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The Effects of Reinforcer-Paired Stimuli on Operant Behavior: Review, Demonstration, and Conceptual Analysis

Timothy Lowell Edwards

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THE EFFECTS OF REINFORCER-PAIRED STIMULI ON
OPERANT BEHAVIOR: REVIEW, DEMONSTRATION,
AND CONCEPTUAL ANALYSIS

by

Timothy Lowell Edwards

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Psychology
Advisor: Alan Poling, Ph.D.

Western Michigan University
Kalamazoo, Michigan
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WE HEREBY APPROVE THE THESIS SUBMITTED BY

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Review, Demonstration, and Conceptual Analysis

AS PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

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THE EFFECTS OF REINFORCER-PAIRED STIMULI ON
OPERANT BEHAVIOR: REVIEW, DEMONSTRATION,
AND CONCEPTUAL ANALYSIS

Timothy Lowell Edwards, M.A.

Western Michigan University, 2012

The presentation of stimuli that have been paired with reinforcers may function as a motivating operation in that the efficacy of the reinforcers appears to increase and the class of responses that have been historically followed by those reinforcers increases in strength. This phenomenon has important implications for a number of behavioral concerns including drug addiction and eating disorders. A review of the existing literature examining this phenomenon presented herein suggests that the phenomenon is reliable and robust but that it is reinforcer-specific. In the animal study that is subsequently described, rats show a higher proportion of responding on average in the presence of the reinforcer-paired stimulus despite pre-session feeding. Although the findings are not statistically significant, data from individual subjects are analyzed for indications of the mechanisms responsible for the effect. An additional brief review analyzing the effects of reinforcer-paired stimuli on consummatory behavior is presented and, given that the presentation of these stimuli also appears to increase consumption of the reinforcing stimulus, it is concluded that it may be fruitful to conceptualize this phenomenon as a conditioned motivating operation.

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Timothy Lowell Edwards

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INTRODUCTION

Does the presentation of a stimulus that has been paired with reinforcement function as a motivating operation? Traditionally, we call stimuli that are correlated with the availability of reinforcement, or “predictive” of reinforcement, discriminative stimuli (Michael, 1982). When one asks why a response is more probable or occurs at a higher rate in the presence of such stimuli, we refer back to the history of the stimulus, the response, and the reinforcer and point out that the response was reinforced in the presence of the stimulus. In many cases, such an explanation is sufficient. However, there are a number of procedures that result in a stimulus that influences the strength of a response but cannot be explained in the same way.

One such procedure involves reinforcing the manipulation of an operandum with a specific reinforcer, then pairing a stimulus with the reinforcer in the absence of the operandum (the order of these two steps can be reversed). Later, with the operandum available, the stimulus can be presented and any change in the rate of response with respect to the operandum can be recorded. There are a number of ways in which this procedure can vary, but the general procedure as described above has been used to study the effects of a stimulus on a response that has never occurred in temporal proximity to the stimulus. The effects are of conceptual interest because the mechanisms by which stimuli of this sort influence operant behavior are not well understood. They are also of practical interest in that there are a number of implications for human behavior, particularly with respect to drug abuse and eating

disorders. A review of the existing studies and their findings will be presented below.

LITERATURE REVIEW

Selection

Relevant articles were located by searching the *Google Scholar*, *PsychInfo*, and *Scopus* databases using a variety of search terms and combinations, including “appetitive stimuli,” “conditioned reinforcers,” “discriminative stimuli,” “food-paired stimuli,” “Pavlovian-instrumental transfer,” “facilitation,” and “motivation.” Due to the wide variety of titles given to the stimuli and procedures of interest, the primary means of locating articles was through an examination of articles citing and cited by the articles located in the initial search.

Studies that implemented the procedures described above or minor variants of the procedure were included in the review. The primary inclusion criteria specified that a stimulus-reinforcer pairing must have been conducted in the absence of the operandum, the manipulation of which would serve as the primary dependent variable in later testing. If the operant response of interest was allowed to occur in close temporal proximity to the reinforcer-paired stimulus in any session other than a test session, the study was excluded from the review due to the additional interpretational issues associated with such procedures. A total of 10 of the articles located satisfied the inclusion criteria and were included in the review.

Review

After training rats to lever press for food under a variable interval 4-min (VI 4-min) schedule, Estes (1943) presented a 60-sec tone followed by food-pellet

delivery 10 times in each daily experimental session for three days. The lever was removed for each of the tone-food pairing sessions. Following tone-food pairing, with the lever replaced but inoperative, the tone was again presented for two 10-min intervals during the 60-min session. During the intervals in which the tone was presented, response rates were much higher than rates during surrounding intervals.

In a follow-up study, Estes (1948) reversed the order of the operant training and stimulus-reinforcer pairing, pairing the stimulus and reinforcer before proceeding with lever training. He also examined the effects of more tone-food pairings and longer-duration (15-min) stimulus presentations during testing with one group of rats. Otherwise, the procedures were similar to those described above. As in the earlier study, when the tone was presented, response rates increased in both groups. However, with the group exposed to more tone-food pairings, there was a larger rate increase in the presence of the tone. Estes also found that the increase in rate was generally limited to the first five min of stimulus presentation.

Van Dyne (1971) trained rats to lever press for food under a VI 40-sec schedule then paired a 10-sec light and sound with electronic brain stimulation (EBS) delivery. In later testing under extinction conditions the rate of lever pressing was suppressed by the presentation of the EBS-paired stimulus. It is important to note that the reinforcer for the lever press and the reinforcer paired with the stimulus were qualitatively different. Van Dyne noted that these results are consistent with the suggestion that stimulus-reinforcer pairings can result in conditioned responses that are incompatible with operant responding. Baxter and Zamble (1982) also demonstrated the reinforcer-specificity of the facilitative effect (see below).

Lovibond (1980) paired four distinct environments with four different

deprivation and feeding conditions for four groups of rats: food-deprived and fed, food-deprived and not fed, not deprived and fed, and not deprived and not fed. In the food-paired environments, rats were placed in the environment without food for 30 to 300 seconds, after which food was made available for the remainder of the session. After operant training in the home cage, a lever was placed in each of the test environments. Because the rats spent a considerable amount of time manipulating the feeding mechanism, the mechanism was removed. The rate of lever pressing with the feeding apparatus removed was highest in the food-deprived and fed group, followed by the not deprived and fed, not deprived and not fed, and deprived and not fed groups, respectively. The only statistically significant difference, however, was for the deprived and not fed group, which produced the lowest rate of response.

Edgar, Hall, and Pearce (1981) found that a long-duration (90-sec) white noise preceding food delivery later resulted in facilitation of lever pressing maintained on VI 5-min schedules of reinforcement (Experiment IV). However, the findings were not statistically significant. Some details of the experimental arrangements make interpretation difficult. For example, lever pressing was occasionally reinforced with food during test sessions, and food was delivered following the white noise presentation in test sessions for all groups.

