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Operant Place Conditioning Measures Examined Using Two Nondrug Reinforcers

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CROWDER, W. F. AND C. W. HUTTO, JR. *Operant place conditioning measures examined using two nondrug reinforcers.* PHARMACOL BIOCHEM BEHAV **41**(4) 817-824, 1992.—Detection of water and social play reinforcers by a place conditioning method based on instrumental conditioning was investigated in rats and compared to detection by conditioned place preference, a method currently used primarily to measure drug reinforcement. Operant place conditioning measures of reinforcement were choices between the reward and nonreward chambers during an apparatus exploration test and during a discrete-trials choice test and also, in some experiments, choices and latencies of chamber entry during training. Three of these four measures showed larger reinforcement effects than did the conditioned place preference measure of relative time spent in the reward chamber. By all reinforcement measures, conditioned place preference training was effective with water reinforcement but was ineffective with social reinforcement. Operant place conditioning was effective with both reinforcers by all measures.

Place conditioning Conditioned place preference Spatial discrimination Choice Latency
Social reinforcement Play Water Rats

STUDIES of the reinforcing properties of drugs in rats most frequently have used continuous reinforcement drug self-administration methods in which the drug is administered through a venous catheter each time a lever is moved. Although the self-administration method is generally accepted for determining whether specific drugs are or are not reinforcing under given conditions, when self-administration rate is used to compare efficacies of different drugs or different doses there may be contamination of data from satiation or disruption effects. At the higher dose range, satiation or disruption may greatly depress rate, resulting in the inverted-U relationship often found between dose and rate. Under these conditions, a rate change in either direction does not unequivocally signify a reinforcement change in either the same or the opposite direction (12,19,27).

Such distortions can be prevented by using discrete trials, each of which ends with a drug administration and which are spaced far enough apart for complete recovery from satiation and disruption. One widely used distributed-trials method is conditioned place preference (CPP). Training consists of confining rats to one compartment (positive compartment) in the presence of a possibly reinforcing stimulus and to a second compartment (negative compartment) without the stimulus. In a subsequent test when the rat can move freely between the two compartments, the time spent in each is recorded. Relative time spent in the two compartments is held to reflect reinforcement. Although it circumvents satiation effects, CPP appears to have serious flaws of its own, some of which are discussed below. A number of reviews and methodological discussions of CPP and self-administration have recently appeared (3,5, 12,17,19,27,28,30).

We developed a procedure that combines some of the features of drug self-administration with some of the features of CPP. Operant place conditioning (OPC) is a discrete-trial spatial discrimination counterpart of drug self-administration, a variety of instrumental conditioning in which the reinforced response is entering a chamber rather than pressing a lever. Most of its features are shared with drug-reinforced maze learning (23,24) and it shares with CPP the features of spatial discrimination and discrete training trials. As with CPP, its training trials are spaced far enough apart to prevent satiation effects from interfering with conditioning or with performance. It differs from CPP in three main ways: a) It measures reinforcement by the behavior of going to a chamber, rather than by the time spent there; b) the reinforcer is contingent upon the subject's behavior of entering the positive chamber, whereas in CPP the drug is independent of the animal's behavior; and c) the chamber stimulus precedes the reinforcing effect; in CPP with drugs, there is no consistent temporal relationship between chamber stimuli and the onset of the drug effect, the drug sometimes being given 30 min or more prior to chamber exposure.

The present experiments were concerned with the first two of these features of OPC: measurement of reinforcement

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by chamber entry and training through instrumental conditioning. The main questions addressed were which behaviors in spatial discrimination situations are more affected by reinforcement and whether placing a rat into a chamber (placement training) is as effective as having the rat enter the chamber (approach training). In addition, information was obtained on whether the lengthy exposures to the positive and negative chambers used in CPP training (usually 15 min or longer) are essential to the conditioning process.

Although the CPP method is used primarily as a test of drug reinforcement, part of the evidence for its validity is that it detects several nondrug reinforcers, specifically food [(16); see also (25)], electrical brain stimulation (7,8), copulation (14), and social interaction with another rat (18). Six largely exploratory experiments are here reported, using water and social interaction to examine the features of OPC and compare them with the features of CPP. Four of the experiments used both placement and approach training and two used approach training only. All employed chamber entry measures of reinforcement and three also obtained the CPP measures of time spent in the entered chamber. Because the OPC method was being developed, no attempt was made to standardize the procedural details, so quantitative comparisons among these experiments would not usually be appropriate.

