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EXAMINING THE EFFECTS OF REINFORCEMENT
CONTEXT ON RELAPSE OF OBSERVING

by

Eric A. Thrailkill

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Psychology

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2011

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ABSTRACT

Examining the Effects of Reinforcement Context on Relapse of Observing

by

Eric A. Thraillkill, Master of Science

Utah State University, 2011

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Department: Psychology

Attentional biases occur with various psychological disorders, including drug addiction and anxiety. Conditioned reinforcement likely plays a role in maintaining attentional biases to stimuli associated with reinforcement for unwanted behavior. The observing-response procedure is considered a model of attending as reflected by responding maintained by conditioned reinforcement. Effects of primary reinforcement on the persistence of observing have been studied in the framework of behavioral momentum theory. Studies have shown observing-responses to be more resistant to change in contexts arranging relatively higher rates of primary reinforcement. Recently, behavioral momentum theory has been extended to describe the effects of primary reinforcement context in relapse phenomena. The present thesis aimed to extend research on the resistance to change of observing to animal models of relapse. Pigeons responded on a two-component multiple schedule of observing-response procedures. In a rich

component, observing responses produced stimuli correlated with a high rate of variable-interval (VI) food reinforcement (Rich S+). In a lean component, observing responses produced stimuli correlated with a low rate of VI food reinforcement (Lean S+). Following stable performance, responding was extinguished by removing food and S+ presentations. After extinction, relapse was assessed by reinstatement tests consisting of response-independent presentations of food or S+. Replicating earlier results, observing- and food-key responding was more resistant to extinction in the Rich component. Food reinstatement had no systematic effect on extinguished food- and observing-key responding. However, S+ reinstatement resulted in relapse of extinguished observing- and food-key responding. Relapse during S+ reinstatement was greater in the Rich component than the Lean component. Reinstatement of responding by S+ presentations resulted in a greater overall increase in responding on the food-key relative to the observing-key. This result suggests that an important functional relationship between the presence of S+ stimuli and increased rates of primary reinforcement for food key responding remained intact during extinction. The results show that observing is susceptible to relapse, and the magnitude of relapse depends on baseline primary reinforcement rate in a context.

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Eric A. Thrailkill

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INTRODUCTION

Attentional biases are defined as a disproportionate reactivity to stimuli associated with concern-related events (Mathews & MacLeod, 2005; Robbins & Ehrman, 2004). Biased information processing characterizes various psychological disorders and is well studied in drug abuse research (MacLeod, Mathews, & Tata, 1986). Showing a bias to a stimulus increases the likelihood of further exposure to the stimulus. Previous research has suggested that conditioned reinforcement can be a potential underlying mechanism responsible for maintaining this process (Robinson & Berridge, 1993). Traditional definitions of conditioned reinforcement state that a neutral stimulus comes to function as a conditioned reinforcer as a result of a predictive temporal association with primary reinforcement (Fantino, 1977; Williams, 1994). Drug-associated conditioned reinforcers have been shown to increase the persistence, and precipitate relapse, of drug-seeking behavior in animals (Shaham, Shalev, Lu, de Wit, & Stewart, 2003; Shahan & Jimenez-Gomez, 2006). While much is known about the persistence and relapse of responding maintained by primary reinforcement, relatively little is known about environmental parameters affecting persistence and relapse of responding maintained by conditioned reinforcement.

The reinstatement procedure is a well-studied model of relapse (Epstein, Preston, Stewart, & Shaham, 2006). Three phases comprise the typical reinstatement procedure. First, training is conducted in which a response is reinforced. Second, reinforcement is discontinued and the response experiences extinction. Finally, the reinstatement phase consists of the reintroduction of the reinforcer, reinforcement-associated stimuli, or application of stress. Cue-induced reinstatement, in which relapse of extinguished

responding is elicited by the re-introduction of stimuli predictive of reinforcement, has been demonstrated in several experiments with rats trained to self-administer drugs (Cox, Hogan, Kristian, & Race, 2002; See, 2002; Shaham et al., 2003). One question that remains is whether responding maintained by the production of stimuli associated with primary reinforcement (i.e., attending/responding for conditioned reinforcement) is susceptible to relapse. Previous studies have shown re-exposure to a drug to reinstate conditioned reinforcing effects of drug-associated contexts (Mueller & Stewart, 2000). However, the effects of re-introduction of conditioned reinforcing stimuli and reinforcement context on relapse of extinguished attending (indexed as responding maintained by conditioned reinforcement) remain to be seen.

The observing response procedure is an animal model of attending to stimuli associated with primary reinforcement, as well as a means of studying responding maintained by conditioned reinforcement (Dinsmoor, 1985). Observing responses do not alter the schedule of primary reinforcement. Instead, they produce stimuli indicative of the schedule of primary reinforcement in effect. The conditioned reinforcing property of a stimulus that signals a reduction in delay to primary reinforcement relative to the stimuli in its absence is traditionally thought to maintain observing responses (Fantino, 1977). Dinsmoor (1985) interpreted observing responses as those that “bring the organism’s sensory receptors into contact with stimuli to be discriminated.” Subsequent research has developed the observing response procedure as an animal model of attending to stimuli associated with conditions of primary reinforcement, as well as attending to

drug-associated cues (i.e., responding maintained by drug-associated conditioned reinforcement; Shahan, 2002; Shahan & Jimenez-Gomez, 2006).

Observing has also been used to study how reinforcement context affects the persistence of attending. Shahan, Magee, and Dobberstein (2003) arranged a multiple schedule of observing response procedures in order to assess responding maintained by conditioned reinforcement in the framework of behavioral momentum theory (Nevin & Grace, 2000). According to behavioral momentum theory, a higher rate of primary reinforcement in stimulus context endows behavior in its presence with greater behavioral mass, as indicated by resistance to disruption, relative to a stimulus context with a lower overall rate of primary reinforcement (Nevin, Tota, Torquato, & Shull, 1990). In accordance, Shahan et al. (2003) found observing to be more resistant to change in a component arranging a higher overall rate of primary reinforcement, relative to a component arranging a lower overall rate of primary reinforcement.

The focus of this report is to extend the multiple schedule of observing response procedures to the reinstatement model of relapse to assess the effect of baseline primary reinforcement rate in a component on relapse of attending (Shahan et al., 2003; Shahan & Podlesnik, 2005, 2008b). Recently, a series of experiments by Podlesnik and Shahan (2009, 2010) detailed the effects of reinforcement context on relapse of responding maintained by primary reinforcement. Based on their results it was expected that attending (i.e., responding maintained by conditioned reinforcement) would show greater relapse in a stimulus context associated with a higher overall rate of primary reinforcement.

PREVIOUS WORK – LITERATURE REVIEW

The Problem of Attentional Bias

Attentional biases are widespread in psychological disorders. Certain stimuli command a disproportionate amount of attention for individuals with clinical diagnoses, including anxiety disorders (Baños, Quero, & Botella, 2008; MacLeod et al., 1986; Mogg, Garner, & Bradley, 2007), posttraumatic stress disorder (Pineles, Shipherd, Welch, & Yovel, 2007), eating disorders (Shafran, Lee, Cooper, Palmer, & Fairburn, 2007), obsessive-compulsive disorder (Tata, Leibowitz, Prunty, Cameron, & Pickering, 1996), and drug addiction (Hogarth, Dickinson, & Duka, 2003; Robbins & Ehrman, 2004). Interventions focusing on avoiding these stimuli have shown limited efficacy (Conklin & Tiffany, 2002). Also, several studies have shown attentional biases to predict treatment outcomes (i.e., relapse; Field & Cox, 2008). A better understanding of attentional biases is important for the development of treatment strategies that aim to decrease persistent and relapsing problem behaviors.