Baxter and Zamble (1982) found in their first experiment that stimuli paired with Electronic Brain Stimulation (EBS) later facilitated operant responding, which had previously resulted in EBS delivery. A two-bar procedure was used in operant training in which responding on one lever (the operant response) would produce a second “delivery” lever, responses on the second bar functioning as a simulated consummatory response. In experiment two, a stimulus that was paired with EBS

failed to facilitate an operant that had previously resulted in food, suggesting an incompatibility between the two events. In experiment three, food-paired stimuli facilitated operant behavior that had previously been followed by food. In experiment four, the stimulus-reinforcer pairing procedure was carried out in the presence of conditions more or less like the conditions present during operant conditioning. For group one, the animal was restrained, no operandum was present, and EBS was delivered regardless of the animal's behavior. For group two, the animal was unrestrained, no operandum was present, and EBS was delivered regardless of the animal's behavior. For group three, the animal was unrestrained, the "delivery" bar was presented concurrently with the onset of the first EBS pulse, but the EBS was delivered regardless of the animal's behavior. For group four, the animal was unrestrained and the "delivery" bar had to be pressed for ESB to be delivered. The EBS-paired stimulus facilitated operant responding in all groups but had a greater facilitative effect as the conditions became more similar to operant training conditions.

Lovibond (1983), in a study with rabbits, found that a stimulus paired with intraoral sucrose delivery later facilitated responding that was maintained under both VI and variable ratio (VR) schedules of reinforcement with sucrose. The primary difference between outcomes under the two schedule types was that responding was elevated both during and after presentation of the paired stimulus under VR conditions but was only elevated during presentation of the stimulus under VI conditions. In all three of the experiments reported in this study, responding was clearly facilitated by the stimulus.

Colwill and Rescorla (1988, Experiment 3) compared the effects of a

reinforcer-paired stimulus to the effects of a discriminative stimulus by examining the frequency of responses that had been reinforced with the same reinforcer but not in the presence of the same stimuli. They found that the discriminative stimulus facilitated responding when the response had previously been followed by the same reinforcer. They also found elevated rates of responding in the presence of the reinforcer-paired stimulus, but the rate difference was not statistically significant. Interestingly, they found that the reinforcer-paired stimulus had an inhibitory effect on a response that had been reinforced with a different reinforcer.

Corbit and Janak (2007), in experiment one, paired ethanol delivery with a sound, reinforced lever presses with ethanol, then presented the sound during extinction sessions. Sound presentation had a large facilitative effect on lever pressing. In experiment two, one sound was paired with ethanol and another with sucrose. After reinforcing lever pressing on one lever with ethanol and lever pressing on the other lever with sucrose (in separate sessions), both levers were made available during extinction sessions while the two sounds were presented periodically. When the sound paired with ethanol was presented, responding on both levers occurred at a high rate. When the sound paired with sucrose was presented, responding on the sucrose lever occurred at a high rate while responding on the ethanol lever occurred at a relatively low rate. Rate of response on the sucrose lever was just as high during the ethanol-paired sound as with sucrose-paired sound. In experiment three, the procedures in experiment two were replicated except that polycose was used instead of ethanol. In the testing phase, there was a higher rate of response on the sucrose lever in the presence of the sucrose-paired stimulus and on the polycose lever in the presence of the polycose-paired stimulus.

Galarce, Crombag, and Holland (2007) paired sucrose with one sound and maltodextrin with another sound. The rats were then trained to press one lever for sucrose and, in separate sessions, another lever for maltodextrin. During test sessions, one inoperative lever was made available and the two sounds were presented in a random order. Regardless of the sound presented or the lever available, there was an increase in rate of response during sound presentation relative to the rate during intervals of silence. However, a much higher rate of responding was observed when the reinforcer associated with the available lever was consistent with the reinforcer paired with the presented sound.

Discussion

From the results of the studies reviewed above, it appears that the presentation of a stimulus that has previously been paired with a reinforcer has a facilitative effect on the entire class of operant responses associated with that same reinforcer. The reinforcer-specificity of the effect is particularly interesting, especially in light of research on “positive conditioned suppression.” In Azrin and Hake’s (1969) seminal study, a suppression of instrumental responding was found to occur in the presence of a stimulus that had been paired with a reinforcer. However, upon reexamination of Azrin and Hake’s study, Baxter and Zamble (1982) discovered that the suppression effect was only clear when a reinforcer different from the one used in operant training was paired with the stimulus. Other studies of positive conditioned suppression have used similar procedures and found varying results (Davis & McIntire, 1969; Hake & Powell, 1970; Meltzer & Brahlek, 1970; Miczek & Grossman, 1971), but these studies were excluded from the present review because they did not meet inclusion

criteria due to procedural differences (e.g., the paired stimulus was presented dependent on the operant response; Azrin & Hake, 1969).

Following from the above evidence, it seems that positive conditioned suppression is actually a side effect of an increase in the strength of an incompatible class of responses, often due to the presentation of a stimulus that was paired with a qualitatively different reinforcer, an observation that has been made by others (e.g., Poling, Urbain, & Thompson, 1977). Davison, Sheldon, and Lobb (1980), after examining the effects of signaled “noncontingent” reinforcement in a concurrent-chains procedure, concluded that the data produced by studies examining positive conditioned suppression are “adulterated by adventitious and idiosyncratic behavior-reinforcement contingencies [Herrnstein, 1966] by behavioral drift [Herrnstein, 1966] and by idiosyncratic history or nurture” (p. 57).

The phenomenon of interest in the present review is marked by an increase in a measurable response rate rather than an absence of responding on the operandum associated with dependent variable, as in the positive conditioned suppression paradigm. However, it is not clear from the data provided in the studies reviewed what mechanisms are responsible for the obtained outcomes. Many authors explain the results with reference to concepts related to motivation. For example, Lovibond (1980) discussed the possibility of the activation of “motivational centers,” and Estes (1943; 1948) discussed his results in terms of anticipatory states. Given the recent reconceptualization of motivating operations in behavior analysis (see Laraway, Snyckerski, Michael, & Poling, 2003; Michael, 1982; 1983; 2000), an analysis of this phenomenon in terms of motivating operations may be fruitful.

A study was conducted to further examine the influence of reinforcer-paired

stimuli on a response that had been reinforced with that reinforcer. Unlike the studies reviewed above, animals were fed prior to test sessions, a manipulation that may shed light on the motivational component of the present phenomenon. Additionally, unlike previous studies, data from individual subjects rather than aggregate data were examined and are presented below.

EXPERIMENT

Method

Subjects

The subjects were six Sprague-Dawley rats with experimental histories consisting of exposure to basic schedules of reinforcement and discrimination training with visual stimuli in a basic behavior analysis learning laboratory using water as the only primary reinforcer. The rats were between 205 and 256 days old, weighing between 350 and 490 g. They were housed individually in 20 cm by 40 cm cages in a colony room, and maintained under a 12:12 light-dark cycle starting at 7 a.m. All rats were reduced to 80% of their *ad-libitum* weight and maintained at this reduced weight for the duration of the experiment. All procedures were approved by the Western Michigan University Institutional Animal Care and Use Committee.

Apparatus

Experimental sessions were conducted in six Med Associates operant chambers measuring 31.5 cm long × 25.5 cm wide × 25 cm high (Med Associates, St. Albans, VT). In each chamber, an aperture located 2 cm above the floor contained a food cup into which 45-mg food (BioServ, Frenchtown, NJ) pellets were delivered. Entries into the food cup were recorded with a photobeam installed at the entrance of the food aperture. A retractable lever located 6 cm above the floor and to the left of the food aperture was inserted into the chamber during lever training and testing phases. Each chamber was equipped with a speaker, mounted flush with the top at the

right of the back wall, opposite the intelligence panel. A 7-W white houselight mounted at the top of the back wall was illuminated throughout each experimental session. Each chamber was housed in a sound- and light-attenuating shell equipped with an exhaust fan, providing masking noise and ventilation. Experimental events were controlled with a personal computer running MED-PC® software (v. IV for Windows) connected to the MED-Associates interfaces required for operant chamber control and audio generation.

