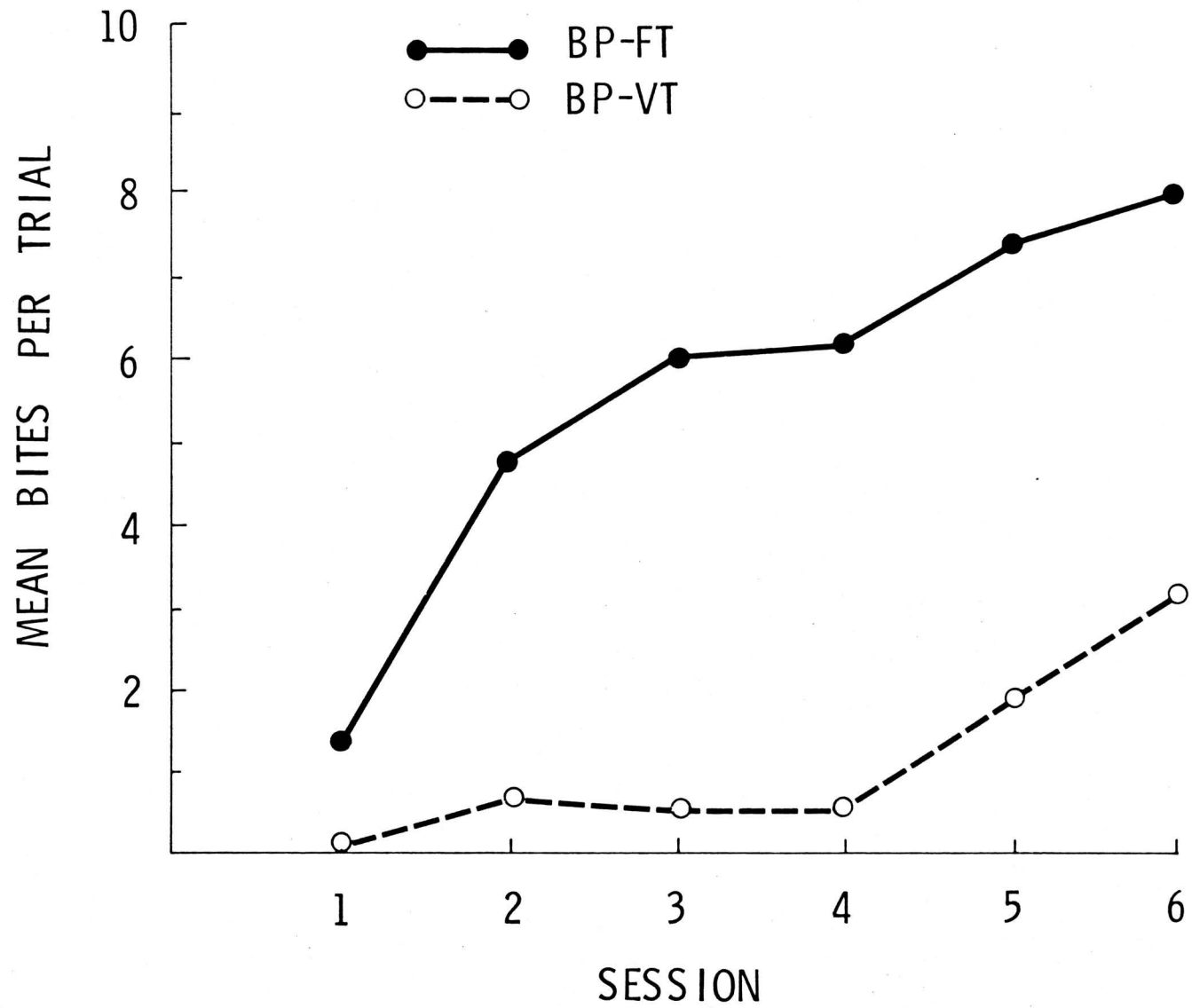
portion of the ITI and the CS periods spent in the front half. As in Experiment I, the proportion of the ITI spent in the front half as substantially greater than .50. During the CS periods group BP-FT spent significantly more time forward than group BP-VT (F = 6.00, df = 1/10, r = 1). Note however, that despite a slight tendency for group BP-VT to move away from the tube, the proportion of the CS periods remained near .70. As in Experiment I, no observations were made of subjects' behavior other than attack upon the bite-tube and position in the chamber. Thus, it is not known whether the non-biters may have approached and made contact with the tube during CS periods, which might account for the time spent in the front half of the chamber.

As predicted by the implicit avoidance hypothesis, the results of Experiment IV demonstrate that the development of attack via the backward-pairing procedure depends upon the presentation of conditioning trials on a fixed-time schedule. The implicit avoidance hypothesis accounts for these results in the following way: Shock elicits attack. If attack is reliably followed by a relatively long shock-free interval, the subject associates biting the tube with the subsequent shock-free period. Hence, the subject will attack the bite-tube on test trials. However, if shocks are randomly distributed in time elicited attack will not reliably predict any shock-free interval; hence, subjects will not bite the tube on test trials.

Although the primary result of the present experiment was predicted by the implicit avoidance hypothesis, some aspects of the data