The persistent nature of attentional biases has been well studied in drug abuse research. For example, Cox et al. (2002) measured alcohol abusers' and nonabusers' attentional distraction for alcohol-related (logo-types), concern-related (based on interviews assessing individual concerns), or neutral stimuli. Alcohol-abusers were assessed before and after entering a 4-week treatment program. A nonabuser control group was also tested on two occasions separated by a similar interval. The authors classified alcohol abusers as “successful” and “unsuccessful” based on an assessment of

their drinking patterns conducted three months after discharge from the treatment facility. Attentional biases for alcohol-related stimuli in successful alcohol abusers and control participants did not change between the two testing times. However, the unsuccessful alcohol abusers showed a large increase in attentional distraction when tested immediately prior to discharge. These results suggest that attentional biases may increase during treatment and interfere with treatment efficacy for some individuals. Therefore, it is important to understand the variables affecting attention to substance-related stimuli in order to address their persistent motivating effects on behavior.

A reciprocal relationship between the excitatory effects of substance-related stimuli and subjective craving likely maintains attentional biases in addicted individuals (Field & Cox, 2008). Craving can be triggered when a substance user encounters substance-related stimuli, which can lead to an increase in the attention-grabbing properties of substance-related stimuli (Robinson & Berridge, 1993). Because of this process, it may be difficult for a substance abuser to apply attentional resources to cognitive or behavioral avoidance strategies aimed at stopping use or preventing relapse (Franken, 2003). This reciprocal process can be attributed to substance-related stimuli acquiring motivational properties through classical conditioning (Pavlov, 1927). Many studies have shown that substance-related stimuli elicit conditioned responses in substance abusers (O'Brien, Childress, Ehrman, & Robbins, 1998). In addition to increasing drug-seeking behavior, substance-related stimuli have been shown to act as conditioned reinforcers, functioning to maintain the behavior that produces them

(Schuster & Woods, 1968; Smith, Werner, & Davis, 1977). Thus, responding maintained by conditioned reinforcement may provide a useful analog of attentional biases.

Traditional definitions of conditioned reinforcement refer to the ability of an initially neutral event to acquire value because of its relation to primary reinforcement, and then to serve as an effective reinforcer itself (Williams, 1994). Robinson and Berridge (1993) suggested that drug-associated conditioned reinforcers should be especially salient and likely to command attention. The presence of drug-associated stimuli is often predictive of, or signals the availability of the drug. Thus, attending to substance-related stimuli is itself reinforced by the increased probability of primary reinforcement signaled by these stimuli (Shahan & Jimenez-Gomez, 2006).

Contemporary theories of addiction emphasize the role of drug-associated conditioned reinforcers in supporting drug-seeking behavior and inducing relapse (Robinson & Berridge; See, 2002).

Exposure to Cues and Relapse

Several animal models are commonly used to study relapse to drug-seeking behavior. A common aspect of all animal relapse models is a three-phase procedure beginning with a trained response to produce drug reinforcement, followed by extinction of responding by removal of reinforcement, and finally, a phase where stimuli are manipulated to induce relapse (Bouton & Schwartztruber, 1991; Shaham et al., 2003). The renewal model typically involves developing an association between reinforcement and a specific context (Bouton, 2002). Following training, responding is extinguished in a

novel context. Relapse is defined as the increase of the extinguished response when the animal is re-exposed to the training context.

Another model of relapse is resurgence (Epstein & Skinner, 1980). Following initial training of a target response, the response is extinguished while reinforcement is made available for an alternative response. Relapse of the target response is typically observed when reinforcement is also removed for the alternative response.

Finally, the most studied animal model of relapse is reinstatement (Shaham et al., 2003). Following initial training of a behavior, reinforcement is removed until behavior decreases below an experimenter-defined criterion. Relapse of extinguished behavior can be induced when the animal encounters the reinforcer, conditioned stimuli, or stress. Extinguished drug-seeking behavior has been shown to increase following administration of the drug, exposure to stress, or re-introducing drug-associated stimuli. Reinstatement of behavior by exposure to conditioned stimuli provides an important method for studying the role of conditioned reinforcement in relapse.

Cue-induced reinstatement of drug-seeking behavior is a robust phenomenon in preclinical addiction research. Typically, rats are trained to self-administer drugs paired with a discrete stimulus (Ball, Walsh, & Rebec, 2007). Extinction of responding occurs in the absence of both the drug and the drug-paired cue. Extinction in the absence of drug-associated cues allows the predictive relation between the cues and reinforcement to remain intact (Weiss et al., 1999). Only the drug-cue is presented in the reinstatement phase. Cue-induced reinstatement of responding has been demonstrated with rats responding for cocaine (Alleweireldt, Weber, & Neisewander, 2001), methamphetamine

(Yan, Yamada, Nitta, & Nabeshima, 2007), opiates (Gracy, Dankiewicz, Weiss, & Koob, 2000), 3,4-Methylenedioxymethamphetamine (MDMA; Ball, Walsh, & Rebec, 2007), alcohol (Ciccocioppo, Lin, Martin-Fardon, & Weiss, 2003), and nicotine (Liu, Caggiula, Palmatier, Donny, & Sved, 2008; Liu, Caggiula, Yee, Nobuta, Poland, & Pechnick, 2006). These studies suggest that presenting conditioned reinforcers can elicit increases in extinguished seeking behavior toward primary reinforcers. Altogether, the reinstatement procedure allows measurement of the persistence of behavior in extinction, as well as relapse of behavior after presentations of primary or conditioned reinforcers.

Relapse of Attending as Relapse of Cue-seeking

One question that remains is whether responding maintained by contact with the conditioned reinforcer *itself* is susceptible to relapse. If so, then based on findings that a process similar to conditioned reinforcement maintains attentional biases to predictive cues (Field & Cox, 2008), it may be the case that attentional biases are susceptible to relapse. Animal models of behavior maintained by the production of reinforcement cues (i.e., conditioned reinforcement) can address this question, because behavior maintained by the conditioned reinforcing effects of cues can be measured separately and independent from behavior directed toward the primary reinforcer.