Stimulus-Reinforcer Pairing

The rats were exposed to daily 30-min sessions of sound-food pairings for 10 days in which 10 variable 2-min intervals of silence were each followed by a 1-min interval of sound presentation. For three of the rats the sound was an 80-dB, 2000 Hz tone; for the other rats it was an 80-dB white noise. During each 1-min sound presentation, five food deliveries of two pellets each occurred under a variable time 12-sec schedule (a total of 100 sound-paired food pellet deliveries per session). During this phase, the lever was not inserted into the chamber. The number of food magazine entries during silence and sound intervals was recorded.

This method of stimulus-reinforcer pairing, a long duration stimulus paired with randomly timed reinforcer delivery, was chosen because responding during the period of stimulus presentation could be compared meaningfully to a comparable period of no programmed stimulus or a control stimulus during testing. This method also appears to be an efficient method of examining the motivational effects of stimulus presentation (see Holland, 2004).

Lever Training

Following the 10 stimulus-reinforcer pairing sessions, the rats were exposed to 30-min sessions in which presses of the lever inserted into the chamber were followed by food. Because all of the rats had previously received lever training, little additional training was necessary. After an initial session in which each lever press was followed by a food-pellet, food pellets were delivered under VI 30-sec (1 day), 60-sec (1 day), 90-sec (2 days), and 2-min (2 days) schedules. No sounds were presented during this phase. The number of lever presses and number of magazine entries were recorded.

Testing

Testing was conducted in the absence of any reinforcer delivery. Rats were fed their daily ration of food 30 min before each session. This abolishing operation was used to lessen the reinforcing efficacy of food and lower the background rate of responding. If subjects still responded more on average during presentation of the reinforcer-paired stimulus, this would be indicative of stimulus presentation functioning as a motivating operation. To prevent extensive weakening of the effects of the stimulus-reinforcer pairing and the lever training, testing sessions were 5 min long, consisting of 2 min of baseline, a 1-min event, and another 2 min of baseline, respectively. The 1-min event was either the reinforcer-paired sound (S+), a sound that had not been paired with the reinforcer (S-), or an interval of silence (N). Subjects were never exposed to the S- outside of testing sessions. Although presenting a novel stimulus might disrupt ongoing behavior, it was reasoned that a

novel control sound would provide more meaningful information than a stimulus that had been consistently presented in the absence of reinforcement.

The type of event that was scheduled to be presented for each test session was counterbalanced across subjects. During testing the lever was inserted into the chamber but lever presses had no programmed consequences. Lever presses and head entries during baseline and event intervals were recorded. On the two days following each testing session, rats were exposed to one 30-min session of lever pressing under a VI 2-min schedule of reinforcement and one session of stimulus-reinforcer pairing as described above. The order of lever training and pairing was alternated with each rotation. This three-day sequence of testing and training was repeated until all rats had been exposed to all events three times.

Results

Training

To determine if the sound came to function as a discriminative stimulus for magazine entry during stimulus-reinforcer pairing sessions, the proportion of magazine entries that occurred during sound presentations was calculated for each rat (Figure 1). The tone was the S+ for the first three rats (A1 – A3) and the white noise was the S+ for the last three (A4 – A6). The dashed line indicates the proportion of entries that would be expected if the stimulus did not function as a discriminative stimulus (10 min of S+ divided by 30-min session length). With the exception of subject A1, magazine entry increased to a high proportion by the end of the 10-day training period (connected data points) and remained high or continued to rise during

maintenance sessions (disconnected points).

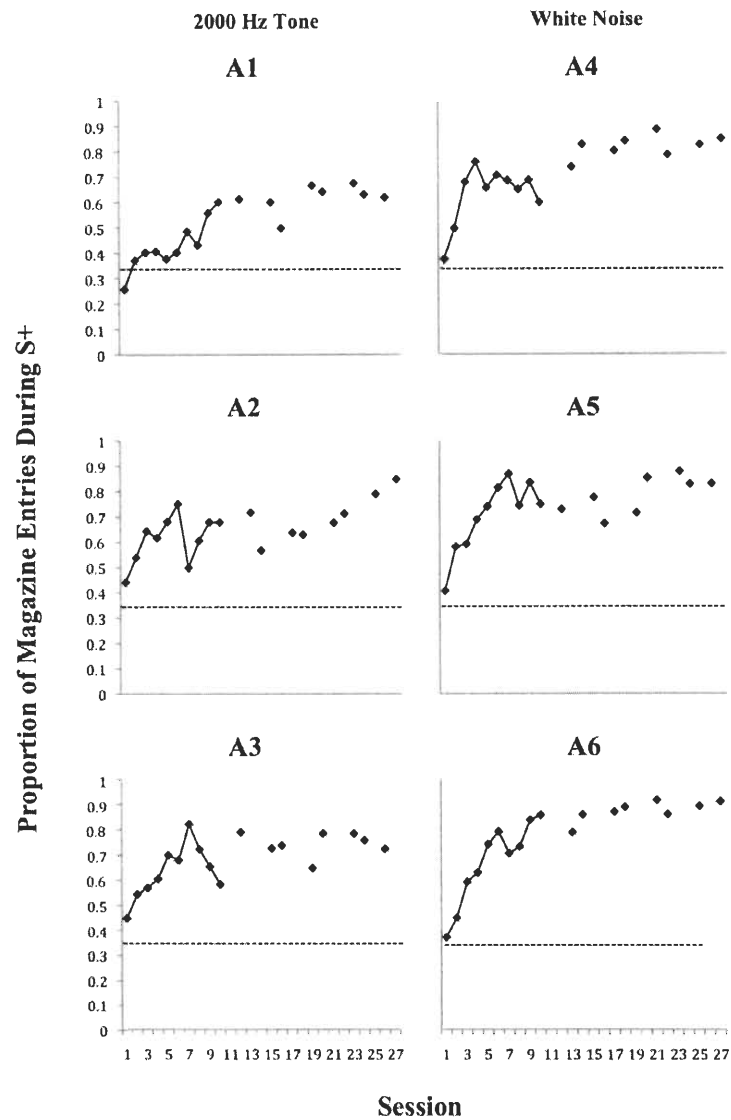


Figure 1. Proportion of magazine entries occurring during 1-min sound presentation during training (connected points) and during maintenance (disconnected points), the horizontal dotted line indicating the proportion expected in the absence of any effect.

By the last day of VI training, rate of response was less than 20 responses per min for all subjects except for A2 who, during the last two session, responded an

average of 34 times per min.

Testing

The general effect of presenting the S+ during test sessions was assessed by examining the proportion of lever presses that occurred during the S+ interval relative to the proportion observed during the S- and the N intervals. Figure 2 shows the proportion of lever presses during each event interval for each rat, averaged across sessions. Averages are displayed because, with few exceptions, proportions were consistent across sessions. As noted above, the outcomes for both groups were not equivalent. For the rats in the white noise group and one rat in the tone group (A1), a higher proportion of lever presses occurred during the S+ presentation. Across all rats, the average proportion of lever presses during S+ is higher, but for two of the six subjects a higher proportion of responding occurred in both control conditions.