Figure 4-4

Average proportion of CS and ITI periods spent in the front half of the chamber.
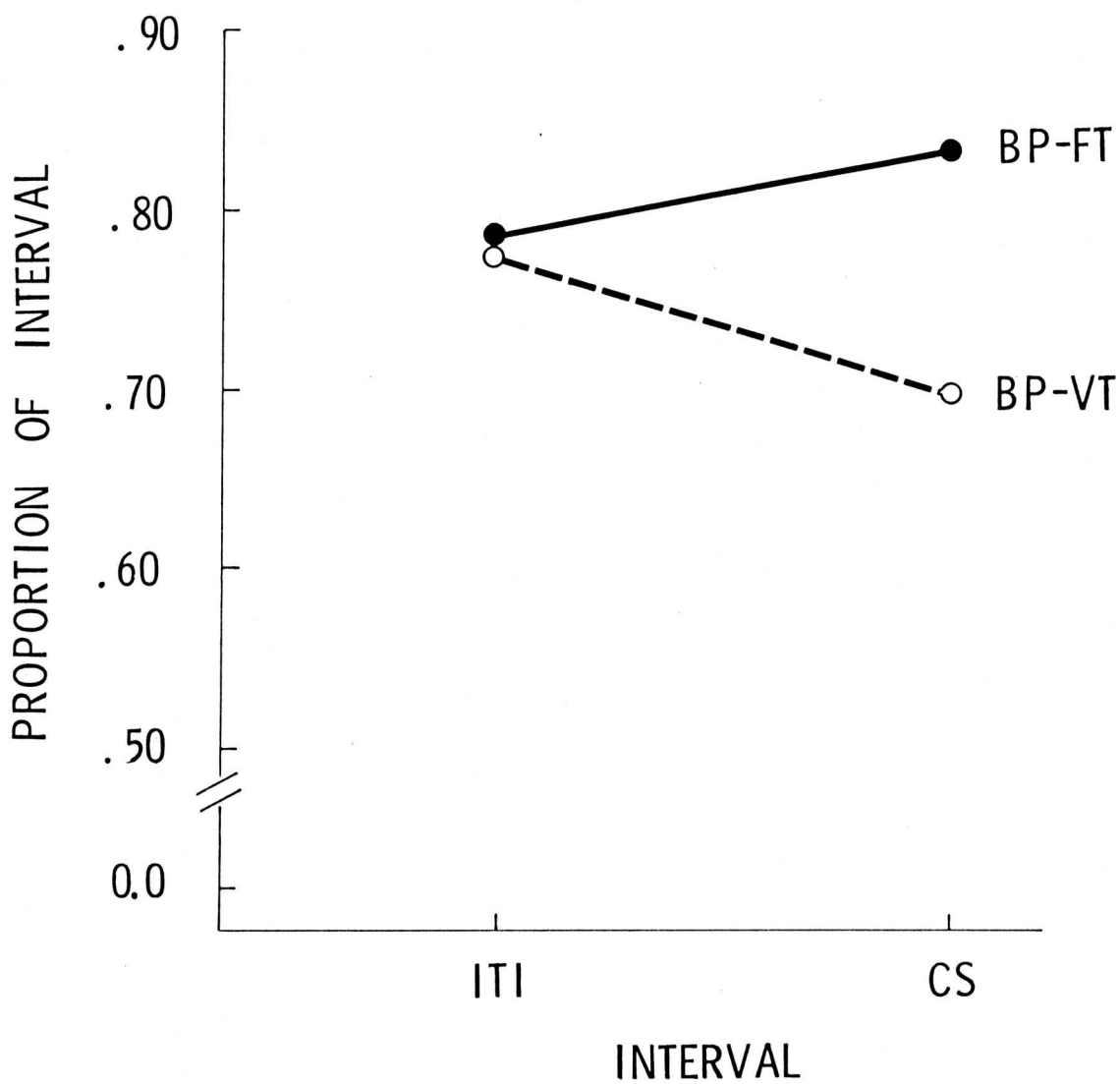
pose serious problems for the hypothesis. First, attack was not the response initially elicited by shock. In Experiments I and IV post-shock attack only emerged after an average of 17.5 shock trials. Thus, considerable experience with the situation preceded even the initial emergence of postshock attack. The initiation of attack cannot be explained in terms of avoidance behavior, implicit or otherwise. The initial responses of the subjects to the shock consisted of screaming, jumping, and vigourous locomotion in the chamber. Yet, these responses were not conditioned.

A second problem is illustrated in Figure 4-3 which shows the development of postshock attack in groups BP-FT and BP-VT. Postshock attack began to emerge in group BP-VT in session 5, after an average of 46 trials. This finding is incompatible with the implicit avoidance hypothesis which predicts that postshock behavior should not increase in magnitude under the VT schedule because such behavior could not have any safety-predictive properties.

In conclusion, Experiment IV demonstrates that backward excitatory conditioning does not occur in the backward-pairing procedure. Unfortunately, the implicit avoidance hypothesis encountered serious difficulties in accounting for the results. In the following chapter an alternative analysis will be developed.

CHAPTER III

General Discussion

The forward-pairing procedure

Although the predictions made by the stimulus-substitution analy-
sis seemed to be generally confirmed by the fact that reliable con-
ditioned attack was obtained with the forward-pairing procedure, the
finding that a substantial proportion (47%) of the subjects failed to
acquire conditioned attack questions the applicability of the stimulus-
substitution principle. On the other hand, it can be argued that some
of the subjects which did not develop conditioned attack under the FP
procedure simply did not have attack in their UCR repertoires. For
example, the data of Experiment II which showed that only those sub-
jects which reliably engaged in postshock attack developed conditioned
attack are consistent with this suggestion. Moreover, Azrin et al.
(1964) reported that postshock attack could not be elicited in a
sizeable proportion (20%) of their subjects. And in the present ex-
periments, 3 of the 14 subjects run on the BP-FT procedure likewise
failed to develop postshock attack. Failure to obtain conditioned
attack in a number of subjects is potentially compatible with the
stimulus-substitution analysis, on the assumption that UCRs other than
attack can be observed. Thus, the stimulus-substitution principle is
potentially capable of describing the data generated by the forward-

pairing procedure.

The possibility that more than one UCR may be elicited by shock presents procedural difficulties for predicting the outcome of the FP procedure. It is necessary to predict the proportion of subjects which will develop conditioned attack. In Experiment I, group BP was originally included to monitor elicited attack. Although strong "unconditioned" attack developed in 4 of the 6 subjects in group BP, only a single subject in group FP developed conditioned attack. There was thus a large discrepancy in the probability of attack between these two groups, so the BP procedure had very little predictive power. In the same manner, considering group BP-VT to be a monitor of "uncon- ditioned" attack for group FP-VT, the same pattern of results obtained. Group BP-VT displayed very little "unconditioned" attack, but strong conditioned attack was obtained in group FP-VT. Again, the results of the BP procedure could not have been used to accurately predict the results of the FP procedure. In the present preparation, the use of independent control groups to assess the UCR is clearly inappropriate. The major difficulty with such groups is that the backward-pairing pro- cedure is itself a conditioning procedure.

In order to predict the outcome of forward-pairings it appears necessary to assess unconditioned attack in subjects individually. However, it is clearly impossible to simply test the subjects for the occurrence of postshock attack without contaminating the subsequent

conditioning data with pretest learning. The procedure used in Experiment II, which allowed the subjects to attack the bite-tube CS after shock, would.have been an ideal solution to this problem except for the discovery that in a number of subjects conditioned attack developed before postshock attack.

At this point it might be argued that the FP procedure is analogous to the study by Zentall and Hogan (1975) in which autoshaped keypecking in pigeons was obtained despite the presentation of inaccessible grain. In that experiment, performance of the UCR was found not to be necessary for the CR to emerge. The obvious conclusion is that the FP procedure is simply another case in which the UCR need not precede the development of the CR. However, there is a critical difference between the FP procedure and the Zentall and Hogan study which questions that conclusion.