Evidence from experiments using the conditioned-place preference (CPP) procedure with rats suggests that re-exposure to drug can reinstate the conditioned reinforcing effects of drug cues (Mueller & Stewart, 2000; Parker & McDonald, 2000). The CPP procedure consists of initially allowing rats to explore a three-chamber

apparatus, followed by pairing one of the two adjacent chambers with reinforcement. More time spent in the reinforcement chamber when allowed to choose between adjacent chambers is evidence of conditioned preference for the contextual cues associated with the reinforcement chamber. Mueller and Stewart established CPP in rats by pairing one chamber with injections of cocaine and the opposite chamber with saline. After training, preference for the cocaine-paired chamber was extinguished by pairing both chambers with saline. In a subsequent reinstatement test, the experimenter administered an injection of cocaine prior to preference testing. Rats showed a significant increase in preference for the cocaine chamber following cocaine injections. Mueller and Stewart interpreted this result as drug renewing the incentive value of drug-associated cues (cocaine chamber). For the present purposes, this result provides a demonstration of relapse of extinguished cue-maintained behavior after contact with the cue-associated reinforcement. However, these results do not provide an account of behavior maintained by primary reinforcement, because the rats did not self-administer the drug. The history of primary reinforcement associated with contextual cues has been shown to affect the persistence of behavior in extinction and subsequent magnitude of relapse of responding (Podlesnik & Shahan, 2009). However, these effects have not been shown with responding to produce the cues. Also, in Mueller and Stewart's study, extinction of place preference was conducted by allowing the rats to continue to enter and spend time in the cocaine-paired chamber, and thus responding to produce the stimuli was extinguished. Mueller and Stewart (2000) did not extinguish the response to produce the stimuli by removing the stimuli, and thus could not test whether place preference would be reinstated after exposure to the cocaine-

paired chamber itself. To answer the question of whether responding maintained by the production of cues will relapse after re-exposure to cues, responding for primary and conditioned reinforcement needs to be measured and manipulated separately.

The observing-response procedure is a method of studying responding maintained by conditioned reinforcement, and is considered an animal model of attending to cues (Dinsmoor, 1985). Originally developed by Wyckoff (1952), the observing-response procedure arranges a response that produces changes in discriminative stimuli correlated with otherwise unsignaled periods of reinforcement (S+) or extinction (S-). Observing behavior is defined as the act of bringing the sensory organs into contact with stimuli, and is thus considered to be an animal analog of attending to stimuli associated with conditions of primary reinforcement (Dinsmoor, 1985). Observing-responses do not affect the rate or availability of primary reinforcement. Observing to produce S+ is often used to study changes in conditioned reinforcement in relation to changes in primary reinforcement (Fantino, 1977). Changes in discriminative stimuli maintain observing behavior only when they are correlated with conditions of primary reinforcement (i.e., they are informative, have value, signal a reduction in delay to reinforcement; Dinsmoor, 1985; Fantino, 1977; Lieberman, Cathro, Nichol, & Watson, 1997; Wyckoff, 1952). The observing-response procedure provides a means of manipulating parameters of primary and conditioned reinforcement separately in order to study primary reinforcement effects on attending, as indexed by responding maintained by conditioned reinforcement.

The observing-response procedure has been used as an animal model of attending to drug cues. Shahan and Jimenez-Gomez (2006) examined variations in the persistence

of rats' observing behavior for alcohol-cues in extinction as a function of alcohol concentration (i.e., magnitude). Responding for cues associated with higher concentrations of alcohol was more persistent than responding for lower concentrations. The authors interpreted this finding as cues associated with higher concentrations of alcohol acting as higher valued conditioned reinforcers. Also, observing-response rates were only affected by changes in rate of alcohol delivery and not the total amount of alcohol consumed, suggesting that observing rates depend on rates of primary reinforcement signaled by the cues. This study exemplifies how the observing-response procedure can be applied to study changes in responding maintained by conditioned reinforcers as a function of changes in the primary reinforcement they signal. The observing-response procedure is an established model of attending to cues, and allows independent manipulation of variables affecting responding maintained by primary and conditioned reinforcement.

Resistance to Change of Observing

The observing-response procedure has been used to study how reinforcement context affects the persistence of attending to cues. Shahan et al. (2003) conducted experiments examining the persistence of pigeons' observing behavior by arranging a multiple schedule of independent observing-response procedures signaled by distinct stimuli. During baseline, in the Rich component, observing-responses produced stimuli correlated with alternating periods of a high rate of reinforcement (random-interval (RI) 15-s schedule of reinforcement) and no consequence (extinction) for responding on a

separate key (food-key). In the lean component, observing-responses produced stimuli correlated with alternating periods of RI 60-s schedule of reinforcement and extinction. To assess persistence in each component, satiation by feeding prior to the session was used to disrupt performance. Observing-response rates in the rich component were more resistant to pre-session feeding than rates in the lean component. The authors concluded that the persistence of observing, as indicated by resistance to satiation, depends on the rate of primary reinforcement experienced in the component during baseline.

Similar findings characterize research concerning the impact of primary reinforcement conditions on the persistence of operant behavior maintained by primary reinforcement. Behavioral momentum theory has established a framework for assessing the strength of behavior, as indexed by its resistance to change in the face of disruption (Nevin & Grace, 2000). Typically, operant responding is established in a multiple schedule consisting of signaled periods of high or low rates of primary reinforcement. Resistance to change of responding is measured as the proportion of baseline response rate maintained during disruption by satiation, extinction, or added free presentations of the reinforcer. Several studies have demonstrated that resistance to change of operant behavior is dependent on the overall rate of reinforcement in a component (Nevin, 1992). For example, when reinforcement rates are equated in a two-component multiple schedule, adding noncontingent reinforcer deliveries to one component increases overall reinforcement rate in the component (the overall stimulus-reinforcer relation), but decreases response rate by degrading the contingency between responding and reinforcement (the response-reinforcer relation). However, responding in the component

with added free reinforcers is more resistant to disruption, suggesting that the overall stimulus-reinforcer relation in the component determines resistance to change (Nevin et al., 1990). Behavioral momentum theory has been applied to study persistent behavior in populations ranging from humans to goldfish, and thus provides a robust framework for characterizing the strength of behavior as indexed by resistance to change (Nevin & Grace, 2000). Several experiments by Shahan and colleagues (Shahan et al., 2003; Shahan & Podlesnik, 2005, 2008b) have applied the behavioral momentum approach to analyze the effects of primary and conditioned reinforcement parameters on resistance to change of responding maintained by conditioned reinforcement in the observing-response procedure.

Based on results from several experiments manipulating parameters of conditioned and primary reinforcement, Shahan and Podlesnik (2008a) concluded that the resistance to change of observing depends on the overall rate of primary reinforcement in a context. They noted that observing occurs in the presence of a mixed-schedule stimulus signaling the overall primary reinforcement rate within the component. Additionally, observing responses produce stimuli in the presence of contextual stimuli indicative of the primary reinforcement conditions in effect. One series of experiments manipulated the rate of conditioned reinforcement for observing, resulting in higher observing rates in one component, while keeping primary reinforcement rates constant (Shahan & Podlesnik, 2005). Another series of experiments manipulated the value of the conditioned reinforcer by making periods of primary reinforcement more or less frequent in one component (Shahan & Podlesnik, 2008b). In spite of these systematic manipulations of

observing rates and parameters of conditioned reinforcement, resistance to change of observing depended on the rate of primary reinforcement in the context signaled by the component stimuli. These results suggest that the persistence of attending to cues, as indexed by responding maintained by conditioned reinforcement, depends on the overall primary reinforcement rate experienced in the context.