Water reinforcement was used in two of the experiments. Water was used instead of food both to better control residual reinforcer odors and test the generality of the reported positive results with food. The usefulness of including an additional consumable reinforcer besides food is suggested by the anomolous results obtained with CPP based on saccharin drinking. Saccharin, which supports instrumental conditioning (6,10), does not support CPP under conditions in which sucrose does support it (26).

The other four experiments employed social interaction reinforcement. The need to include a nonconsumable reinforcer stems from a special property of consumable reinforcers as they are ordinarily administered. Unlike a drug reinforcer, food or water is located in one specific place, where the animal either stays or often returns. If learned in the chamber, such behaviors might influence either approach to or staying in that chamber during a preference test in ways that other reinforcers would not. Social reinforcers were chosen for the present experiments because they lack this feature but are effective incentives for learning (11,15). The specific type of social reinforcer employed here is sometimes called "rough-and-tumble play" (22). It is associated with younger rats, up to 60 days of age (9). It appears to be a pure positive reinforcer, whereas social reinforcement in adult rats is thought to be based on aggression or on fear reduction (20,21), and so could be either a positive or a negative reinforcer. Most reinforcing drugs are regarded as positive reinforcers (27).

METHOD

Subjects

Subjects were male Sprague-Dawley rats (Holtzman Company, Madison, WI; Harlan Sprague Dawley, Indianapolis, IN). Experiments on water reinforcement used adult rats, up to 120 days old, housed individually with food available ad lib. Subjects to receive water reinforcement were watered for 15 min once daily for 13 days prior to the start of training. For social reinforcement, subjects were 31–52 days old at the start of training. Individual caging (for social deprivation) preceded training by 1 day. Food and water were available ad lib to the social reinforcement subjects.

Apparatus

The two identical discrimination boxes each consisted of three chambers, arranged to form a T, with the neutral chamber as the stem. The end chambers, one black, the other white, were each 27 × 18 cm (L × W). Floors were tactually distinct, one being of stainless steel rods, the other of either different size rods or wire mesh. Room light entered both chambers through the lid, with more light entering the black than the white chamber. The white chamber had a slight vinegar odor from having a small amount of 2% acetic acid applied to its end wall.

The black and white chambers were separated by a wall, one end of which bisected the open end of the neutral chamber. As with CPP apparatus, the only route between the end chambers was through the neutral chamber. This arrangement was designed to facilitate the control of choice behavior by visual stimuli from the chambers by ensuring that the animal faced both the black and the white chambers when leaving the neutral chamber. In the conventional linear apparatus, the rat can face only one end chamber at a time when leaving the neutral chamber.

The neutral chamber, 27 × 15 cm, had grey walls and a floor of grey plastic. In Experiments 1 and 2, its floor was elevated 10 cm above those of the other chambers; in the remaining experiments, all floors were on the same level. The openings from the neutral chamber to the end chambers had sliding doors of black or white cardboard. Each time the subject left the neutral chamber, the number of seconds spent in the neutral chamber, side entered, and time spent on that side could be recorded by a microcomputer. In some experiments, the latencies of entering the end chambers from the neutral chamber during training were registered automatically in tenths of seconds.

GENERAL PROCEDURES

Subjects (n = 12–15) were randomly assigned to groups and to the black or the white chamber as positive. Water reinforcement consisted of 15 ml tapwater in a cup located by the end wall of the positive chamber; the negative chamber did not contain a cup. Social reinforcement was provided by rats of similar specifications to the subjects. In each experiment, for reasons of economy, only six or eight partners were used. To reduce possible resulting satiation effects, each subject interacted with half the partners in rotation.

The experiments began with habituation to the apparatus by repeated brief placement in each chamber, one or two 15-min periods of exploration of the entire apparatus, or both, as indicated in the individual procedures. In some experiments, the 15-min habituation periods also served as pretests.

Approach Training

Nonchoice training. Only one chamber was accessible on a trial, with positive and negative chambers alternating. If the open chamber was positive, it contained a cup of water or the partner was immediately placed into it; if negative, the subject remained there without the reinforcer.

Choice training. On choice trials, a rat was placed into the neutral chamber, facing away from the entrances to the black and white chambers. It was allowed to enter either chamber, and the door was closed. As in nonchoice training, a positive chamber either contained water or had the partner placed into it when the subject had entered. Only the odd-numbered trials were choice trials; the even-numbered trials were forced to the

side not previously chosen so the two sides were experienced equally. On these "forced" trials, the side chosen on the previous trial was closed off, the rat was placed into the neutral chamber, allowed to enter the accessible side, and confined in that side. Again, the reinforcer was presented when the side was positive.