In the Zentall and Hogan (1975) study, the pigeon's UCR to food was known beforehand even though performance of the UCR was not permitted in the experiment. Thus, the pigeon's CR could be predicted on the basis of its UCR. The situation in the present experiments is quite different: The UCR elicited by shock is not known a priori. The argument, suggested by analogy with Zentall and Hogan's investigation, that subjects which developed conditioned attack under the FP procedure must therefore have possessed attack as a UCR is a non sequitur: No predictions follow from such an argument. Moreover, the

subjects in Experiment II were not prevented from attacking the tube after shock; yet, a number of them attacked before shock without having previously exhibited attack as a "UCR". This discovery raises serious problems for the stimulus-substitution principle both as a description and as a possible explanation of the present results.

Since attack may emerge as a CR before it develops as a UCR, one cannot conclude that the control of attack was transferred from the UCS to the CS. Thus, the stimulus-substitution principle appears to be inapplicable to the FP procedure. When one considers how shock as a UCS differs, for example, from grain presentation as a UCS this conclusion is clarified.

Presenting food to a pigeon will elicit eating only if the subject is appropriately motivated. The usual procedure to motivate the subject is to deprive it of food, which makes it differentially responsive to food stimuli. There are thus two factors which contribute to the emergence of the UCR; 1) a motivational state--"hunger"--and 2) environmental stimuli--food--which determine the specific topography of behavior and initiate the response (see Bindra, 1974). These two factors likewise operate in the attack situation. Up to this point shock has been regarded as a UCS on the assumption that it elicited attack. But there is no way to determine whether attack is a UCR to the shock itself, or whether it is a response to the target stimulus which is potentiated by the shock. In fact, the latter interpretation

has some support in the literature which shows that shock can poten-

tiate responses to environmental stimuli (Caggiula, 1972; Segal, 1972).

A simple assumption for the present preparation, which also fits the

distinction between motivating and eliciting conditions, is that shock

is analogous to food-deprivation procedures as a motivational operation.

It is the presentation of the bite-tube that functions analogously to

food-delivery in determining the locus and topography of responses.

The stimulus-substitution interpretation of the autoshaping situ-

ation is that, as a consequence of the stimulus-stimulus association,

eating responses elicited by food (the UCS) are transferred to a

localized non-food stimulus (the CS). Thus, in the autoshaping pro-

cedure, the S-S association determines the nature of the response con-

trolled by the CS. The present analysis of the FP procedure, however,

argues that shock only establishes a motivational state in which at-

tack is highly probable: It does not directly elicit attack. The

association created via classical conditioning procedures in the pres-

ent preparation ensures that this motivational state and the bite-tube

which elicits attack coincide in time. It remains to be seen whether

this analysis is consistent with the data from the backward-pairing

procedure.

The backward-pairing procedure

The major difficulty encountered by the implicit avoidance hypo-

thesis in the present data was the fact that postshock attack emerged

only after several shock trials. Even if the implicit avoidance hypo-

thesis can account for the maintenance of attack on test trials, a second process is needed to account for the initial development of attack.

Throughout the experiments on the backward-pairing procedure implicit response-stimulus contingencies between biting and shock-free periods have been confounded with explicit stimulus-stimulus contingencies existing between the bite-tube and shock-free periods. Indeed, these explicit contingencies exist from the outset of training trials while the implicit contingencies arise only with the emergence of attack. Thus, it seems possible that the development and maintenance of attack in the backward-pairing procedure might be due to forward safety-signal properties of the bite-tube, rather than to safety-predictive properties of attack itself.

Both the design and results of the experiments with the backward-pairing procedure closely resemble an experiment by Moscovitch and LoLordo (1968). These investigators gave groups of dogs backward-pairings of a shock UCS and a tone CS using either a constant 3 min ITI or a random ITI; or, they delayed the CS by 15 sec from shock offset using the constant ITI. When the CSs were superimposed on a Sidman avoidance hurdle-jumping baseline, significant reductions in the rate of avoidance behavior during the CS were found only in those subjects which had received CSs associated with the constant ITI. The CS presented on the random ITI schedule had no effect on avoidance response rates. Moscovitch and LoLordo (1968) concluded that a CS will become

a safety-signal via backward-pairings only if it predicts a rela-
tively long shock-free period. If there is no reliable shock-free
interval, no.conditioning will occur.

The results of the present experiments with the backward-pairing
procedure are consistent with the findings of Moscovitch and LoLordo,
and seem to require the conclusion that attack in the backward-pairing
procedure is a function of the negative predictive relation of the
bite-tube to shock.

Taking all the present experiments together, there arises the
curious finding that attack may be conditioned via either positive
or negative classical contingencies. While it seems rational for an
animal to attack an object associated with an aversive event, the dis-
covery that the same animal will vigorously attack an object associated
with "safety" or the absence of aversive stimulation is both surprising
and unique in the literature.

An alternative analysis: Opponent-process theory

The experiments reported above demonstrate that either of two
Pavlovian conditioning procedures may be used to condition attack
behavior in Squirrel monkeys. One is the fear-conditioning procedure
in which the CS precedes shock. The other is a safety-signal proce-
dure in which the CS follows shock and predicts a relatively long per-
iod free from shock. The results show that a predictive contingency
between the bite-tube and shock is necessary for the development of

attack in both the FP and BP procedures: Very little attack occurred among the subjects run on the BP-VT or the Random procedure, neither of which contained either a positive or a negative contingency. So, in the sense that it depends on predictive classical contingencies, conditioned attack is a true classical conditioning phenomenon.

But, the explanations of the FP and BP procedures developed in the previous sections are discordant since they make opposite predictions. The safety-signal analysis predicts that attack should not occur in the FP procedure because the bite-tube predicts shock. The fear conditioning analysis, however, predicts that attack should not be conditioned in the BP procedure because the bite-tube does not predict shock. Clearly, both predictions are erroneous, and the accounts of the FP and BP procedures need to be reconciled.

Despite the overall similarities in outcomes, there are some differences between the results of the two procedures which suggest an alternative analysis. Subjects in the FP procedure, as a rule, spent less time in attack and made several approach/withdrawal movements during CS presentations. On the other hand, subjects run on the BP-FT procedure tended to make one relatively long attack upon the bite-tube during each presentation. It seems clear that the FP and the BP subjects differ less in the probability of attack than they do in concurrent approach/withdrawal responses. Thus, it is suggested that the magnitude of attack behavior is inversely related to the strength of concurrent fear processes controlled by the CS. This suggestion needs to be incorporated into a consistent account of both the FP and the BP procedures.