Extending a Model of Persistence of Attending to Relapse

Podlesnik and Shahan (2009; Expt. 1) have shown greater reinstatement of operant responding in a context previously associated with a higher rate of primary reinforcement. Pigeons responded to produce food reinforcement after a variable-interval in two components of a multiple schedule. In one component, additional reinforcers were delivered independent of responding in order to increase the overall rate of reinforcement (better stimulus-reinforcer relation). In the second phase, responding in both components was extinguished to a criterion of below 10% of baseline. Following extinction, reinstatement tests were conducted over four sessions, in which reinforcers were delivered at the beginning of each component of the session. Response rates increased significantly in both components, and to a higher degree in the rich component relative to the lean component. The aim of the present study is to extend this approach to responding maintained by the production of conditioned reinforcement in the observing-response procedure. Based on the results of Podlesnik and Shahan, it was predicted that observing would increase to a greater level in a context previously signaling a higher overall rate of primary reinforcement.

Findings from studies assessing animal models of attention, relapse, and persistence provide a framework to address the question of whether attending to cues is susceptible to relapse. Taken together, results from cue-induced reinstatement experiments suggest that extinguished responding for primary reinforcement relapses when cues are presented. Research on the observing-response procedure provides evidence that rate of extinction of responding maintained by conditioned reinforcement depends on the rate of primary reinforcement experienced in the context. This leaves the question, would extinguished observing behavior relapse when the conditioned reinforcer is presented? And, if so, would the magnitude of relapse of observing behavior depend on the context of primary reinforcement? The present experiment was conducted to address these questions using a multiple schedule of observing-response procedures similar to those employed by Shahan and colleagues (2003, 2005, 2008b). This approach is an attempt to test a model of relapse of attending as indexed by responding maintained by conditioned reinforcement. By using pigeons observing for conditioned reinforcement, it is possible to examine effects of baseline reinforcement rate on persistence and relapse of observing. This approach allows a delineation of variables affecting relapse of attending, including the re-introduction of conditioned cues absent during extinction, as well as the primary reinforcer. Systematic tests of variables that produce relapse to responding for primary and conditioned reinforcers have potential to identify additional factors to be addressed in strategies aimed at reducing relapse in future animal models and clinical trials, and builds upon previous work examining relapse of simple operant responding maintained directly by primary reinforcement.

In the present study, pigeons responded for food reinforcement and conditioned reinforcers associated with food availability (S+) in a two-component multiple-schedule of observing-response procedures. One component arranged a high rate of primary reinforcement for food-key responding during food periods (Rich component). The other component arranged a low rate of primary reinforcement for food-key responding during food periods (Lean component). In both components, observing responses produced periods of S+ at the same rate when food was available. Reinforcement for observing- and food-key responding was extinguished to below ten percent of baseline in the absence of food and S+. Following extinction, free presentations of food or S+ in each component were delivered to assess reinstatement of observing- and food-key responding. It was predicted that, like extinguished responding for primary reinforcement, extinguished observing-responses would increase when conditioned reinforcement (S+) was contacted, and to a greater degree in a context associated with a higher rate of primary reinforcement. This experiment applied an established framework used to investigate relapse of responding maintained by primary reinforcement to responding maintained by conditioned reinforcement.

Statement of the Problem

Attentional biases are prevalent in many psychological disorders and predict treatment outcomes. Animal models of such disorders are important for addressing why some environmental stimuli have disproportionate control over attention. Previous research suggests that stimuli associated with drug reinforcement serves to maintain

drug-seeking behavior and induce relapse. The reinstatement model of relapse arranges contact with reinforcement following extinction. This contact results in relapse of behavior previously associated with that reinforcer. To extend the reinstatement model to study relapse of attending in an animal model, the observing-response procedure allows responses to produce stimuli associated with conditions of primary reinforcement. Primary reinforcement rate has been shown to determine resistance to change of observing in a multiple schedule when disrupted by satiation or extinction. The framework of behavioral momentum theory has recently been extended to account for effect of reinforcement context in animal models of relapse. Greater relapse has been shown with responding in a multiple schedule component with a relatively higher rate of primary reinforcement. The present study extends this framework to examine the effects of baseline primary reinforcement rate on relapse of extinguished observing behavior. Thus, the aim is to examine reinstatement of behavior maintained by conditioned reinforcement as a model of relapse of attending to stimuli associated with primary reinforcement.

METHOD

Design

This experiment used a small-*N* repeated-measures design, with all animals experiencing all experimental conditions. In this design, the animal's behavior in one condition serves as a control or comparison for its behavior in other conditions (Sidman, 1960). Large quantities of data were gathered from a relatively small number of animals and conditions were run for extended periods of time. Multiple replications were performed, minimizing the number of animals used and intersubject variability.

Subjects

The subjects were four homing pigeons maintained at approximately 80% of ad libitum weights (± 15 g) by postsession supplemental feeding if needed. Pigeons 218, 658, 1877, and 54 weighed 338 g, 432 g, 396 g, and 455 g, respectively. The pigeons varied in age and experimental history. When not in the experimental sessions, the pigeons were housed individually in stainless-steel cages in a climate-controlled colony room with a 12:12 hr light/dark cycle (lights on at 7:00 am) and free access to water.

Apparatus

The experiment was conducted in four Lehigh Valley Electronics pigeon chambers measuring 350 mm long, 350 mm high, and 300 mm wide. Three response keys were centered on the front panel 83 mm apart and 240 mm from the floor. The keys

measured 25 mm in diameter and required about 0.1 N to operate. A rear-mounted in-line projector illuminated the response keys with the experimental stimuli. The stimuli were yellow, green, red, and blue hues, a vertical line on a black background, and horizontal line on a black background. Reinforcers consisted of 2 s presentations of pigeon chow from an elevated hopper. When raised, the hopper was accessible through a 50 mm wide by 55 mm tall aperture located on the midline of the response panel centered 100 mm above the chamber floor. A 28-V DC clear bulb illuminated the hopper aperture during reinforcement, and all other lights were extinguished while the hopper was activated. A 28-V DC clear bulb mounted 45 mm above the center key on the response panel provided ambient illumination. During a response to a lighted key, the houselight was turned off for 0.01 s in order to provide feedback to the animal. White noise and a ventilation fan in the experimental chamber masked extraneous sounds. In an adjacent room, a computer with Med Associates ® programming and interfacing recorded experimental events. All sessions occurred at approximately the same time each day, and were conducted seven days a week.

Procedure

Pretraining

Initially, subjects were trained on a multiple-schedule of reinforcement. One component of the multiple-schedule was designated the rich component (Rich), while the other component was the lean component (Lean). The first component was selected randomly ($p = .5$), thereafter components alternated for the remainder of the session. Rich

and Lean components alternated every 5 min exclusive of reinforcement time.

Components were separated by a 30-s inter-component interval (ICI) in which all lights were turned off. Schedules were presented on the center key. In the Rich component, responses to the center key produced food after a variable-interval (VI) 30-s schedule, which selected intervals from an exponential distribution (Fleshler & Hoffman, 1962). In the Lean component, responses to the center key produced food on a VI 120-s schedule of reinforcement. VI periods alternated with periods of extinction independently of responding after a variable time averaging 60 s. Component length ranged from 10 s to 110 s in 10-s increments. During extinction (EXT), responses were recorded but had no consequence. Multiple schedule stimuli were counterbalanced across pigeons. For pigeons 218 and 1877, green signaled VI during Rich and blue signaled EXT, and yellow signaled VI and red signaled EXT during Lean. For pigeons 658 and 54, yellow signaled VI and red signaled EXT during Rich, and green signaled VI, and blue signaled EXT in Lean. Sessions were conducted until at least 80% of all responding occurred during VI in Rich and Lean. The training condition was conducted for 33 sessions for all pigeons.