The proportion of magazine entries during S+, S- and N intervals are presented in the same manner (Figure 3). The proportion of magazine entries during S+ was highest for all subjects except for A3. Once again, the proportion was much higher for subjects in the white noise group, an expected outcome given their better performance during stimulus-reinforcer pairing sessions. A high proportion of magazine entries during S+ was predictive of a higher proportion of lever pressing during S+, with the exception of A2, who had a relatively high proportion of magazine entries but a relatively low proportion of lever presses during S+.

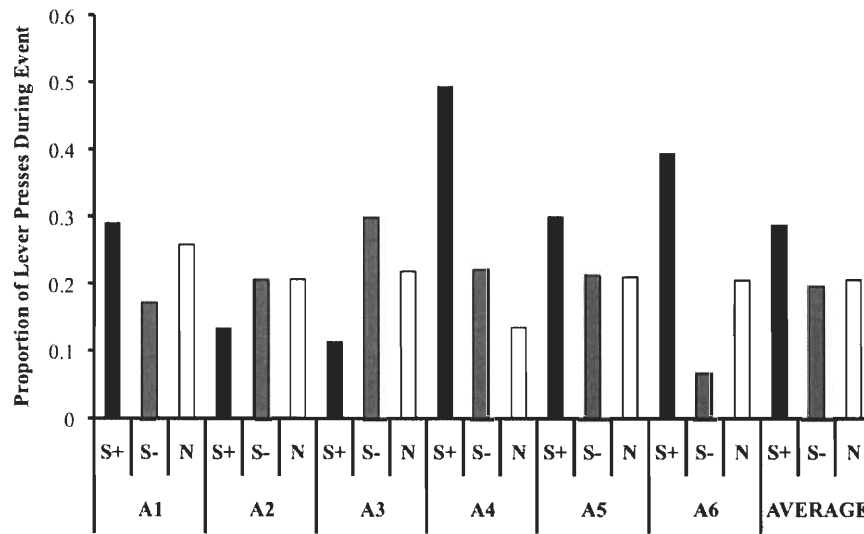


Figure 2. Average proportion of lever presses occurring during each type of event: food-paired sound (S+), control sound (S-), and no sound (N) for each rat, and average proportion across all rats.

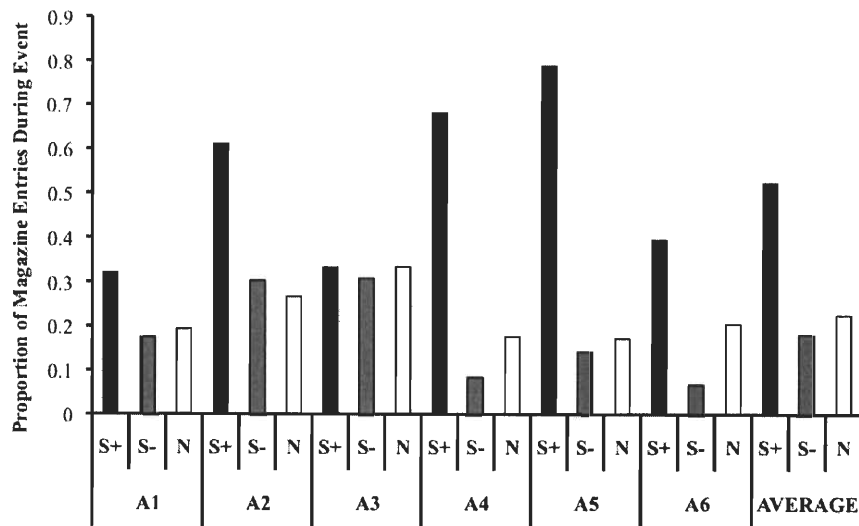


Figure 3. Average proportion of magazine entries occurring during each type of event: food-paired sound (S+), control sound (S-), and no sound (N) for each rat, and average proportion across all rats.

To better understand the relationship between magazine entry and lever pressing, for test sessions in which the S+ was presented, a cumulative record of lever presses and magazine entries was created for each rat in each session (Appendix A). The S+ presentation is indicated by the rectangular box beginning at 120 seconds and ending at 180 seconds. For all rats except A3 (Figure A3 in Appendix A), magazine entries increased noticeably during S+ presentation. In cases where the S+ onset was preceded by a low baseline and followed by an immediate increase in magazine entries and lever presses, the precise timing of the events was examined. With only one exception, after S+ onset, subjects entered the magazine before pressing the lever. In some cases the delay to lever pressing was extreme (Appendix A: Figure A2; Figure A4, bottom panel), but in most other cases lever pressing began immediately after magazine entry. This finding is not surprising, given that magazine entry was frequently reinforced in the presence of the S+.

Results from a two-way ANOVA showed that the proportion of responses occurring during the S+, S- or N event did not change significantly across sessions ($F[2] = .81$; $p = .45$). The difference between the proportion of responses in the presence of the S+ and in the presence of the two control conditions, although improbable in the absence of an effect, was not statistically significant at the .05 level ($F[2] = 2.64$; $p = .08$).

DISCUSSION

In the present study, stimuli paired with reinforcement later facilitated lever pressing even though lever pressing was never reinforced in the presence of the stimulus. Differences were found between the group of rats in which a white noise was paired with food and the group in which a 2000 Hz Tone was paired with food, the tone group showing slower discrimination and little or no facilitation of the operant. Although a sound level meter was used to calibrate the amplitude of both sounds, the different acoustic properties of pure tones and white noise in addition to the fundamental differences between the human and rat aural apparatus may be responsible for the differential outcomes.

The finding of major interest was that, when sound onset was followed by an increase in rate of lever pressing, food-magazine entries occurred before lever presses in all but one instance. This finding can be interpreted in a number of ways. If stimuli associated with magazine entry can function as discriminative stimuli for lever pressing, the observed ordering of events might be expected. It could be argued, however, that, unlike lever presses, magazine entries were reinforced in the presence of the stimulus, so magazine entry should be at greater strength in the presence of the stimulus than the lever press. Therefore, the ordering of events may have been a function of response strength in the presence of the stimulus rather than the result of the stimuli associated with magazine entry serving as discriminative stimuli for the lever press.

Baxter and Zamble (1982) found a weaker facilitative effect when no consummatory response was required, but an effect was still observed (see review). If

future research confirms these findings, particularly under conditions of paralysis, it may be difficult to interpret them without reference to mechanisms other than discriminative stimulus functions.

Discriminative stimuli have a narrowing effect on the class of responses associated with a certain type of reinforcer. For example, a rat that has been fed after pressing a lever in the presence of a tone and after pulling a chain in the presence of a light will press the lever when the tone is presented and pull the chain when the light is presented. Both responses have resulted in food, but the discriminative stimulus functions as a “response-specifying” stimulus. Given the current findings, we may be able to conceptualize stimuli that are predictive of reinforcement as “reinforcer-specifying” stimuli. This is not necessarily a novel suggestion (see Estes, 1943; 1948), and it would not just apply to stimuli that have been paired with reinforcers in the absence of a response requirement (e.g., it would also apply to discriminative stimuli).