The opponent-process model of motivational dynamics proposed by Solomon and Corbit (1974) can be consistently applied to the data of both the forward- and backward-pairings procedures. According to the model, presentation of a strong unconditioned stimulus to a subject activates two motivational processes which control opposite behavioral tendencies. Specifically, the model assumes that a primary "a-process" is directly activated by the UCS and that a compensatory, opponent "b-process" is activated in response to the a-process. The net effect of a UCS is thus to elicit an unconditioned motivational process opposed by a second process which slowly returns the subject to its normal motivational equilibrium. Generally, a-processes are externally controlled: They are reactions to environmental events. The b-processes, on the other hand, are internally controlled: They are initiated by the activation of the a-process, not by the UCS.

Opponent processes ought not to be confused with incompatible responses or motivational states, because both the a- and b-processes are active simultaneously. Also, the b-process depends on the activation of the a-process; conversely, the a-process always activates the b-process. Nor should the opponent-processes be regarded as competing responses or states. There is no suggestion in the model that either the a- or the b-process prevents the other from occurring or that one process eventually acquires exclusive control of behavior. The opponent processes may summate in the behavioral output which reduces the behavioral expression of both processes but does not reduce the activation of either process.

The basic assumption to be made in applying the model to the present data is that attack behavior is an index of the "b-process" and that withdrawal from the bite-tube, screaming, jumping, and loco-motion in the chamber are indices of the "a-process". The rationale for this assignment is simply that it allows description of the re-sults in terms consistent with the opponent-process model and provides a basis for generating predictions. Before proceeding with the analy-sis of the data in terms of the model, the model itself needs to be elucidated.

The workings of the model can be divided into three parts: 1) determinants of the strengths of a- and b-processes; 2) formation of A-states and B-states; and 3) conditioning of A-states and B-states.

First, it is assumed that the strength and duration of the a-process are direct functions of the intensity and duration of the UCS. Moreover, the a-process is elicited at its asymptotic intensity by the initial UCS presentations. The b-process, activated by the a-process, is initially very weak and lags well behind the a-process. Its strength is a direct function of repeated stimulations by the a-process. The b-process slowly and progressively increases in both absolute magnitude and temporal duration. Weakening of the b-process occurs as a simple function of time without stimulation.

Second, A-states and B-states are the net result of the activity of the a- and b-processes during and after presentation of a UCS. An

A-state is present throughout the duration of the UCS. This state is composed of both the a-process and the compensatory b-process. Thus, a subject's reaction to a UCS will diminish as the UCS is repeated because the increasingly strong b-process masks the expression of the a-process. Offset of the UCS terminates the a-process, but since the b-process decays slowly, there is a relatively long after-reaction (called a B-state) in which only the b-process is active. The intensity and duration of the B-state, like the b-process itself, increases as a function of repeated stimulation and diminishes by the passage of time without stimulation.

Third, while the opponent-process theory assumes that both A-states and B-states can be conditioned, the assumption reduces to the possibility of conditioning the a-process alone. Since the b-process can be elicited only in reaction to the a-process, a CS+ which predicts a UCS can directly activate only the a-process. The b-process will be elicited by the a-process. Thus, the b-process is not directly conditioned to a CS+.

From the assumption that only the a-process can be directly conditioned, it follows that a subject will exhibit a B-state in response to a CS- only to the extent that a conditioned a-process, perhaps controlled by apparatus cues, is inhibited by the CS-. A B-state would not be elicited by a CS- presented to a subject in a familiar apparatus which had never been associated with the UCS, and which consequently would not activate an a-process.

The general features of the model have been discussed. Its adequacy as a description of the present data can now be assessed.

1. The backward-pairing procedure

One salient aspect of the data was the delay in the onset of postshock attack. Under the FT schedule, attack emerged in about 20 trials; while under the VT schedule, about 45 trials were required to produce postshock attack. Furthermore, reliable conditioned attack among the subjects engaging in postshock attack was obtained only under the FT schedule.

According to the opponent-process model, the initial shocks elicit an a-process at its maximal intensity. Moreover, since there is no explicit CS+, it is likely that the a-process becomes conditioned to apparatus cues. The b-process increases in strength with repeated shock presentations equally under both VT and FT schedules. However, over successive trials on the FT schedule the subject learns that shock is followed by the absence of shock. Thus, the conditioned a-process comes to be inhibited in the postshock period, leaving only the b-process active--the B-state. Under the VT schedule there is very little reliable shock-free time; hence, one would expect that very little postshock inhibition of the conditioned a-process would occur and consequently the expression of the b-process as attack should take longer to develop. The delay in the initiation of postshock attack can thus be regarded as reflecting both the inhibition of the conditioned

a-process during the postshock period and the growing strength of the b-process. The correlation of the bite-tube with the shock-free period on the FT schedule ensures that the bite-tube will acquire the ability to control the B-state by inhibiting the conditioned a-process.

The opponent-process model predicts that by extending the duration of the sessions run on the VT schedule, postshock attack should emerge late in a session due to the continued strengthening of the b-process. The model also predicts, however, that even if postshock attack were obtained under the VT procedure, attack on test trials would be very weak since the bite-tube would not be a CS-.

The ability of the bite-tube to control attack on test trials in the BP procedure depends on its ability to inhibit fear, the a-process. If there were no ongoing conditioned a-process to be inhibited then presenting the bite-tube would not produce attack. Such a situation might be arranged by the use of a signalled shock procedure in conjunction with backward-pairings of shock and bite-tube. Omitting the signal on test trials should reduce attack to a level representing residual activation of the b-process in response to the session as a whole.

2. The forward-pairing procedure

The opponent-process model easily accounts for the development of attack in the forward-pairing procedure. Forward-pairings of the bite-tube and shock produce a conditioned A-state consisting of both the

a-process, activated by the association of CS with UCS, and the b-process, activated by the a-process. Repeated conditioning trials strengthen the b-process. Thus, in the FP procedure attack should emerge as a function of repeated conditioning trials independently of the emergence of postshock attack. Since both the a- and b-processes are simultaneously active during the CS, the opponent-process model predicts that attack should be relatively less strong than in the BP-FT procedure. Variations in the strength of attack between subjects might be viewed as functions of individual differences in the magnitude of the conditioned a-process, or in the time-course and asymptotic strength of the b-process. It should be possible to measure the conditioned a-process directly in terms of withdrawal, jumping, locomotion, etc., independently of the presence of attack behavior. Because the opponent-process theory views attack behavior as a function of two motivational processes, rather than simply as a response to a stimulus, the possibility raised in a earlier section that the behavioral repertoires of some subjects may simply not include attack requires a parametric investigation of the variables assumed to control both processes.

In general, the opponent-process model predicts that procedures which reduce the level of fear (the a-process) in the FP procedure should increase the level of attack. A number of possible ways to investigate this prediction can be suggested.