Observing-Response Procedure

Following training, stimuli present during EXT were removed and mixed schedule stimuli were introduced on the left (observing) key. The first component was chosen randomly ($p = .5$), and alternated for the remainder of each session. Each component was in effect for 5 min, and was separated by a 30-s ICI. Rich components consisted of periods of a VI 30- s schedule of reinforcement alternating with EXT on the center key. Lean components consisted of periods of a VI 120-s schedule of

reinforcement alternating with EXT on the center key. Components alternated after variable times averaging 60 s (ranging from 11 to 10 s in 10-s increments).

Nondifferential mixed schedule stimuli were presented on the center (food) key and left (observing) key regardless of whether VI or EXT was in effect on the food key (Figure 1).

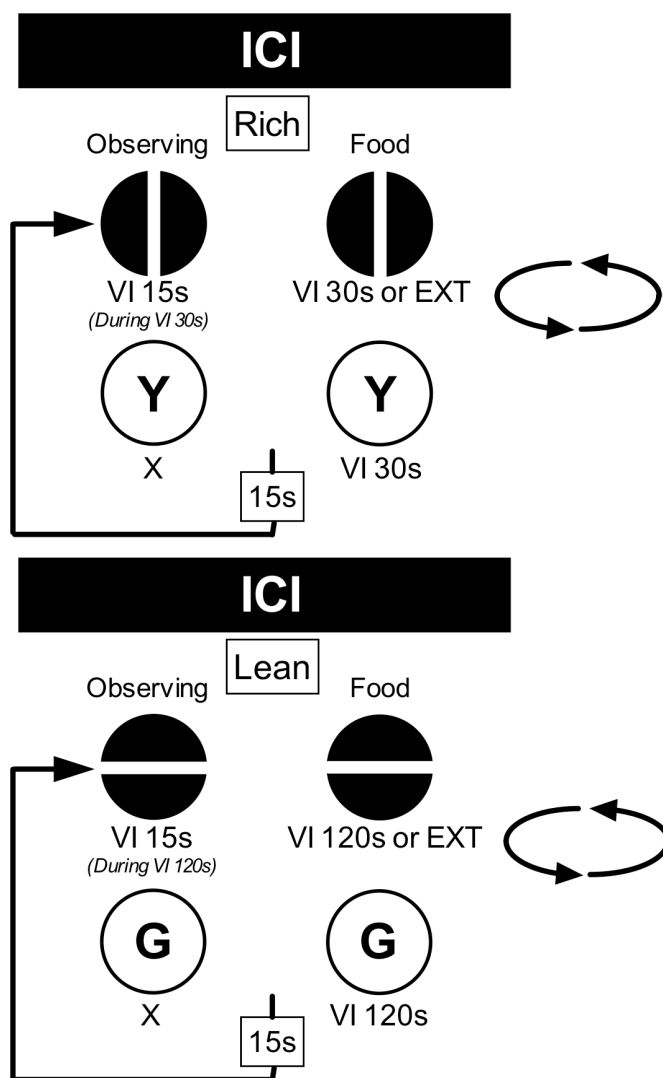


Figure 1. Diagram of the multiple schedule of observing-response procedures.

Mixed-schedule stimuli were a white vertical line on a black background during Rich, and a white horizontal line on a black background during Lean for pigeons 658 and 54. Mixed-schedule stimuli were reversed for pigeons 218 and 1877. Rich and Lean multiple-schedule stimuli (S+) remained the same as in pretraining for all pigeons (Table 1). The right key was dark and inoperative throughout all experimental procedures. Observing-responses produced S+ only when the VI component was in effect on the food-key and when a VI 15 s schedule on the observing-key had elapsed. The VI timer for the observing-key did not operate during EXT periods on the food-key and stimuli associated with EXT in prior training were not presented (Dinsmoor, Browne, & Lawrence, 1972; Dinsmoor, Mulvaney, & Jwaideh, 1981; Shahan, Podlesnik, & Jimenez-Gomez, 2006). A changeover delay prevented responses on the food-key from producing reinforcement within 3 s of a response to the observing-key. Additional observing responses during S+ were recorded but had no programmed consequences. This condition remained in effect for 100 sessions. Additionally, observing response rates and food-key response rates in the Rich and Lean components were stable as judged visually across at least five sessions.

Table 1

Mixed and S+ Stimuli for Each Pigeon

Pigeon	Component stimuli			
	Mixed		S+	
	Rich	Lean	Rich	Lean
218	horizontal line	vertical line	green	yellow
658	vertical line	horizontal line	yellow	green
1877	horizontal line	vertical line	green	yellow
54	vertical line	horizontal line	yellow	green

Extinction

Following stability, responding to both the food-key and observing-key was extinguished by cancelling all scheduled consequences for responses to the observing and food keys. Mixed-schedule stimuli for each component continued to be presented during each session. Extinction continued until response rates for each pigeon reached 10% of baseline or below for at least one session.

Reinstatement Tests

Pigeons 658, and 54 experienced S+ reinstatement prior to food reinstatement, and pigeons 218 and 1877 experienced food reinstatement prior to S+ reinstatement. Pigeons 218, and 54 began reinstatement in the Rich component, and pigeons 658, and 1877 began reinstatement in the Lean component. Following the first reinstatement test, pigeons received four additional days of extinction before being tested for reinstatement with the stimuli (food or S+) not received in the first reinstatement test. The first component was reversed for the first session in the second reinstatement test and alternated for each session thereafter.

Food Reinstatement

Food reinstatement tests were conducted across four consecutive sessions. Food reinstatement consisted of response-independent 2 s hopper presentations. Hopper presentations occurred every 75 s, on average (VT 75 s). The schedule of hopper presentations was chosen to be the average scheduled rate of primary reinforcement during VI periods across components in baseline. Hopper presentations occurred

independent of schedule component in effect. The first component in the first day of reinstatement was counterbalanced across pigeons. The first component alternated for the remaining food reinstatement sessions.

S+ Reinstatement

S+ reinstatement tests were conducted across four consecutive sessions. S+ reinstatement consisted of response-independent presentations of 15 s periods of S+ occurring every 30 s, on average (VT 30 s). The schedule of S+ deliveries was chosen to be the average scheduled rate of S+ periods across components during baseline. S+ periods were presented independent of schedule component in effect. The first component in the first day of reinstatement was counterbalanced across pigeons. The first component alternated for the remaining S+ reinstatement sessions.

RESULTS

Baseline Response Rates

Figure 2 shows average response rates on the observing-key, the food-key during S+, and the food-key during the mixed schedule for baseline in the Rich and Lean components. Average response rates are from the last 10 days of baseline for all pigeons. Observing-response rates were higher in the Rich component than in the Lean component in baseline for three of the four pigeons. Food-key response rates during S+ presentations were slightly higher in the Lean component for pigeons 218, 658, and 1877, but were higher in the Rich component for pigeon 54. Food-key response rates in the presence of mixed-schedule stimuli were higher in the Rich component for all pigeons.