For example, Colwill and Rescorla (1988, Experiment 1) reinforced one response with food and another response with sucrose, each in the presence of a light or a noise. They then trained two different responses, one with food and one with sucrose, in the absence of the stimuli. Under extinction conditions the two operanda associated with the second (stimulus absent) phase were made available and the light and noise were presented periodically. When a stimulus was presented, rate of response was highest on the operandum associated with the stimulus-consistent reinforcer. In experiment two, the authors ruled out the possibility of control by stimuli associated with the two different responses by training only one response for two different reinforcers, each associated with a distinct stimulus, in phase one. Even

under these conditions, the response trained in the absence of the stimulus was controlled by the “reinforcer-specifying” stimulus.

We might summarize the effect as follows. In the absence of specific discriminative stimuli, the presentation of a stimulus that has historically been paired with a reinforcer leads to an increase in the strength of responses that have been followed by that reinforcer, barring environmental or motivational restraints. But this summary is highly suggestive of another interpretation. Returning to the question posed at the beginning of this paper, could the presentation of a reinforcer-paired stimulus constitute a motivating operation?

For a process to be considered a motivating operation, according to the current conceptualization, it must pass a two-part test: it must lead to (1) an increase in the reinforcing (or punishing) efficacy of a stimulus and (2) an increase (or decrease) in the class of responses that have been reinforced with that stimulus (Laraway, Snyckerski, Michael, & Poling, 2003). Below I will review some evidence that the first requirement is met. If the evidence is sufficient, given the findings in the review and experiment described above, the second requirement should also be met.

The first required effect of a motivating operation is generally called the “value-altering” effect. This effect is somewhat difficult to demonstrate, particularly since it is not entirely clear how one can assess the reinforcing efficacy of a stimulus without looking at the second effect, the frequency of a reinforced response. One method may be to look at the effect of the putative motivating operation on the rate of acquisition of a response when it is followed by the stimulus in question. If the rate of acquisition is faster under the conditions brought about by the process, it may be argued that the reinforcer is made more effective by the operation.

Another way of testing for the value-altering effect may be to look at the amount of time the organism engages with the stimulus (e.g., sexual contact) or consumes the stimulus (e.g., food or water) as a function of the putative motivating operation. For example, after a period of food deprivation (a well established motivating operation) an animal consumes considerably more food than after an equivalent period in which the animal has access to food. Although there may be better evidence for the value-altering effect of the presentation of reinforcer-paired stimuli, the effects of this operation on consumption will be examined below.

Zamble (1973) fed one group of food-deprived rats at random times following a 15-min stimulus presentation and another control group independent of the stimulus presentation (Experiment 1). In experiment two the control group was fed and then exposed to the stimulus. Rats in the experimental group consumed more food and lost weight more slowly than rats in the control group.

Lovibond (1980, Experiment 2) presented a 1- to 9-min stimulus before daily feeding sessions for one group of rats, presented a stimulus independent of food delivery for another group, and presented no stimulus for a third group. In test sessions in which the stimulus was presented prior to feeding, rats in the experimental group ate an average of 13% more than the rats in the “no stimulus” group and 11% more than the rats in the control stimulus group.

Zamble, Baxter, and Baxter (1980) presented a stimulus prior to daily watering sessions for one group of rats and after daily watering sessions for another group. The rats in the forward conditioning group consumed more water than the rats in the backward conditioning group. The effect was also found to be subject to reversal when conditions were reversed for the two groups.

Weingarten (1983) repeatedly presented a 4.5-min buzzer and light combination to rats, giving them access to a liquid diet during the last 30-sec of the stimulus. For the remainder of the experiment, the rats were given free access to the same liquid diet. In experiment one, when the stimulus was presented, latency to meal initiation was substantially lower than when a control stimulus was presented. In experiment two, during 15-min test sessions, when the stimulus was presented, the sated rats ate approximately 20% of their daily intake whereas presentation of the control stimulus resulted in little or no eating. It was also found that the rats “compensated” for the extra eating by eating less outside of experimental sessions on days when the food-paired stimulus was presented.

Galarce, Crombag, and Holland (2007), in experiment two, presented rats with sucrose in the presence of one sound and maltodextrin in the presence of another sound. They were then given free access to a sucrose or maltodextrin solution in the presence of the paired sound, the unpaired sound, or no sound. The rats consumed more of the solution in the presence of the sound that had been paired with that solution as compared with the other sound or silence.

While this may not be a complete review of the available literature examining consumption in the presence of stimuli paired with the substance being consumed, no studies were located in which the effect did not obtain. The effect appears to be robust and has been observed with a number of qualitatively different reinforcers. One might argue that the classical conditioning procedures used in the above studies prepare the animals to consume more (e.g., by increasing salivation). This may be the case, but the mechanism responsible for the effect does not necessarily detract from the present analysis. Indeed, as Michael (1993) indicated, motivating operations appear to be

closely linked to respondent behavior. Further research in this area would be beneficial.

With few exceptions, in the studies examining the effects of reinforcer-paired stimuli, “motivational properties” of the stimuli have been mentioned. Many of the terms previously used to describe these stimuli are also suggestive of their effects (e.g., conditioned incentive stimuli, appetitive stimuli). This is clearly not a good reason for the induction of “reinforcer-paired stimulus presentation” into the class of procedures known as motivating operations. However, it is clear that the present author is not the first to conceive of these stimuli as relevant to “motivation.”

CONCLUSION

The effects of reinforcer-paired stimuli on later operant responding can be interpreted in a number of ways. In the present paper, it has been suggested that the stimuli can be treated as discriminative stimuli, “reinforcer-specifying” stimuli, or their presentation as motivating operations. There are other interpretations that have not been presented for consideration, many of them involving reference to anticipation, drive, and motivational centers, and there are undoubtedly additional interpretations that do not refer to mediating constructs. Ultimately, our goal is to develop a practical understanding of environment-behavior relationships. Which of the interpretations presented here gets us closer to that goal?

The interpretation requiring the least amount of change to the current conceptual state of our field is that these stimuli function as discriminative stimuli and nothing more, but evidence from studies in which no consummatory response is required suggests that this analysis is incomplete. An interpretation that views these stimuli as reinforcer-specifying stimuli may be more practical in that it does not require the analysis of unobservable discriminative stimuli. However, neither of these approaches predicts the effect reviewed briefly above in which animals consumed more of the reinforcing substance in the presence of the reinforcer-paired stimulus. Therefore, conceptualizing this effect as a motivating operation may lead to better prediction and control of the relevant behavior.

An interesting side effect of conceptualizing this process as a motivating operation is that the presentation of discriminative stimuli would also constitute a motivating operation. It is hard to know what, if any, impact this change might have

on our understanding of discriminative stimuli and, by default, conditioned reinforcers. It is also conceivable that, as with most other currently recognized motivating operations, there is a complimentary motivating operation, in this case, the presentation of a stimulus that has been paired with the absence of a reinforcer, which might be expected to have the opposite effect (i.e., a decrease in the strength of responses that have been historically followed by that reinforcer).