The simplest procedure would be to establish a second stimulus as a CS- by superimposing it on the bite-tube CS in unreinforced trials (Rescorla, 1969). The level of attack should be greater on CS- trials than on training trials with the CS+ alone. Incidentally, the model predicts that a CS- superimposed on the bite-tube in the BP-VT procedure should likewise elevate attack.

A second method might be to give initial forward-pairings using a compound CS consisting of a tone plus the bite-tube. Test trials with the bite-tube alone should produce more attack than training trials. The rationale here is that with a compound CS the control of the conditioned a-process should be divided between the elements of the CS (Rescorla & Wagner, 1972). Thus, presenting only one element should only partially activate the a-process, resulting in a relatively stronger b-process; hence, more attack.

This suggestion assumes that the strength of the b-process is independent of the level of activation of the a-process. Although Solomon and Corbit (1974) do not explicitly make this assumption, their model does explicitly assume that the strength of the b-process is a function of its repeated elicitation. It follows that on a given trial, the strength of the b-process will be determined by the frequency of previous activations; it will not depend on the present strength of the conditioned a-process.

A third way to proceed has been explicitly proposed by Solomon

and Corbit (1974). They suggested that preexposing a subject to an aversive UCS should <u>retard</u> subsequent conditioning of the CS+ but <u>facilitate</u> conditioning of the CS-. According to the opponent-process theory, preexposing the UCS would strengthen the b-process. Thus, when conditioning begins, the effects of the a-process controlled by a CS+ will be masked because of the strong b-process developed through UCS preexposure. For the same reason, a CS- will rapidly acquire inhibitory properties.

Applied to the attack conditioning preparation, Solomon and Corbit's proposal requires some modification. Preexposing the monkeys to the shock should <u>facilitate</u> conditioning of attack in the forward-pairing procedure because the b-process would be strong from the outset of conditioning. Such a demonstration would show that attack is a function of the b-process, and moreover; it would argue against a simple habituation account of UCS preexposure in which the UCS is viewed as becoming simply less effective.

Conclusion

Opponent-process theory (Solomon & Corbit, 1974) provides a consistent theoretical description of the data generated by both the forward-pairing and the backward-pairing procedures. In addition, a number of testable predictions emerge from the opponent-process analysis of attack behavior in the present preparation. Generally, procedures which decrease the a-process or increase the b-process

should elevate the levels of attack, while increases in the a-process or decreases in the b-process should reduce attack.

Apart from the present preparation, the opponent-process model is generally applicable to the phenomenon of pain-elicited attack in Squirrel monkeys. The relationship of postshock attack to the duration of the intershock interval is particularly relevant to the present discussion. Hutchinson et al. (1971) reported that the amount of postshock attack was a direct function of the duration of the intershock interval. Furthermore, at short intervals (15 sec--30 sec) attack declined both within and between sessions, while at longer intervals (2 min--4 min) attack progressively increased both within and between sessions to the point that some subjects spent nearly entire sessions in attack. This latter finding was termed "facilitation" by Hutchinson et al. (1971).

The opponent-process model views the outcome of the unsignalled shock procedures used by Hutchinson et al. in terms of the relative strengths of the a- and b-processes. High frequencies of shock delivery should produce a relatively strong conditioned a-process controlled by apparatus cues. Moreover, since there is very little shock-free time, very little B-state should be observed. The model predicts, however, that a signalled or unsignalled termination of the shock series should produce a B-state. Hutchinson et al. (1971) have provided data showing that some subjects engaging in small amounts of post-

shock attack exhibit prolonged attack episodes when shock is terminated. O'Kelly and Steckle (1939) as well, reported that fighting among their subjects continued for as long as 15 hours after the cessation of shock. The model also predicts that when shock is terminated attack should be recovered among subjects which may have ceased to attack during shock presentations.

Facilitation of attack can be explained in terms of the effects of shock frequency on the strengths of the a- and b-processes. The strength of the a-process is a joint function of the intensity of shock and the frequency of shock delivery. Thus, for a given intensity of shock as shock frequency decreases so does the strength of the con-ditioned a-process. In general, the strength of the b-process is also a function of the frequency of stimulation. But, the b-process will continue to be strengthened by stimulation that decreases in frequency so long as the stimuli are not so infrequent that the b-process fades completely during the interstimulus interval. Thus, facilitation of attack comes about when the strength of the conditioned a-process has been reduced by the use of a schedule in which shocks are infrequent, but still frequent enough to continue to strengthen the b-process. Sessions themselves can also be regarded as events activating both a- and b-processes. Thus, repeated sessions of shock delivery should progressively increase the b-process across sessions. The result would be facilitation of attack across sessions.

The opponent-process model predicts that facilitation can be

reduced or prevented by either of two procedures. First, the use of signalled shock procedures should reduce the degree to which apparatus cues control the a-process, and consequently the b-process. Second, increasing either the intershock or the intersession interval should reduce the within and between session increments in attack. The reason for this prediction is that since the b-process decays as a function of time without stimulation, increasing the interstimulus or the inter-session interval should decrease the extent to which the b-process will be strengthened by the succeeding activations of the b-process.

Finally, the application of the opponent-process theory to the data generated by the forward- and backward-pairing procedures has some implications for a learning interpretation. First, attack is not regarded as a conditioned response in either the FP or BP procedures. According to the model, the b-process is activated only in reaction to the a-process. Thus, "conditioned" attack in both the FP and BP procedures is viewed in terms of concurrent activation or inhibition of the conditioned a-process. The strength of attack behavior is only secondarily a function of the learning variables which determine the strength of the conditioned a-process. Primarily, attack behavior in the present preparation is seen as a joint function of the rules govern-ing the absolute strength of the b-process and of the relative strength of the b-process with respect to the a-process.

A second implication of the opponent-process analysis is that the stimulus-substitution principle is superfluous in the present experi-

ments. Although the opponent-process model does not predict that attack (or for that matter, any behavior in particular) will emerge in the present preparation, the emergence of attack cannot be explained in terms of the stimulus-substitution principle. The opponent-process analysis generally places the discussion of the experiments in terms quite different from those initially proposed. Instead of presenting a problem in learning, which is the present experiment appears limited to the formation of simple associations, the forward- and backward-pairing procedures present a problem for motivational analysis. The processes by which specific responses come to be controlled by the a- and b-processes, in addition to the parametric relations which UCS intensity and interstimulus interval bear to the time-course, asymptotes, and possibly the behavioral indices of the a- and b-processes are topics for future investigation.

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APPENDIX A

Experiment I

Trial in which first attack occurred;
number of trials in which attack occurred;
proportion of CS and ITI periods spent in front half of chamber.