Figure 3 shows obtained rate of food delivery overall, during S+ periods, and during mixed-schedule stimuli, as well as obtained S+ delivery rates in baseline. Overall food rates approached 1 per minute in the Rich component and .25 per minute in the Lean component. Obtained food rates in S+ approached 2 per minute in the Rich component and .5 per minute in the Lean component for all pigeons. Obtained food rates approximate their programmed values of 0.5 and .25 foods per minute during the mixed schedule for Rich and Lean, respectively. Earned S+ rates were higher in the Rich component for pigeon 218, but only slightly higher during the Rich component than during the Lean component for pigeons 658, 54, and 1877.

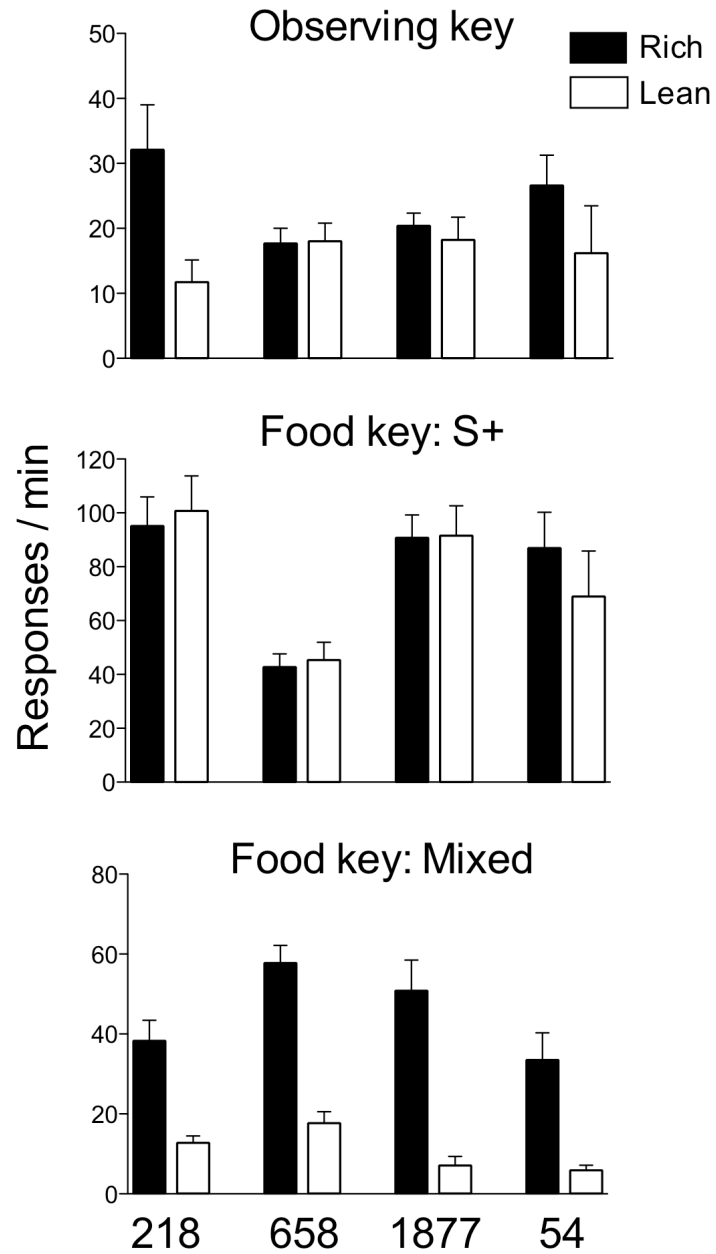


Figure 2. Baseline response rates. Mean responses per minute for observing, food-key during S+, and food-key during mixed. Means are calculated over the last 10 sessions of baseline prior to extinction for all pigeons (+/- 1 SD).

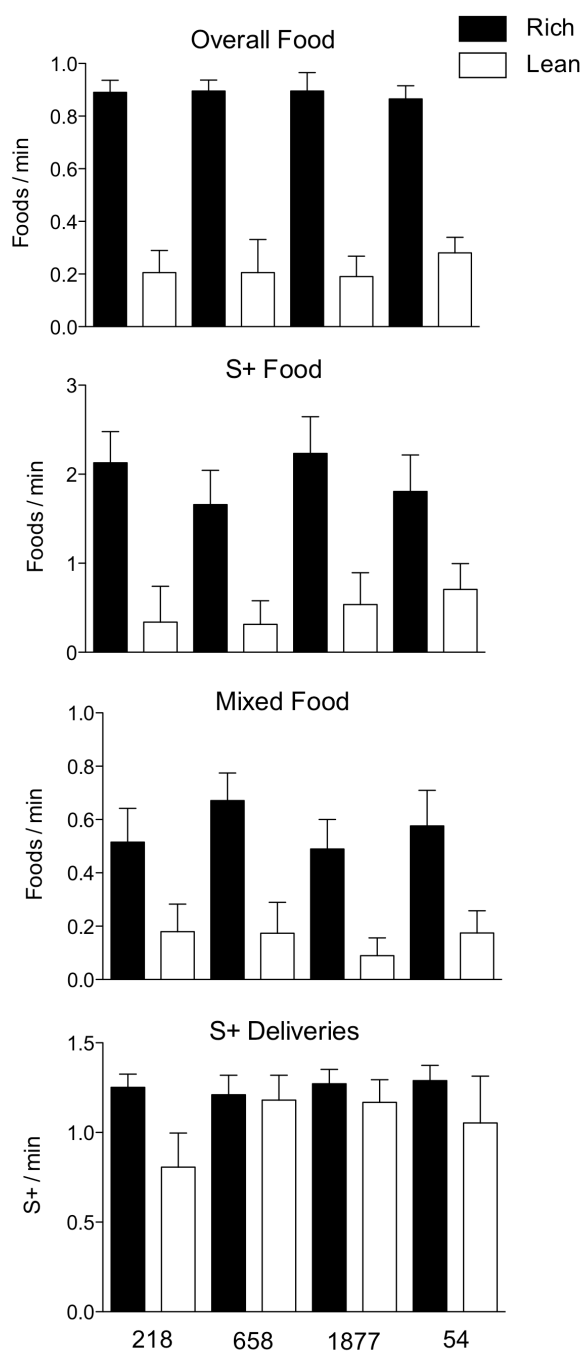


Figure 3. Baseline reinforcer rates. Mean reinforcers per minute for food-key responding for overall, during S+, and during mixed schedule stimuli in Rich and Lean. The bottom panel is mean S+ rates for responses on the observing key. Means are calculated over the last 10 sessions prior to extinction (+/- 1 SD).