Additional empirical and conceptual work may be needed before a decision can be reached about how this phenomenon should be conceptualized within the modern behavior analytic framework. From the present review and experimental findings, it seems that a reasonably well-established effect once interpreted as motivational in nature has been orphaned, possibly as a result of recent revisions to our understanding of motivation. Michael (1993) outlined three conditioned motivating operations (CMOs; motivating operations that are effective due to events in the organism's ontogenic history), but the procedures under review do not meet the definition of "surrogate," "reflexive," or "transitive" CMOs. Michael indicated that his list of CMOs was not intended to be exhaustive, and it appears that the current phenomenon is a good candidate for the list of CMOs.

REFERENCES

- Azrin, N. H., & Hake, D. F. (1969). Positive conditioned suppression: Conditioned suppression using positive reinforcers as the unconditioned stimuli. *Journal of the Experimental Analysis of Behavior*, *12*, 167–173.
- Baxter, D. J., & Zamble, E. (1982). Reinforcer and response specificity in appetitive transfer of control. *Animal Learning & Behavior*, *10*, 201-210.
- Colwill, R. M., & Rescorla, R. A. (1988). Associations between the discriminative stimulus and the reinforcer in instrumental learning. *Journal of Experimental Psychology: Animal Behavior Processes*, *14*, 155–164.
- Corbit, L. H., & Janak, P.H. (2007). Ethanol-associated cues produce general Pavlovian-instrumental transfer. *Alcoholism: Clinical and Experimental Research*, *31*, 766–774.
- Davis, H., & McIntire, R. W. (1969). Conditioned suppression under positive, negative, and no contingency between conditioned and unconditioned stimuli. *Journal of the Experimental Analysis of Behavior*, *12*, 633-640.
- Davison, M., Sheldon, L., & Lobb, B. (1980). Positive conditioned suppression: Transfer of performance between contingent and non-contingent reinforcement situations. *Journal of the Experimental Analysis of Behavior*, *33*, 51-57.
- Edgar, D., Hall, G., & Pearce, J, M. (1981). Enhancement of food-rewarded

- instrumental responding by an appetitive conditioned stimulus. *Quarterly Journal of Experimental Psychology*, 33B, 3-19.
- Estes, W. K. (1943). Discriminative conditioning: I. A discriminative property of conditioned anticipation. *Journal of Experimental Psychology*, 32, 150-155.
- Estes, W. K. (1948). Discriminative conditioning: II. Effects of a Pavlovian conditioned stimulus upon a subsequently established operant response. *Journal of Experimental Psychology*, 38, 173-177.
- Galarce, E. M., Crombag, H. S., & Holland, P. C. (2007). Reinforcer-specificity of appetitive and consummatory behavior of rats after Pavlovian conditioning with food reinforcers. *Physiology & Behavior*, 91, 95–105.
- Hake, D. F., & Powell, I. (1970). Positive reinforcement and suppression from the same occurrence of the unconditioned stimulus in a positive conditioned suppression procedure. *Journal of the Experimental Analysis of Behavior*, 14, 24-57.
- Herrnstein, R. J. (1966). Superstition: A corollary to the principles of operant conditioning. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts.
- Holland, P. C. (2004). Relations between Pavlovian-instrumental transfer and reinforcer devaluation. *Journal of Experimental Psychology: Animal Behavior Processes*, 30, 104-117.
- Laraway, S., Snycerski, S., Michael, J., & Poling, A. (2003). Motivating operations and terms to describe them: some further refinements. *Journal of Applied*

- Behavior Analysis*, 36, 407-414.
- Lovibond, P. F. (1980) Effects of long- and variable-duration signals for food on activity, instrumental responding and eating. *Learning and Motivation*, 77, 164-184.
- Lovibond, P. F. (1983). Facilitation of instrumental behavior by a Pavlovian appetitive conditioned stimulus. *Journal of Experimental Psychology: Animal Behavior Processes*, 9, 225-247.
- Meltzer, D., & Brahlek J. A. (1970). Conditioned suppression and conditioned enhancement with the same positive UCS: an effect of CS duration. *Journal of the Experimental Analysis of Behavior*, 13, 67-73.
- Michael, J. (1982). Distinguishing between discriminative and motivational functions of stimuli. *Journal of the Experimental Analysis of Behavior*, 37, 149-155.
- Michael, J. (1993). Establishing operations. *The Behavior Analyst*, 16, 191-206.
- Michael, J. (2000). Implications and refinements of the establishing operation concept. *Journal of Applied Behavior Analysis*, 33, 401-410.
- Miczek, K. A., & Grossman, S. P. (1971). Positive conditioned suppression: Effects of CS duration. *Journal of the Experimental Analysis of Behavior*, 15, 243-247.
- Poling, A., Urbain, C., & Thompson, T. (1977). Effects of *d*-amphetamine and chlordiazepoxide on positive conditioned suppression. *Pharmacology Biochemistry and Behavior*, 7, 233-238
- Van Dyne, G. (1971) Conditioned suppression with a positive US in the rat. *Journal*

of Comparative and Physiological Psychology, 77, 131-135.

Weingarten, H. P. (1983). Conditioned cues elicit feeding in sated rats: A role for learning in meal initiation. *Science*, 220, 431-432.

Zamble, E. (1973). Augmentation of eating following a signal for feeding in rats. *Learning and Motivation*, 4, 138-147.

Zamble, E. (1974). Pavlovian appetitive conditioning under curare in rats. *Animal Learning and Behavior*, 2, 101-105.

Zamble, E., Baxter, J. B., & Baxter, L. (1980). Influences of conditioned incentive stimuli on water intake. *Canadian Journal of Psychology*, 34, 82-85.

Appendix A
Cumulative Graphs for Individual Subjects

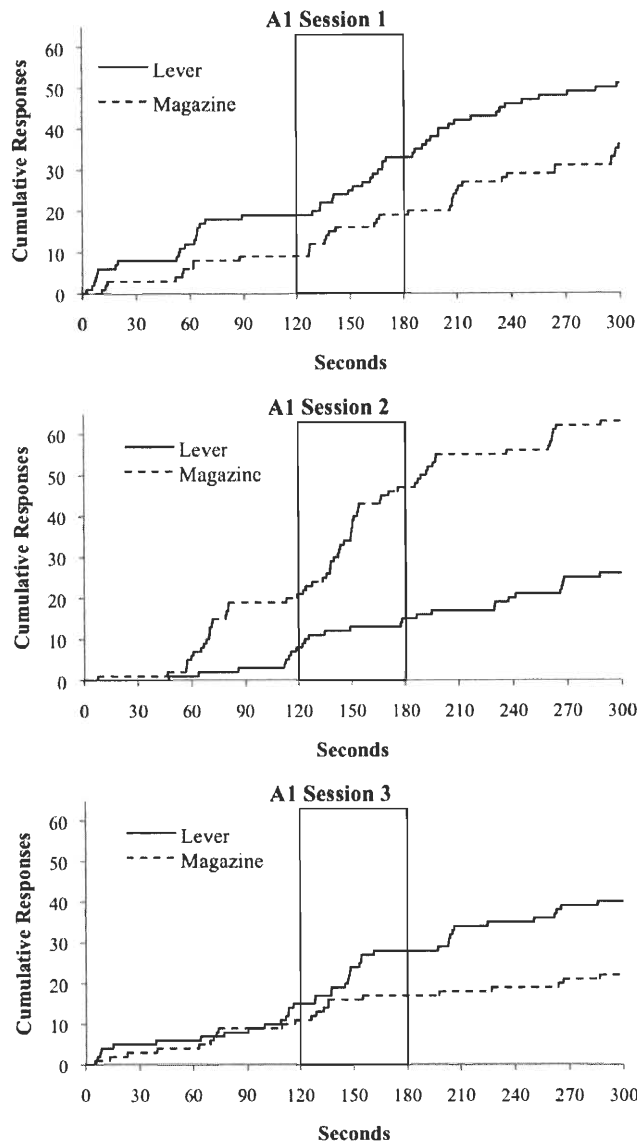


Figure A1. Subject A1, cumulative lever presses and magazine entries during testing sessions in which the food-paired stimulus was presented, stimulus presentation indicated by the rectangular box starting at 120-s and ending at 180-s.