In nonchoice and choice training, up to three 1- or 2-min opportunities to enter the chamber were given on each trial if necessary, with 1 min between opportunities. Three successive failures to enter would result in the animal being placed into the designated chamber in nonchoice training or in a randomly selected chamber in choice training.

Placement Training

Subjects were placed into their positive and negative sides in alteration, with the doors closed. Reinforcement was the same as in nonchoice and choice training.

Testing and Data Analysis

Time-and-Entries Test (T&E Test). This test was administered after training and, in three experiments, prior to training as well. Rats were placed into the neutral chamber, facing the rear wall, and were allowed access to the entire apparatus for 15 min. Number of entries into each side and times spent on each side were automatically recorded. The entries score was the percentage of entries into the positive chamber. The time score was the percentage of time spent in the positive chamber, excluding the time spent in the neutral chamber. (The basis for including time spent was not that it was assumed to measure reinforcement, but only for comparison purposes, as the reinforcement measure employed in CPP.) In the final two experiments, the T&E test was omitted.

Discrete-Trials Choice Test (DC Test). In the last four experiments, training was followed by six discrete choice trials. In the water reinforcement experiments, these trials were given over the 3 days after the T&E posttest. In the final two social reinforcement experiments, they were given in succession, 15 s apart, beginning immediately after the last training trial. DC trials resembled choice training trials without reinforcement. In each trial, the rat was placed into the neutral chamber, facing away from the exits, and allowed to enter either chamber. It was removed from the apparatus after 1 min or when it returned to the neutral chamber, whichever came first. On each trial, up to three opportunities to choose were given if necessary, with 30 or 60 s between opportunities.

Measures during conditioning. With choice training, on each choice trial after the first the subject's choice of which chamber to enter provided a measure of reinforcement. With nonchoice training, starting with Experiment 3 all training trials after the first pair provided measures of reinforcement in the relative latencies of entering the two chambers.

Treatment of data. For each subject, the entry and choice scores were the percentages of positive side entries and choices, that is, 100 positive ÷ (positive + negative). In the DC test, trials in which no choice was made were excluded in calculating a subject's score. For choices in training, the first conditioning trial was excluded in computing the percentage. The subject's time score was the percentage of end-chamber time spent in the positive chamber. Individual latency scores for training were the subjects' medians of the final three positive and three negative trials. In calculating the medians, trials on which no entry occurred in the three 60-s opportunities were arbitrarily scored as 180 s. Individual median latencies were log transformed to reduce heterogeneity of variance in statistical analysis. The latencies in seconds presented are the antilogs of the group means of these log median latencies.

Statistical analysis. With subjects assigned randomly to black or white positive, any black or white bias would appear as random error unless specifically dealt with. Therefore, black-white positive was used as a variable in analysis of variance (ANOVA). With *t*-tests, the equivalent analysis was to compare subgroups reinforced on the two sides for black-side (or white-side) times or entries. In most experiments, these analyses substantially increased the size of the *t* or *F*. In addition, they prevented any imbalances in the number of black-positive and white-positive subjects from being able to create a positive-side or negative-side bias.

In some experiments, we attempted to reduce error variance with the aid of T&E pretests. Given sufficiently high correlations between pre- and posttests, changes from pre- to posttest could be much less variable than the posttest scores. As it turned out, the correlations were usually too low to increase statistical power.

All significance levels are two-tailed. Group differences were tested with ANOVA. In the experiments that included pretests, repeated-measures ANOVA was also carried out.

PROCEDURES AND RESULTS FOR INDIVIDUAL EXPERIMENTS

Experiment 1: Choice and Placement Training with Social Reinforcement

All phases of the experiment were completed in a single session. Apparatus habituation consisted of 2.5 min in each chamber, followed by 15 min of exploration of the entire apparatus. During this second phase of habituation, entries into the black and white chambers were recorded, along with the total time spent in each. In this way, the habituation also served as a T&E pretest. This period was followed immediately by approach or placement training.