Extinction

Absolute response rates and response rates as a proportion of baseline for individual EXT sessions are presented in Table 2. Figure 4 shows food-key response rates during EXT as a proportion of preextinction baseline response rates for Rich and Lean. With the exception of pigeon 1877, food-key response rates decreased more relative to baseline in the Lean component over sessions of extinction. In the last day of the EXT condition, food-key response rates for pigeons 1877 and 218 were above zero per min, and food-key response rates for pigeons 54 and 658 were at, or very close to, zero per min. Figure 5 shows observing-response rates during EXT as a proportion of preextinction baseline response rates for Rich and Lean components over sessions of EXT. With the exception of pigeon 54, who showed no difference, observing-response rates decreased more relative to baseline in the Lean component over the EXT condition. Proportion of baseline response rates for all pigeons in the Rich component showed an increase above 1.0 on the first day of extinction, and with the exception of pigeon 658, showed a decrease below 1.0 on the subsequent day. All pigeons reached the extinction criteria of at, or below 10% of baseline observing-response rates for at least one day before being moved to the reinstatement condition. Pigeons 54, 1877, and 658 fulfilled the extinction criteria after 12 days, and pigeon 218 fulfilled the criteria after 14 days of extinction.

Table 2

Conditions, Sessions, Response Rates, and Proportion of Baseline Across Subjects

Subject	Condition	Sessions	1st Comp	Response rate						Proportion of baseline						
				Rich			Lean			Rich			Lean			
				Obs	S+	Mixed	Obs	S+	Mixed	Obs	S+	Mixed	Obs	S+	Mixed	
218	BL	100		32.10	95.13	38.28	11.49	96.88	12.85	-	-	-	-	-	-	
				<i>6.31</i>	<i>10.85</i>	<i>5.10</i>	<i>3.15</i>	<i>14.37</i>	<i>1.77</i>	-	-	-	-	-	-	
	EXT	1		35.01	-	21.36	9.70	-	14.45	1.09	-	0.56	0.84	-	1.12	
	EXT	1		18.86	-	25.41	3.75	-	10.95	0.59	-	0.66	0.33	-	0.85	
	EXT	1		12.30	-	27.96	4.55	-	9.00	0.38	-	0.73	0.40	-	0.70	
	EXT	1		17.21	-	19.46	1.05	-	3.20	0.54	-	0.51	0.09	-	0.25	
	EXT	1		14.20	-	15.15	2.50	-	2.10	0.44	-	0.40	0.22	-	0.16	
	EXT	1		14.10	-	12.30	1.45	-	2.15	0.44	-	0.32	0.13	-	0.17	
	EXT	1		10.40	-	13.50	0.95	-	1.35	0.32	-	0.35	0.08	-	0.11	
	EXT	1		9.20	-	14.85	1.75	-	1.45	0.29	-	0.39	0.15	-	0.11	
	EXT	1		3.10	-	14.05	0.85	-	1.05	0.10	-	0.37	0.07	-	0.08	
	EXT	1		2.95	-	11.45	0.05	-	0.50	0.09	-	0.30	0.00	-	0.04	
	EXT	1		4.95	-	15.45	0.95	-	1.10	0.15	-	0.40	0.08	-	0.09	
	EXT	1		8.10	-	22.16	0.85	-	3.00	0.25	-	0.58	0.07	-	0.23	
	EXT	1		5.25	-	19.86	0.45	-	1.25	0.16	-	0.52	0.04	-	0.10	
	EXT	1		0.60	-	12.50	0.10	-	0.60	0.02	-	0.33	0.01	-	0.05	
	F	1	R		7.65	-	23.06	3.20	-	7.45	0.24	-	0.53	0.28	-	0.58
	F	1	L		4.85	-	47.84	2.10	-	16.05	0.15	-	1.20	0.18	-	1.25
	F	1	R		1.35	-	47.99	0.45	-	11.05	0.04	-	1.30	0.04	-	0.86
	F	1	L		0.35	-	51.67	0.00	-	12.00	0.01	-	1.38	0.00	-	0.93
	EXT	1			2.40	-	52.51	0.70	-	15.05	0.07	-	1.43	0.06	-	1.17
	EXT	1			1.75	-	33.30	0.45	-	5.75	0.05	-	0.93	0.04	-	0.45
	EXT	1			0.80	-	28.71	2.85	-	7.25	0.02	-	0.81	0.25	-	0.56
	EXT	1			0.65	-	15.00	0.05	-	2.75	0.02	-	0.44	0.00	-	0.21
	S+	1	L		0.20	61.63	69.60	0.45	50.81	7.10	0.01	0.65	1.02	0.04	0.52	0.55
	S+	1	R		3.95	56.00	64.77	0.55	32.39	4.00	0.12	0.59	1.05	0.05	0.33	0.31
S+	1	L		3.50	47.23	47.62	0.65	25.17	0.64	0.11	0.50	0.71	0.06	0.26	0.05	
S+	1	R		6.70	24.92	33.46	1.45	2.96	1.43	0.21	0.26	0.54	0.13	0.03	0.11	
658	BL	100		17.93	41.97	57.34	17.64	46.94	17.40	-	-	-	-	-	-	
				<i>2.25</i>	<i>4.70</i>	<i>4.20</i>	<i>2.79</i>	<i>6.35</i>	<i>2.77</i>	-	-	-	-	-	-	
	EXT	1		29.36	-	48.41	20.61	-	14.70	1.64	-	0.84	1.17	-	0.84	
	EXT	1		26.06	-	57.97	15.40	-	11.05	1.45	-	1.01	0.87	-	0.64	
	EXT	1		32.56	-	48.71	12.45	-	4.65	1.82	-	0.85	0.71	-	0.27	
EXT	1		20.86	-	47.76	4.85	-	3.35	1.16	-	0.83	0.28	-	0.19		

(table continues)