	Trial of 1st attack	# trials w/attack	Proportion of time spent in forward half	
			ITI	CS
FP				
1	14	6	.85	.66
2	59	1	.74	.39
3	--	0	.77	.38
4	--	0	.81	.58
5	--	0	.50	.71
6	3	49	.50	.61
BP				
1	17	41	.70	.87
2	--	0	.58	.44
3	16	42	.66	.83
4	38	22	.77	.83
5	26	5	.77	.75
6	3	53	.74	.93
Random				
1	--	0	.78	.77
2	47	1	.68	.54
3	22	7	.46	.30
4	--	0	.43	.20
5	--	0	.70	.43
6	--	0	.17	.76

Experiment I

Total number of bites on Trial 5 over sessions 1-6.

		Session					
Group	Subject	1	2	3	4	5	6
FP	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	8	2	8	4	11
BP	1	0	0	8	12	15	12
	2	0	0	0	0	0	0
	3	0	0	21	19	12	13
	4	0	0	0	0	8	7
	5	0	0	0	0	0	2
	6	5	14	17	17	14	19
Random	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0

Experiment I

Number of bites per trial in Session 7.

Group	Subject	1	2	3	4	5	6	7	8	9	10
FP	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	12	15	15	10	9	9	7	7	7	10
BP	1	8	12	11	13	10	7	6	12	12	9
	2	0	0	0	0	0	0	0	0	0	0
	3	10	7	5	5	6	6	4	4	2	6
	4	11	24	19	15	13	12	11	26	11	10
	5	0	0	0	0	0	0	0	0	0	0
	6	9	9	10	5	10	9	7	5	8	7
Random	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0

APPENDIX B

Experiment II

Total number of bites during preshock CS periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
PS-0	1	9	0	3	0	0	0	0
	2	5	5	17	35	20	28	48
	3	1	0	1	7	31	9	23
	4	0	0	9	42	143	177	218
	5	6	76	59	13	0	0	0
	6	0	0	0	0	0	0	0
PS-10	1	0	0	11	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	116	198	170
	4	0	0	0	0	0	0	0
	5	0	0	0	31	32	61	109
	6	3	47	217	162	164	209	190
PS-30	1	7	13	15	2	0	0	0
	2	0	0	0	23	0	0	0
	3	0	5	49	65	89	35	24
	4	0	20	8	0	0	0	0
	5	0	18	7	0	41	44	66
	6	0	0	0	0	10	46	46

Experiment II

Total number of bites during postshock CS periods over sessions 1-7.

		Session						
Group	Subject	1	2	3	4	5	6	7
PS-10	1	0	17	51	71	10	4	0
	2	0	0	0	0	0	0	0
	3	0	0	0	169	90	74	70
	4	0	0	0	0	0	0	0
	5	0	0	50	52.0	37.0	32.0	28
	6	13	88	42	84.0	63*	56.0	65
PS-30	1	9	19	13	1	0	0	0
	2	0	0	0	52	0	0	0
	3	0	40	142	156	211	175	100
	4	27	40	24	6	0	1	0
	5	0	58	140	132*	166	195	91.0
	6	0	0	0	0	8	16	7.0

* consists of 9 trials

Experiment II

Total duration of attack (in seconds)
during preshock CS periods over sessions 1-7

		Session						
Group	Subject	1	2	3	4	5	6	7
PS-0	1	–	0	4.0	0	0	2.0	1.0
	2	0	15.0	18.0	33.0	21.0	28.0	49.0
	3	0	0	0	13.7	25.4	12.4	14.4
	4	0	0	3.4	15.3	114.0	90.9	122.0
	5	0	30.5	12.4	2.5	.5	0	7.2
	6	0	0	0	0	0	0	0
PS-10	1	–	0	19.0	0	0	0	0
	2	–	0	0	0	0	0	0
	3	0	0	0	0	42.9	78.5	49.5
	4	0	0	0	0	0	0	0
	5	0	0	0	22.2	62.5	102.2	123.2
	6	0	32.6	96.5	108.4	120.2	120.8	117.7
PS-30	1	–	39.0	81.0	100.0*	74.0	75.0	76.0
	2	–	0	0	38.0	41.0	90.0	85.0
	3	0	2.7	25.7	39.6	47.4	21.4	8.9
	4	1.3	21.1	9.7	6.5	.9	.2	.8
	5	0	0	6.0	1.7*	11.2	20.2	38.2
	6	0	0	0	0	2.3	25.8	23.3

* consists of 9 trials

Experiment II

Total duration of attack (in seconds)
during postshock CS periods over sessions 1-7

		Session						
Group	Subject	1	2	3	4	5	6	7
PS-10	1	–	14	54.0	51.0	15.0	3.0	0
	2	–	0	0	0	0	0	0
	3	0	0	0	29.1	59.7	54.3	38.6
	4	0	0	0	0	0	–	0
	5	0	0	30	44	65	71	47.7
	6	13	61	91	79	83	84	58.5
PS-30	1	–	62.0	193.0	181.0	216.0	203.0	125.0
	2	0	0	0	76.0	103.0	151.0	124.0
	3	0	31.2	89.1	124.2	85.3	86.1	27.2
	4	21.9	56.8	20.5	15.1	.3	2.4	3.5
	5	0	24	48	47	107	153	56.7
	6	0	0	0	0	5	5	7.1

Experiment II

Total time (in seconds) spent in front half of chamber
during preshock CS periods over sessions 1-7.
Maximum of 200 sec/session

Group	Subject	Session 1	2	3	4	5	6	7
PS-0	1	77.6	85.8	141.5	159.5	141.6	164.6	171.3
	2	64.1	47.2	103.3	102.8	85.4	114.7	126.4
	3	87.1	119.0	133.8	161.4	143.0	152.5	127.3
	4	22.7	105.5	152.4	150.0	186.1	184.1	193.4
	5	53.9	70.5	93	67	66.3	56.7	83.4
	6	29	73.9	80.4	74.3	74.2	69	19.5
PS-10	1	22.0	121.4	130.9	150.7	179.3	183.1	186.7
	2	29.6	14.5	17.3	14.5	5.5	1.6	10.1
	3	8.1	6.7	37.2	45.2	84.4	151.4	108.1
	4	68	104.3	80.5	94.4	85.7	89.5	87.2
	5	6.7	5.0	26.6	107.4	146.4	158	185.2
	6	17.2	116.4	156.4	174	171.1	173.1	169.7
PS-30	1	144.1	161.2	137.5	172.2	119.8	119.6	148.6
	2	54.0	47.3	38.0	145.3	112.8	128.3	161.9
	3	118.8	141.2	155.6	148.8	150.8	179.9	181.2
	4	28.0	97.5	131.4	103.9	81.2	93.5	90.8
	5	46.3	76.8	90.5	79.5*	98.5	98.8	137.7
	6	26.5	46.7	55.6	62.6	41.0	113.2	76.2

* consists of 9 trials

Experiment II

Total time (in seconds) spent in front half of chamber
during postshock CS periods over sessions 1-7. Maximum of 100 sec/
session for group PS-10, and maximum of 300 sec/session for group PS-30.