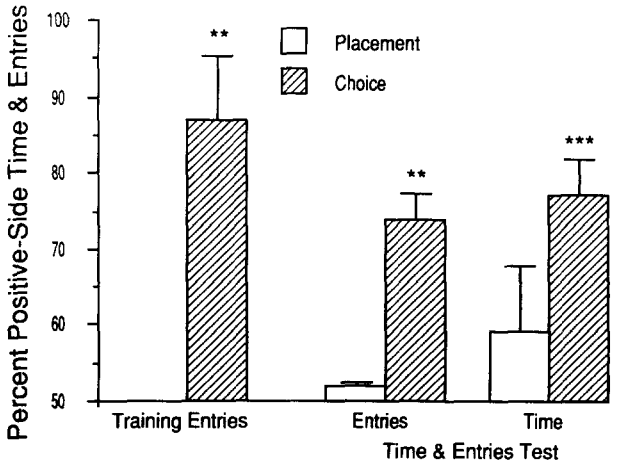

FIG. 1. Choice and placement training with social reinforcement (Exp. 1). Data are mean percentages for entries into water side during training as well as for times spent in the T&E test. In this and subsequent figures that depict percentages, the "chance" expectancy is 50%. In all figures, error bars represent standard errors of means and asterisks represent the significance of the results for an individual group when compared to chance: $*p = 0.05$, $**p = 0.01$, $***p = 0.001$. $n = 12$.

Approach-trained subjects received 16 alternating choice and forced trials with 15-s intertrial intervals. Time in the positive and negative chambers was 70 s. When reinforced, a subject was alone for the first 10 s while its partner was being transferred to the chamber, then the two rats were together for 1 min. When not reinforced, the subject spent 70 s alone in its negative chamber. Placement-trained subjects were placed into the black chamber on odd-numbered trials and into the white chamber on even trials. All other aspects of their training were identical to those of approach-trained subjects. The T&E test was given immediately after the final conditioning trial.

As Fig. 1 shows, the choice-trained group chose the positive side on most choice trials after the first in training and, in the T&E test, entered the positive chamber primarily and stayed there most of the time. Two placement-trained subjects spent the entire T&E test period in the neutral chamber. The rest of this group entered the positive side barely over half the time and, although their mean time there was 59%, this was nonsignificant, $p > 0.30$. The groups differed significantly in entries, $F(1,18) = 7.74$, $p = 0.02$, but not in time ($p = 0.09$).

Table 1 shows pre- and posttest results for this experiment and for two others that used pretests. Results for changes from pretest to posttest were largely similar to those for the posttest. The choice group showed large gains, whereas the placement group showed a loss in entries and a nonsignificant gain in time spent. The two groups differed significantly in these changes in entries, $F(1,18) = 15.75$, $p = 0.002$, but time was borderline ($p = 0.07$).

The pretest did not serve its intended function of increasing statistical power. One F for changes was higher than the corresponding one for the posttest, but the other three were lower.

Experiment 2: Number of Choice Training Trials with Social Reinforcement

Two groups received the same treatment as the approach-trained subjects in Experiment 1. One group received 8 training trials; the other group, 16.

Results are shown in Fig. 2. After the first training trial, both groups chose positive in more than 90% of the choice trials; the difference between the groups was nonsignificant ($p = 0.40$). In the T&E test, the two groups entered the positive side equally, spent about the same percentages of end-chamber time there, and did not differ significantly in either entries or time (each $F < 1$). The time and entries percentages were each the highest we ever recorded. Findings were similar for increases in T&E percentages; all four gains were large and highly significant (Table 1) and groups did not differ significantly in these gains (each $F < 1$). Using the pretest did not increase statistical power. One F for changes was approximately the same as that for the posttest, and three were considerably lower than their posttest counterparts.

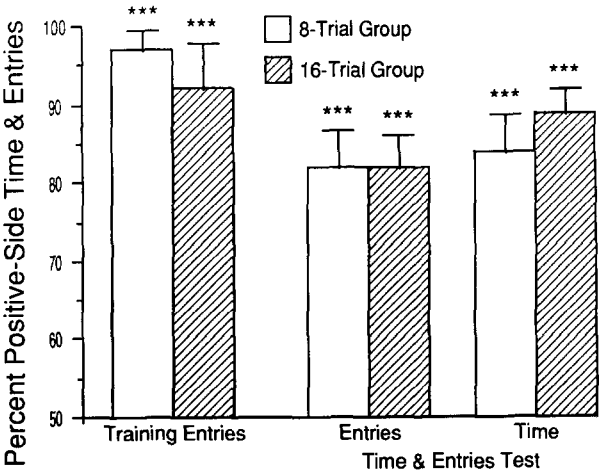

FIG. 2. Choice training with 8 and 16 trials and social reinforcement (Exp. 2). $n = 12$.