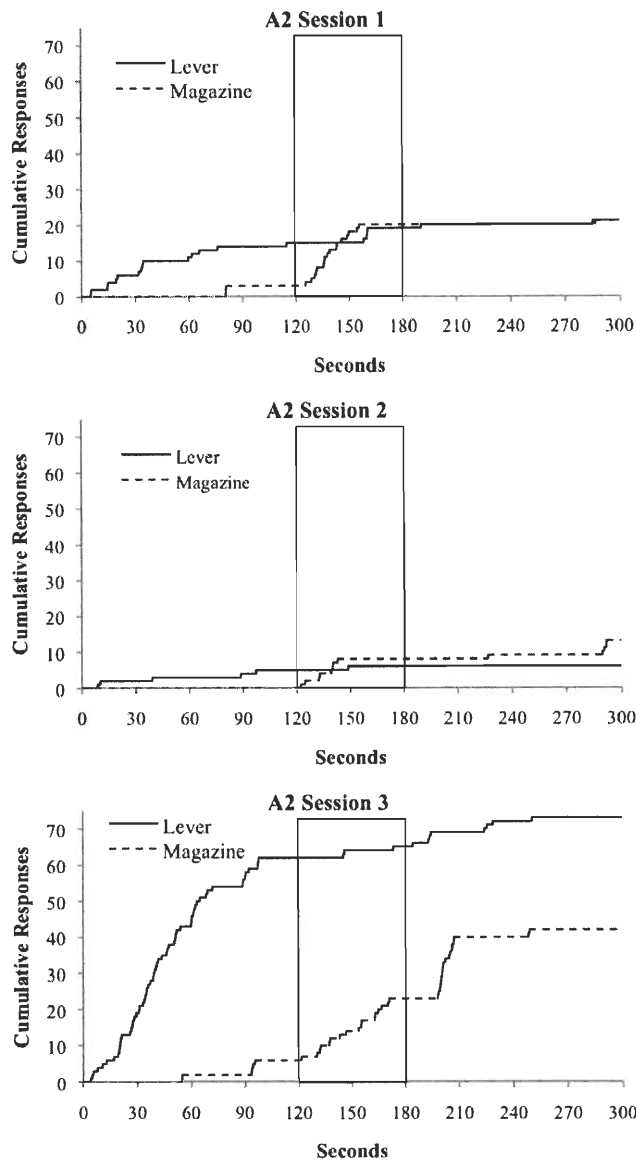


Figure A2. Subject A2, cumulative lever presses and magazine entries during testing sessions in which the food-paired stimulus was presented, stimulus presentation indicated by the rectangular box starting at 120-s and ending at 180-s.

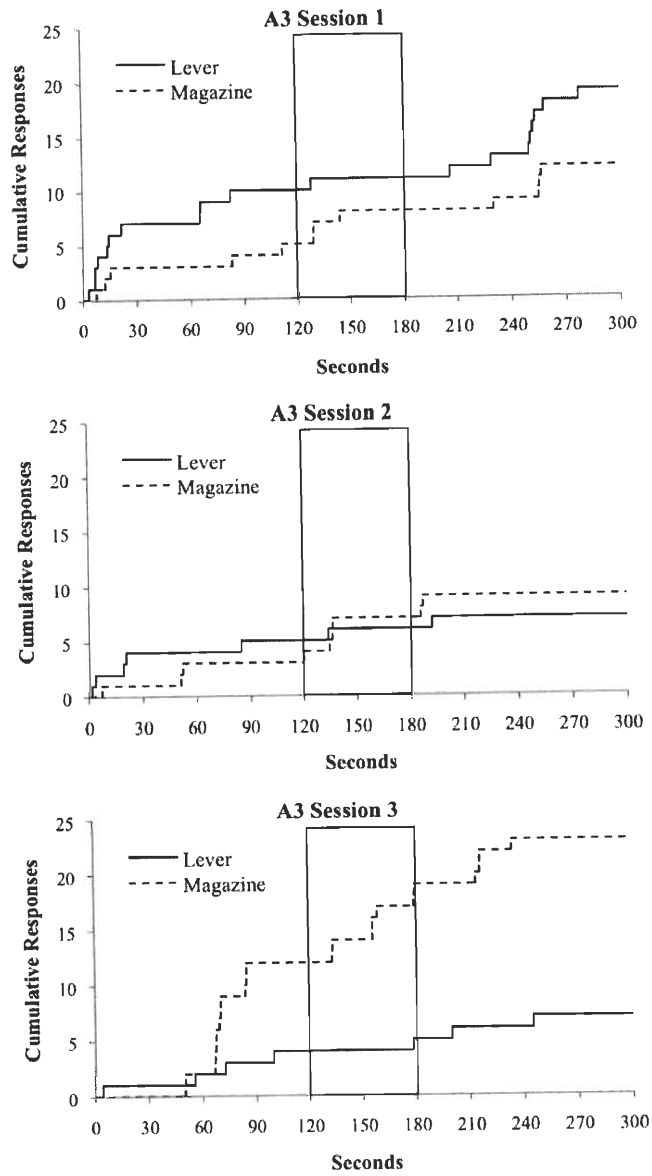


Figure A3. Subject A3, cumulative lever presses and magazine entries during testing sessions in which the food-paired stimulus was presented, stimulus presentation indicated by the rectangular box starting at 120-s and ending at 180-s.