Group	Subject	Session						
		1	2	3	4	5	6	7
PS-10	1	17.8	69.2	85.2	94.3	93.8	98.8	91.1
	2	20.0	23.5	11.7	4.6	1.2	.3	3.3
	3	6.1	12.2	29.7	60.0	88.0	85.3	66.3
	4	49.5	51.3	42.9	47.1	38.2	33.5	48.8
	5	2.9	8.0	40.9	65.6	84.2	88.5	87.5
	6	14.4	78.1	98.5	93.3	91.9	93.7	75.3
PS-30	1	204.7	238.6	261.2	278.9	261.1	231.9	229.8
	2	69.6	39.0	90.0	215.8	154.7	195.6	255.6
	3	162.4	245.6	242.4	245.4	489.3	286.9	295.7
	4	88.6	159.4	180.5	144.6	104.5	93.1	122.1
	5	107.7	125	169.7	179.2*	195.9	242.8	233.8
	6	55.2	100	119	93.3	68.2	97.4	55.4

* consists of 9 trials

Experiment II

Total time (in seconds) spent in front half of chamber during ITI periods
over sessions 1-7. Maximum possible times are:
2200 sec/session for group PS-0
2100 sec/session for group PS-10
1900 sec/session for group PS-30

Group	Subject	1	2	3	4	5	6	7
PS-0	1	1222.2	1213.7	1421.5	1163.0	632.8	851.9	800.3
	2	1018.6	1551.7	965.4	682.8	754.1	808.3	300.0
	3	724.6	671.1	319.2	520.9	207.4	168.9	385.3
	4	338.9	432.6	442.6	827.4	952.9	1187.3	1592.6
	5	446.7	710.0	1097.0	901	997.1	1350	883.3
	6	270.9	902.1	1068.8	872.9	729.4	650.5	559.0
PS-10	1	332.4	744.6	920.2	757.9	714.9	794.9	1174.1
	2	192.5	242.3	291.7	379.6	199.4	352.7	420.6
	3	516.0	243.7	37.2	373.2	462.1	1080.0	896.7
	4	604.4	1281.7	357.0	1233.7	827.2	605.3	840.5
	5	430.1	267.6	333.4	326.7	862	987.0	1481.2
	6	196.1	757.4	781.2	719.6	777.4	1087.6	1086.6
PS-30	1	814.2	1177.7	631.5	994.3	762.6	803.6	967.5
	2	347.5	402.5	844.0	851.0	769.2	794.7	926.7
	3	866.1	429.9	1019.2	1404.2	1142.8	1173.3	1744.5
	4	578.2	754.5	224.9	217.5	505.1	590.9	data missing
	5	500.5	505.7	522.8	626.1	753.9	787.2	1087.4
	6	27.7	595.3	400.0	523.1	2.0	381.8	238.1

Experiment II

Total number of entries into the front half of the chamber
during preshock CS periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
PS-0	1	14	26	45	41	60	42	36
	2	10	22	51	57	65	51	33
	3	22	29	35	29	25	36	56
	4	13	44	44	67	17	26	12
	5	22	31	48	98	46	28	29
	6	13	69	73	67	64	69	21
PS-10	1	7	36	45	28	12	14	13
	2	13	23	25	20	17	4	21
	3	5	14	21	20	13	15	24
	4	22	23	22	27	32	22	32
	5	6	5	29	58	33	33	14
	6	18	58	24	20	22	29	28
PS-30	1	17	23	30	21	39	40	31
	2	15	26	28	34	46	60	35
	3	52	32	31	37	43	15	10
	4	34	36	36	46	47	37	40
	5	28	60	94	123*	91	91	55
	6	11	35	55	70	28	37	37

* consists of 9 trials

Experiment II

Total number of entries into the front half of the chamber during
the postshock CS periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
PS-10	1	10	21	13	13	10	10	10
	2	24	31	14	5	4	1	10
	3	9	14	21	20	13	15	24
	4	22	23	22	27	33	22	32
	5	7	4	16	14	11	12	13
	6	19	18	11	11	11	10	31
PS-30	1	29	20	22	17	28	39	47
	2	29	17	43	49	44	47	40
	3	52	32	31	37	43	15	10
	4	34	36	36	46	47	37	40
	5	63	91	105	55	37	37	38
	6	25	55	74*	83	40	55	37

* consists of 9 trials

Experiment II

Total number of entries into the front half of the chamber
during the ITI periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
PS-0	1	115	94	103	184	215	294	228
	2	35	16	27	53	31	45	31
	3	31	20	29	23	14	13	17
	4	59	64	65	116	122	105	117
	5	89	119	156	163	128	113	150
	6	54	67	80	72	79	92	39
PS-10	1	23	54	66	61	80	97	52
	2	98	152	281	356	228	279	305
	3	23	18	20	25	26	32	24
	4	58	23	21	30	35	36	46
	5	59	29	24	23	25	50	97
	6	62	38	78	64	154	187	218
PS-30	1	34	31	67	56	25	28	41
	2	17	6	71	81	75	104	106
	3	111	28	147	146	139	121	92
	4	65	20	23	20	27	27	60
	5	126	122	96	126	257	328	183
	6	6	13	13	12	2	5	44

Experiment II

Total number of nonaggressive contacts with the bite-tube
during the preshock CS periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
PS-0	1	9	20	36	41	55	38	35
	*2	0	9	39	46	57	47	12
	*3	10	20	31	27	31	36	53
	*4	6	52	64	68	35	34	17
	5	2	17	21	8	8	0	9
	6	0	17	26	30	22	34	5
PS-10	1	0	25	32	26	12	10	11
	2	0	0	0	0	0	0	0
	*3	0	0	0	0	26	35	42
	4	10	7	5	8	8	3	8
	*5	1	2	16	58	57	58	38
	*6	8	37	42	63	22	68	52
PS-30	*1	9	18	23	21	34	34	38
	*2	0	0	0	39	39	54	54
	*3	15	24	35	45	47	21	21
	4	26	16	28	20	54	73	50
	*5	7	12	11	1	29	33	30
	*6	33	0	0	0	0	8	37