Experiment 3: Choice, Nonchoice, and Placement Training with Water Reinforcement

After being habituated to the apparatus by 2.5 min of placement into each chamber and two 15-min periods of exploration, subjects received 12 daily training trials, choice, nonchoice, or placement, with 15-min chamber periods and 15 ml water reinforcement. In nonchoice training, latency of chamber entry was measured electrically in units of 0.1 s. One hour after negative trials, rats were watered for 15 min.

For almost half the subjects, T&E data were lost due to computer malfunction. This experiment is nevertheless included here for the choice and latency data obtained in conditioning, as well as for its DC data. Results are shown in Fig. 3. In training, the choice-trained group chose positive on almost all (95%) choice trials after the first and the nonchoice group entered the positive side considerably faster than the

TABLE 1

T & E TEST CONDITIONS, PRETEST RESULTS, POSTTEST RESULTS, AND PRE-TO-POST TEST CORRELATIONS FOR GROUPS RECEIVING PRETESTS

				Percent Positive Side Time						Percent Positive Side Entries					
				Change from Pre to Post						Change from Pre to Post					
Experiment	Train	Reinforcement	Trial	Pre	Post	F	p	r	Post F	Pre	Post	F	p	r	Post F
1	Choice	Play	16	56	77	16.0	0.005	0.30	27.1	50	74	43.4	0.001	0.18	50.9
1	Place	Play	16	55	59	0.2	>0.7	0.52	0.9	57	51	0.5	>0.4	0.59	0.1
2	Choice	Play	16	43	89	41.6	0.001	0.26	138.8	45	82	54.0	0.001	0.42	54.4
2	Choice	Play	8	43	84	28.8	0.001	−0.19	47.7	47	82	22.8	0.001	−0.36	40.5
4	Nonchoice	Water	16	46	58	5.5	0.04	0.56	2.6	44	61	13.4	0.003	0.08	22.2
4	Place	Water	16	57	63	1.7	>0.2	0.50	8.1	47	54	3.3	0.09	0.41	5.4

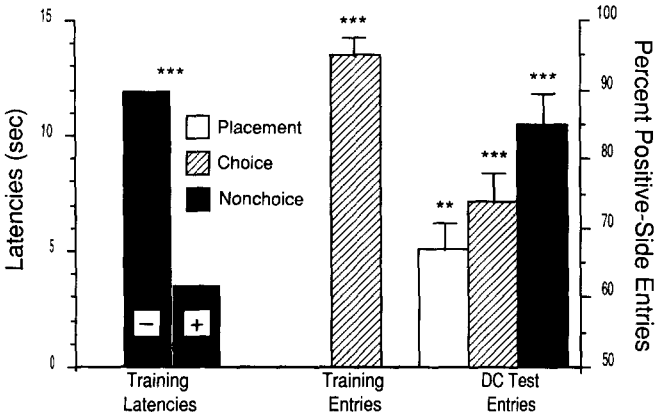

FIG. 3. Choice, nonchoice, and placement training with water reinforcement (Exp. 3). Data shown on left are antilogs of mean logs of individual latency scores for entries into the positive and negative chambers during training. Because standard errors computed on these logs were deceptively small, error bars are not shown. n = 13–14.

negative side. In the DC test, all groups chose the positive side primarily and the groups did not differ significantly ($p > 0.25$).

Experiment 4: Nonchoice and Placement Training with Brief Water Reinforcement

This experiment resembled the preceding one but used 1-min drinking periods with 16 training trials, 2 trials a day. Apparatus habituation consisted of two 15-min exploration periods, the second also being used as a T&E pretest. As in Experiment 3, latencies were measured in nonchoice training. On the first positive trial only, the 1-min period in the chamber began when the rat started to drink. Watering for 15 min started an hour after training.

A choice-trained group was included but results for it are not presented. In the pretest, this group entered the positive side more often than the negative side and stayed there longer (each $p = 0.01$). This statistically improbable outcome of random assignment of subjects to groups and to black- or white-positive precluded any clear interpretation of the results for this group.