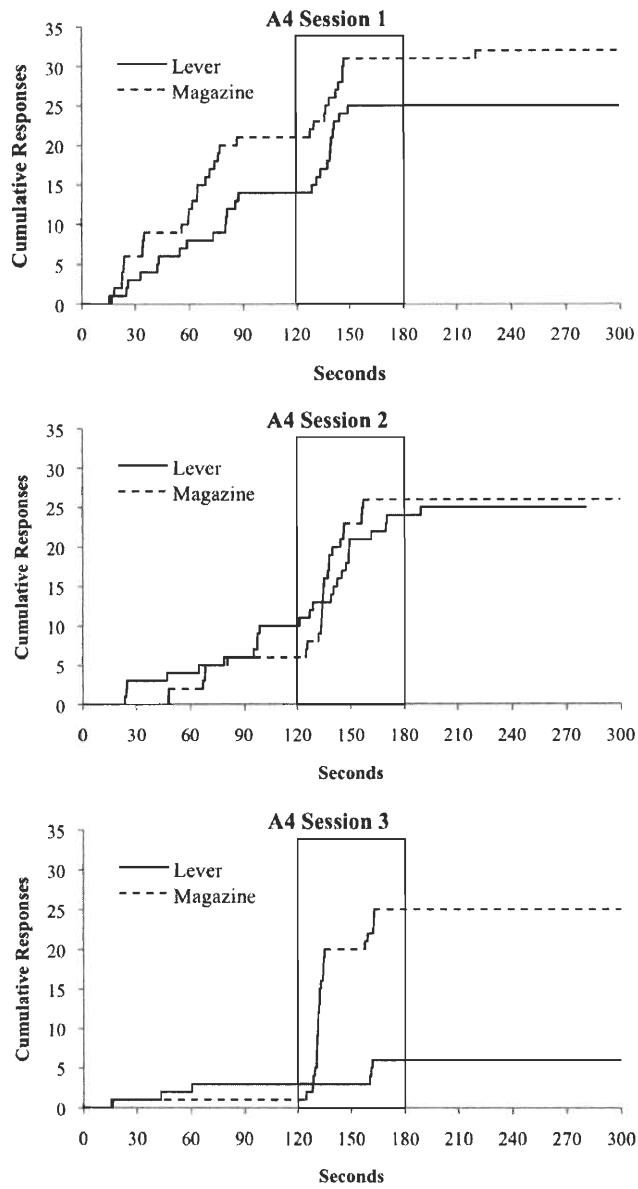


Figure A4. Subject A4, cumulative lever presses and magazine entries during testing sessions in which the food-paired stimulus was presented, stimulus presentation indicated by the rectangular box starting at 120-s and ending at 180-s.

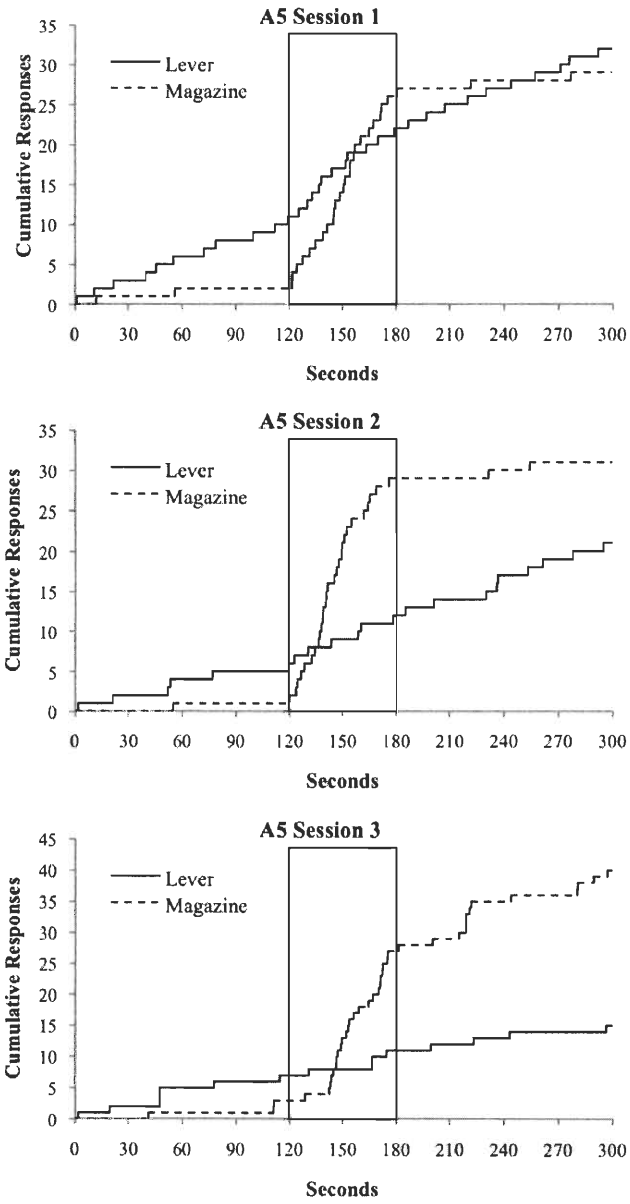


Figure A5. Subject A5, cumulative lever presses and magazine entries during testing sessions in which the food-paired stimulus was presented, stimulus presentation indicated by the rectangular box starting at 120-s and ending at 180-s.

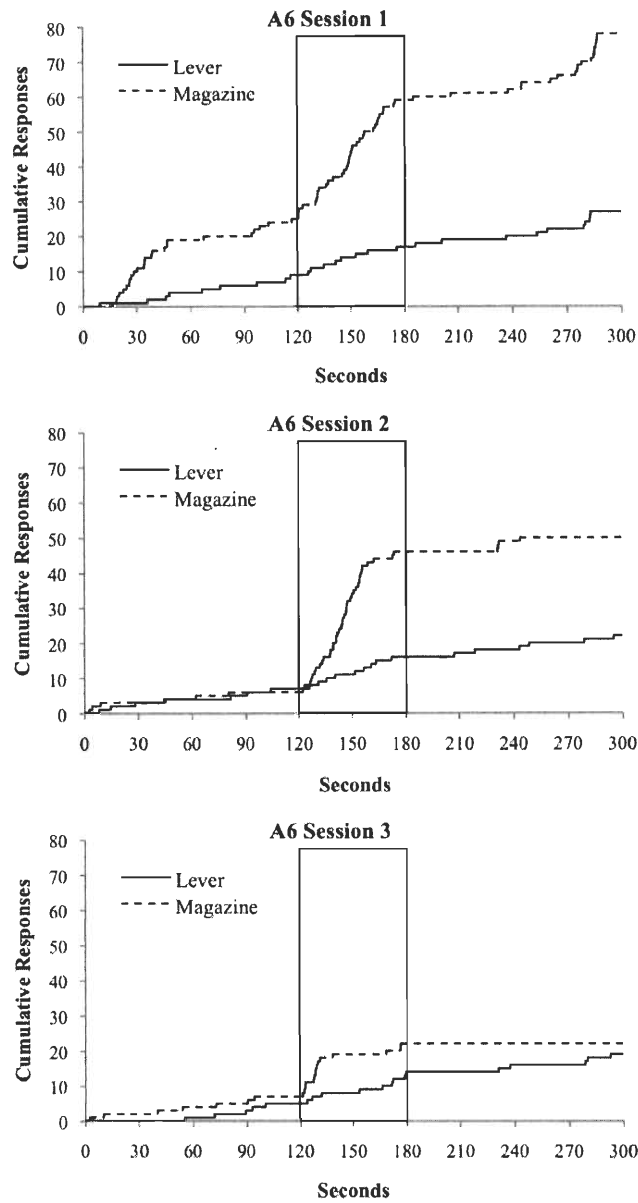


Figure A6. Subject A6, cumulative lever presses and magazine entries during testing sessions in which the food-paired stimulus was presented, stimulus presentation indicated by the rectangular box starting at 120-s and ending at 180-s.

Appendix B

Approval Letter From the Institutional Animal Care and Use Committee

WESTERN MICHIGAN UNIVERSITY

Institutional Animal Care and Use Committee



Date: April 20, 2011

To: Alan Poling, Principal Investigator

From: Robert Eversole, Chair

Re: IACUC Protocol No. 11-03-02

A handwritten signature in black ink, appearing to be "RE", written over the "From" line.

Thank you for submitting the requested revisions. Your protocol titled "Conditioned Reinforcement as a Motivating Operation" has received approval from the Institutional Animal Care and Use Committee. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: April 13, 2012