* indicates subject which attacked tube reliably

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Experiment II

Total number of nonaggressive contacts with the bite-tube
during the postshock CS periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
PS-10	1	10	21	13	13	10	10	0
	2	1	0	0	0	0	0	0
	3	1	4	12	14	14	16	20
	4	9	8	9	12	7	2	7
	5	0	5	10	18	18	18	31
	6	7	12	10	16	15	23	28
PS-30	1	8	14	22	15	22	28	49
	2	2	0	17	32	32	45	41
	3	26	23	28	28	45	18	13
	4	4	28	29	39	40	32	43
	5	13	18	28	44	67	92	54
	6	16	1	1	0	0	17	26

Experiment II

Total number of nonaggressive contacts with the bite-tube
during the ITI periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
PS-0	1	72	73	139	172	199	295	218
	2	14	17	14	17	15	14	33
	3	22	13	19	20	16	13	14
	4	64	59	37	60	53	26	105
	5	23	40	36	38	37	34	40
	6	4	44	74	45	28	25	2
PS-10	1	32	61	26	33	39	37	15
	2	13	0	1	0	0	0	0
	3	0	0	4	6	33	12	11
	4	10	8	8	8	10	2	2
	5	30	25	10	13	8	9	30
	6	46	34	83	49	93	156	207
PS-30	1	21	29	25	28	8	4	6
	2	8	2	127	203	116	89	125
	3	21	24	87	15	10	6	2
	4	19	19	28	19	13	13	9
	5	27	26	13	30	79	55	36
	6	25	2	0	0	0	1	1

APPENDIX C

Experiment III

Total number of bites during CS periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
	1	0	1	0	64	90	50	59
FP-FT	2	17	41	67	63	82	60	76
	3	0	0	0	2	1	0	0
	1	13	8	1	1	0	0	2
FP-VT	2	0	1	114	128	139	172	192
	3	0	36	31	58	32	15	24

Experiment III

Total duration of attack (in seconds)
during CS periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
FP-FT	1	0	.5	0	23.1	54.1	22.9	24.0
	2	15.8	29.5	40.8	36.5	37.8	25.2	39.3
	3	0	0	0	.4	.4	0	0
FP-VT	1	6.6	5.8	.9	.4	0	1.0	12.5
	2	0	.5	47.4	53.7	65.4	119.4	115.7
	3	0	24.9	21.7	51.5	12.1	6.9	16.1

Experiment III

Total number of bites during withdrawal
of the bite-tube over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
	1	0	7	2	20	22	27	12
FP-FT	2	3	20	14	22	18	35	18
	3	0	14	37	70	31	30	3
	1	0	4	4	2	3	1	1
FP-VT	2	8	17	32	15	43	28	22
	3	0	32	33	37	45	45	21

Experiment III

Total duration of attack (in seconds) during withdrawal
of the bite-tube over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
	1	0	.4	.6	9.5	9.7	10.1	4.10
FP-FT	2	3.70	10.0	7.2	8.3	7.0	8.5	7.4
	3	0	6.9	9.01	11.3	7.7	12.6	1.2
	1	0	.5	1.30	.6	2.40	.7	.90
FP-VT	2	0	2.1	7.40	11.40	7.50	14.7	14.90
	3	.4	16.1	13.70	14.00	19.30	12.6	10.00

Experiment III

Trial on which first preshock attack occurred
and trial on which first postshock attack occurred.

Group	Subject	Trial # of first attack preshock	Trial # of first attack postshock
FP-FT	31	13	13
	33	10	7
	35	33	16
FP-VT	32	10	11
	34	20	20
	36	12	8

Experiment III

Total number of entries into the front half of the chamber during
CS periods over sessions 1-7, and during ITI periods over
sessions 1-7 for group FP-FT and sessions 4-6 for group FP-VT.
The data for the ITI periods sessions 1-3 for group FP-VT
are missing due to the loss of the session duration records.

	1	2	3	4	5	6	7
FP-FT							
31	5	20	43	47	46	68	58
33	28	42	36	54	29	40	26
35	19	30	46	55	79	76	88
FP-VT							
32	29	49	41	40	50	51	36
34	27	56	26	33	34	20	25
36	26	31	42	48	80	62	59
ITI							
31	75	81	102	109	140	67	63
33	106	23	30	59	56	62	70
35	87	128	69	77	66	131	153
ITI							
32	--	--	--	56	34	45	--
34	--	--	--	78	35	93	--
36	--	--	--	22	13	15	--

Experiment III

Total number of nonaggressive contacts with the bite-tube
during CS periods over sessions 1-7.

Group	Subject	1	2	3	4	5	6	7
	31	3	11	7	38	86	90	90
FT	33	22	69	66	83	82	73	77
	35	3	3	11	15	12	15	9
	32	2	25	20	25	37	38	52
VT	34	0	6	53	55	66	56	69
	36	6	34	59	75	80	57	62

APPENDIX D

Experiment IV

Number of bites on the test trial (Trial 5) over sessions 1-6.

Group	Subject	1	2	3	4	5	6
BP-FT	1	0	7	10	2	6	6
	2	0	0	2	6	7	5
	3	0	0	0	1	0	0
	4	0	0	12	11	11	12
	5	0	0	0	0	0	0
	6	8	8	9	6	14	12
BP-VT	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	1	2	3
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	13	0	no data	0	1

Experiment IV

Number of bites/trial across session 7.

Group	Subject	1	2	3	4	5	6	7	8	9	10
BP-FT	1	3	5	6	4	4	3	5	0	0	0
	2	5	7	6	3	6	4	5	6	5	4
	3	0	0	0	0	0	0	0	0	0	0
	4	11	5	14	10	8	10	10	10	14	8
	5	0	0	0	0	0	0	0	0	0	0
	6	3	4	6	6	6	4	2	2	3	2
BP-VT	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	1	0	2	1
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	1	0	0	0	0	0	0	0	0

Experiment IV

Total number of bites on shock trials over sessions 1-6.

Group	Subject	1	2	3	4	5	6
BP-FT	1	16	53	70	50	64	58
	2	0	34	54	46	65	58
	3	0	0	0	18	35	44
	4	0	27	107	118	101	127
	5	0	4	16	16	14	0
	6	67	156	111	114	156	170
BP-VT	1	0	0	0	0	0	0
	2	0	0	0	0	53	77
	3	0	0	2	11	25	68
	4	0	0	0	0	0	6
	5	0	0	0	0	0	0
	6	4	53	28	5	34	23

Experiment IV

Average proportions of CS and ITI periods spent in
the front half of the chamber.

Group	Subject	CS	ITI
BP-FT	1	.95	.74
	2	.94	.89
	3	.87	.87
	4	.89	.92
	5	.54	.59
	6	.86	.72
BP-VT	1	.50	.57
	2	.72	.66
	3	.72	.86
	4	.79	.89
	5	.77	.87
	6	.65	.81