As may be seen in Fig. 4, the nonchoice group showed significant effects of reinforcement by all OPC measures applicable to nonchoice training: latencies, DC, and T&E entries. Only time spent was nonsignificant. In addition, it showed significant pre-to-post gains in entries and in time (Table 1). The placement group also showed three significant effects of water drinking: DC scores and both T&E scores. Its pre- to postchanges were not significant for entries or for time (Table 1). The groups differed significantly in T&E entries, $F(1,23) = 4.76$, $p = 0.05$, but not in time, $F < 1$; DC, $p > 0.10$, or in changes in T&E entries, $p > 0.10$, or time, $p > 0.30$.

As in Experiments 1 and 2, the use of the pretest did not increase statistical power. Three pre- to posttest F's were lower than the posttest F's and the fourth approximately equaled its posttest counterpart.

Experiment 5: Choice and Placement Training with Social Reinforcement and the DC Test

Experiment 1 found placement training ineffective in terms of the only measures used, those in the T&E test. Because DC might be markedly more sensitive than either T&E measure, the present experiment replaced the T&E test with the DC test. Habituation and conditioning procedures were the same as in Experiments 1 and 2 except that the chamber and social contact periods were each extended by 10 s. Subjects received 16 trials of either choice or placement training in immediate succession, followed at once by the DC test, with its trials also in immediate succession.

Results are shown in Fig. 5. During conditioning and also in the DC test, choice-trained rats showed a strong disposition to enter the positive side. The placement-trained group chose positive on only 43% of the DC trials ($p = 0.30$) and the difference between the groups was significant, $F(1,26) = 29.9$, $p < 0.001$. These results are consistent with those of Experiment 1 in demonstrating the inability of placement conditioning procedures to detect social play reinforcement.

Experiment 6: Nonchoice Training with Social Reinforcement and Latency Measures

In this experiment, as in Experiments 3 and 4, latency of entering the positive and negative chambers was recorded during training, but social play instead of water was the reinforcer. All other aspects of the procedure were the same as in Experiment 5. Training latencies and the DC mean are shown in Fig. 6. As in previous experiments, both measures showed large effects of reinforcement.

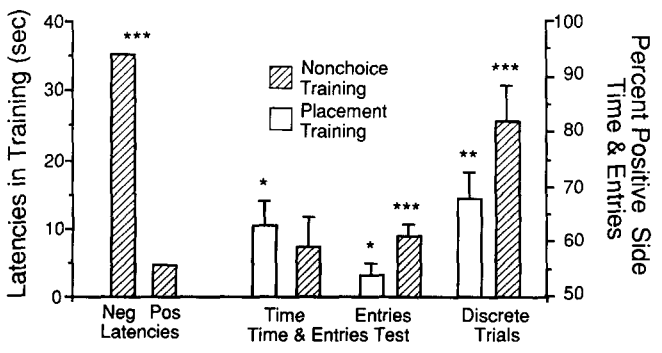

FIG. 4. Nonchoice and placement training with brief water reinforcement (Exp. 4). n = 13–14.

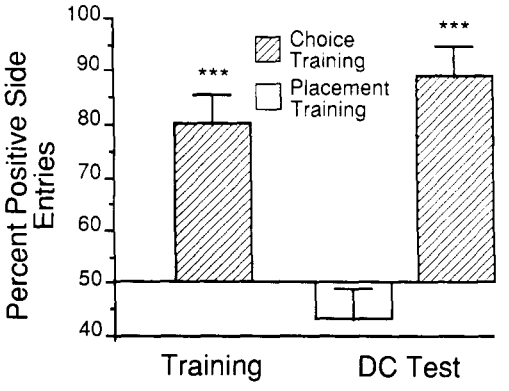

FIG. 5. Choice and placement training with social reinforcement and the DC test (Exp. 5). n = 15.

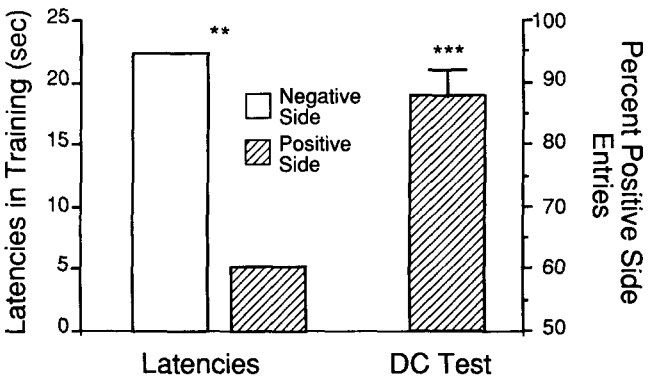

FIG. 6. Nonchoice training with social reinforcement and latency measures (Exp. 6). n = 12.

POSITIVE CHOICES IN TRAINING

For each group given choice training, Table 2 shows the percentage of positive choices on each of the four to eight choice trials in training. All but one group showed marked increases on the second trial. This is not one-trial learning, as every subject received a trial forced to the opposite side between the first and second choice trials.

DISCUSSION OF RESULTS

OPC differs from CPP in its behavioral sign of reinforcement (entering rather than staying) and its basic conditioning paradigm (response contingent rather than stimulus contingent). The main findings of the present experiments pertain to these two characteristics.

Measures of Reinforcement

Four different chamber entry indices of reinforcement were tested; each was found to detect two known reinforcers reliably, with none failing to show significant reinforcement effects in any opportunity that used approach conditioning. When there is doubt or controversy over whether or not a given stimulus is reinforcing, the availability of multiple independent measures of reinforcement may be of particular value. Two of the four measures were recorded during training. The proportion of positive choices was generally high during choice training, and latency differences between the positive and negative sides were large in nonchoice training. These two measures are able to reveal changes in behavior during the conditioning process, an advantage over CPP that is also possessed by drug self-administration.

The time scores of four of the groups were significant and three were the highest we ever recorded. Nevertheless, in each of these four groups still larger effects were shown by the discrete-trials entry measure or measures for that group: DC, training choices, and training latencies.

The finding that placement training generated approach behavior is not supported by CPP studies, which have found that only time spent was affected by the reinforcer, morphine (1,2). The discrepancy may be due to difference in reinforcers or perhaps to the difference in the shape of the apparatus. As noted above, the CPP apparatus allows the subject to face only one end chamber at a time. In addition, in most forms of three-chamber CPP apparatus each time a rat enters the neutral chamber from one conditioning chamber it does so facing the other conditioning chamber, probably resulting in a bias toward equality of entries.

Besides determining the presence or absence of reinforcing effects, reinforcement measures are used to assess differences in reinforcing potency of different stimuli, different quantities of a stimulus, or the same stimulus under different conditions. Often, both types of determinations are made in the same experiment. For maximum usefulness, therefore, a procedure to detect reinforcers should also be sensitive to differences in reinforcer efficacy. With multiple indices, one index might be especially sensitive for detection and another for discrimination of quality of a reinforcer. Reinforcement quantity was not manipulated in the present experiments, so the sensitivity of each of the various OPC indices to amount of water and social play reinforcement is unknown.

Approach and Placement Conditioning

With water reinforcement, placement training was clearly effective, in fact not significantly less so than approach training. Results were entirely different for social reinforcement, with which placement training did not ever generate significant entry or choice behavior. In contrast, each of the five groups receiving approach training with social reinforcement showed significant reinforcement effects in terms of every approach measure used with that group: DC, T&E entries, training choices, and training latencies.

Unlike the present findings, positive results have been reported for placement training with social reinforcement (18). A possible explanation for the discrepancy is the difference in the ages of the subjects. That study used adult rats, for which social interaction is apparently based on fear reduction or aggression (20,21). In addition, its conditioning procedure had one feature used in no other CPP experiment. On half the

TABLE 2

POSITIVE CHOICES IN TRAINING

Experiment	Reinforcement	Choice Trials							
		1	2	3	4	5	6	7	8
1	Play	42	75	83	83	83	92	92	100
2	Play	42	75	92	92	92	92	100	100
2	Play	42	92	100	100				
3	Water	42	75	92	100	100	100		
5	Play	53	47	67	67	73	93	100	100

positive trials, reinforcement was delayed for 10 min, that is, on half the trials the subject was placed in the positive chamber for 10 min before the other rat was presented. Under these circumstances, waiting behavior could have been reinforced in the positive chamber, causing similar waiting (i.e., staying) in the same chamber during the test. In any event, the uniqueness of this conditioning procedure precludes generalizing from the findings.

Experimental Efficiency

A major factor in the experimental efficiency of a conditioning procedure is the number of trials required for conditioning plus testing. Probably no other method is more efficient in this respect than CPP, which can use as few as three sessions (i.e., a pair of sessions for conditioning and one for testing) [(2); see also (5)], although the most common number of sessions is eight (i.e., four pairs), plus sessions used in habituation and testing (5,19). Apart from Experiment 2, we have not investigated the number of pairings required in OPC, but the data in Table 2 indicate that the minimum number may be as few as two pairs, that is, four trials, if not fewer. The method most similar to OPC is T-maze learning, which often requires many more trials. Of the two reported T-maze studies of social play reinforcement (11,15), one needed 40 trials for about 85% positive choices; the other needed up to 70 trials for 100% positive choices. The difference may reflect differences in architecture of the apparatus (the OPC goal boxes are adjacent to its start box and next to each other) or perhaps the use of more sensory modalities in OPC (which is also typical of CPP apparatus).

The amount of time the subject spends in the apparatus is a second factor in efficiency as it affects either the experimenter's time or the number of sets of apparatus needed. With CPP, the usual chamber time is 15–30 min. With OPC, such long periods in the chambers were unnecessary. By the DC measure, as well as by choices and latencies in training, every group receiving approach training with 60–80 s in the chambers showed strong and reliable reinforcement effects. In addition, high T&E entry scores occurred with 70-s chamber periods in Experiments 1 and 2.

Although OPC was developed primarily for distributed trials with highly satiating reinforcers like drugs, it was also found to be suitable for massed trials with a reinforcer that was not highly satiating, specifically, social play. With the T&E test eliminated, a social reinforcement experiment can be completed in a single session of little more than an hour per subject.

GENERAL DISCUSSION

In comparison to the other widely used procedure for assessing drug reinforcement, continuous reinforcement self-administration, the CPP method has a number of experimental advantages (5,17,25). Among the most noteworthy advantages are that a) it is relatively immune from satiating and disrupting effects of the reinforcer (due to long intertrial intervals); b) it is a rate-free measure, especially well suited to studying reward-attenuating effects of receptor blockade and lesions that have motor side effects; c) it requires few drug administrations, so tolerance and toxicity are less problematic; d) the number and timing of drug administrations are controlled by the experimenter, not by the subject; e) it is suitable for aversive, as well as reinforcing, drugs; f) increases in the response measure never imply decreased reinforcement; g) the delay of reinforcement that is inherent in even IV drug administration is well tolerated by spatial choice behavior (29).

At the same time, serious defects in CPP have been pointed out in many papers, including one thorough and detailed assessment (19). Some of the defects are specific to the designs, such as regression effects, but some of them may be inherent to CPP, such as CPP effects occurring in the absence of chamber–drug pairing and effects being obtained that are opposite to those found with established measures. A conceptual weakness is that CPP, which is held to be based on classical conditioning, does not appear to be greatly influenced by classical conditioning variables (3). For example, the chamber conditioned stimulus does not necessarily predict the drug effect; it is sometimes presented after the drug effect is maximal.

Perhaps the most fundamental defect in CPP is the time-spent measure as it relates to the concept of reinforcement. In investigating a new class of possible reinforcers, it would seem important to use a thoroughly established measure of reinforcement. Reinforcement in instrumental conditioning is defined in terms of increased "strength" of behavior, that is, probability, rate, and speed of responding (4,13). Self-administration procedures are direct applications of the definition of reinforcement to drug reinforcers: Lever pressing followed immediately by drug infusion results in a subsequent increase in the rate of pressing. In CPP, the reinforced response is that of entering a chamber so the only response measures consistent with the definition of reinforcement are those pertaining to the strength of that response (i.e., choice and latency), not time spent in the chamber.

To make CPP into a procedure for directly assessing reinforcement as it is currently defined [see (28)], therefore, the time-spent measure should be replaced by a measure of readiness to enter the chamber. The DC test seems to us to be especially well suited to this purpose; it is quick and convenient, typically shows larger effects than either T&E measure, and has never failed to show significant reinforcement effects when some other measure has succeeded (present experiments and unpublished observations).

Once CPP has thus been made consistent with the established definition of reinforcement, the present results suggest that it might benefit from three additional modifications. One is a change in the shape of the apparatus from an alley to one in which the conditioning chambers are side by side and can be viewed simultaneously from the neutral chamber each time a choice is made. Another is a change from placement to approach training both because placement training was found to be ineffective with one of the two reinforcers tested and approach training enables reinforcement effects to be traced throughout conditioning. The third alteration, with many reinforcers, is a reduction in chamber time from the usual 15–30 min to 60–90 s for reasons of experimental efficiency. The result of these changes would be in essence the OPC method, which evolved from CPP by discarding the features of CPP deemed undesirable, while adding some of the desirable features of drug self-administration (12,27,28) and of the T-maze drug reinforcement method (23, 24).

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