Subject	Condition	Sessions	1st Comp	Response rate						Proportion of baseline					
				Rich			Lean			Rich			Lean		
				Obs	S ⁺	Mixed	Obs	S ⁺	Mixed	Obs	S ⁺	Mixed	Obs	S ⁺	Mixed
	EXT	1		15.00	-	32.16	5.45	-	3.70	0.84	-	0.56	0.31	-	0.21
	EXT	1		7.45	-	19.11	0.80	-	0.20	0.42	-	0.33	0.05	-	0.01
	EXT	1		3.35	-	6.85	0.85	-	0.35	0.19	-	0.12	0.05	-	0.02
	EXT	1		6.05	-	6.90	1.15	-	0.10	0.34	-	0.12	0.07	-	0.01
	EXT	1		2.65	-	8.00	1.05	-	0.10	0.15	-	0.14	0.06	-	0.01
	EXT	1		1.80	-	0.30	0.30	-	0.00	0.10	-	0.01	0.02	-	0.00
	EXT	1		0.55	-	0.00	0.10	-	0.00	0.03	-	0.00	0.01	-	0.00
	EXT	1		1.05	-	0.85	1.05	-	0.10	0.06	-	0.01	0.06	-	0.01
	S+	1	L	2.34	30.67	35.71	0.15	25.69	2.52	0.13	0.73	0.62	0.01	0.55	0.14
	S+	1	R	3.70	8.89	4.83	0.00	0.00	0.00	0.21	0.21	0.08	0.00	0.00	0.00
	S ⁺	1	L	0.76	18.07	20.92	0.51	1.92	0.29	0.04	0.43	0.36	0.03	0.04	0.02
	S+	1	R	0.16	5.38	2.67	0.44	1.85	0.00	0.01	0.13	0.05	0.03	0.04	0.00
	EXT	1		0.25	-	0.00	0.00	-	0.00	0.01	-	0.00	0.00	-	0.00
	EXT	1		0.00	-	0.10	0.05	-	0.00	0.00	-	0.00	0.00	-	0.00
	EXT	1		0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00
	EXT	1		0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00
	F	1	R	0.00	-	7.10	0.05	-	1.05	0.00	-	0.12	0.00	-	0.06
	F	1	L	0.10	-	7.75	0.00	-	0.00	0.01	-	0.14	0.00	-	0.00
	F	1	R	0.00	-	6.50	0.05	-	2.40	0.00	-	0.11	0.00	-	0.14
	F	1	L	0.00	-	2.90	0.00	-	0.20	0.00	-	0.05	0.00	-	0.01
1877	BL	100		20.87	91.27	49.50	18.10	93.75	6.53	-	-	-	-	-	-
				1.89	8.34	7.65	3.36	10.78	2.51	-	-	-	-	-	-
	EXT	1		24.21	-	21.91	11.95	-	9.15	1.16	-	0.44	0.66	-	1.40
	EXT	1		12.80	-	17.71	4.45	-	7.10	0.61	-	0.36	0.25	-	1.09
	EXT	1		10.05	-	18.01	4.00	-	4.10	0.48	-	0.36	0.22	-	0.63
	EXT	1		6.45	-	16.86	3.90	-	3.65	0.31	-	0.34	0.22	-	0.56
	EXT	1		2.45	-	10.25	0.90	-	2.00	0.12	-	0.21	0.05	-	0.31
	EXT	1		1.30	-	6.90	1.00	-	1.75	0.06	-	0.14	0.06	-	0.27
	EXT	1		3.75	-	8.60	2.05	-	2.20	0.18	-	0.17	0.11	-	0.34
	EXT	1		2.55	-	9.85	2.05	-	0.95	0.12	-	0.20	0.11	-	0.15
	EXT	1		2.90	-	3.75	1.10	-	0.70	0.14	-	0.08	0.06	-	0.11
	EXT	1		7.65	-	6.75	0.50	-	0.25	0.37	-	0.14	0.03	-	0.04
	EXT	1		4.70	-	13.85	3.90	-	5.45	0.23	-	0.28	0.22	-	0.83
	EXT	1		0.70	-	3.35	1.35	-	1.10	0.03	-	0.07	0.07	-	0.17
	F	1	L	1.25	-	34.41	0.30	-	10.35	0.06	-	0.70	0.02	-	1.58
	F	1	R	2.35	-	38.91	0.35	-	16.00	0.11	-	0.79	0.02	-	2.45
	F	1	L	1.55	-	39.26	0.50	-	5.55	0.07	-	0.79	0.03	-	0.85
	F	1	R	1.95	-	46.16	0.25	-	10.80	0.09	-	0.93	0.01	-	1.65
	EXT	1		2.05	-	36.61	3.10	-	10.60	0.10	-	0.74	0.17	-	1.62
	EXT	1		2.30	-	32.31	0.55	-	3.55	0.11	-	0.65	0.03	-	0.54
	EXT	1		0.20	-	15.40	0.15	-	3.30	0.01	-	0.31	0.01	-	0.51
	EXT	1		0.30	-	5.30	0.80	-	1.30	0.01	-	0.11	0.04	-	0.20

(table continues)

Subject	Condition	Sessions	1st Comp	Response rate						Proportion of baseline					
				Rich			Lean			Rich			Lean		
				Obs	S+	Mixed	Obs	S+	Mixed	Obs	S+	Mixed	Obs	S+	Mixed
	S+	1	R	2.62	58.40	63.81	0.55	41.79	2.35	0.13	0.64	1.29	0.03	0.45	0.36
	S+	1	L	0.53	40.15	41.08	0.07	23.85	0.52	0.03	0.44	0.83	0.00	0.25	0.08
	S+	1	R	0.53	36.15	28.62	0.00	14.77	0.15	0.03	0.40	0.58	0.00	0.16	0.02
	S+	1	L	0.15	8.44	7.17	0.00	6.62	0.37	0.01	0.09	0.14	0.00	0.07	0.06
54	BL	100		25.40	81.66	32.73	15.75	62.41	5.70	-	-	-	-	-	-
				<i>4.78</i>	<i>14.17</i>	<i>6.57</i>	<i>7.14</i>	<i>19.74</i>	<i>1.54</i>	-	-	-	-	-	-
	EXT	1		16.15	-	18.51	15.90	-	4.90	0.64	-	0.57	1.01	-	0.86
	EXT	1		17.51	-	26.91	9.80	-	3.60	0.69	-	0.82	0.62	-	0.63
	EXT	1		8.90	-	21.11	4.45	-	1.95	0.35	-	0.64	0.28	-	0.34
	EXT	1		4.75	-	9.00	1.60	-	0.70	0.19	-	0.28	0.10	-	0.12
	EXT	1		10.40	-	18.21	2.60	-	0.65	0.41	-	0.56	0.17	-	0.11
	EXT	1		3.00	-	2.55	3.25	-	0.40	0.12	-	0.08	0.21	-	0.07
	EXT	1		3.70	-	1.85	0.25	-	0.00	0.15	-	0.06	0.02	-	0.00
	EXT	1		3.20	-	2.40	2.80	-	0.05	0.13	-	0.07	0.18	-	0.01
	EXT	1		0.65	-	0.40	1.00	-	0.10	0.03	-	0.01	0.06	-	0.02
	EXT	1		0.05	-	0.00	0.05	-	0.00	0.00	-	0.00	0.00	-	0.00
	EXT	1		0.55	-	0.20	0.00	-	0.00	0.02	-	0.01	0.00	-	0.00
	EXT	1		0.00	-	0.00	0.45	-	0.05	0.00	-	0.00	0.03	-	0.01
	S+	1	R	6.37	17.08	5.48	1.15	7.71	0.00	0.25	0.21	0.17	0.07	0.12	0.00
	S+	1	L	3.36	15.50	4.93	0.45	3.26	0.00	0.13	0.19	0.15	0.03	0.05	0.00
	S+	1	R	5.28	7.07	4.96	1.68	1.04	0.21	0.21	0.09	0.15	0.11	0.02	0.04
	S+	1	L	1.23	0.57	0.23	0.51	0.00	0.00	0.05	0.01	0.01	0.03	0.00	0.00
	EXT	1		0.00	-	0.15	0.75	-	0.00	0.00	-	0.00	0.05	-	0.00
	EXT	1		0.75	-	0.00	0.10	-	0.00	0.03	-	0.00	0.01	-	0.00
	EXT	1		0.15	-	0.05	0.30	-	0.00	0.01	-	0.00	0.02	-	0.00
	EXT	1		0.05	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00
	F	1	L	0.55	-	0.45	1.05	-	0.30	0.02	-	0.01	0.07	-	0.05
	F	1	R	1.50	-	0.45	0.45	-	0.00	0.06	-	0.01	0.03	-	0.00
	F	1	L	0.45	-	0.00	0.00	-	0.10	0.02	-	0.00	0.00	-	0.02
	F	1	R	0.10	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00

Note. Sessions of baseline and average baseline response rates for observing-responses, food-key responses during S+, and food-key responses during mixed schedule stimuli are presented on the left. Baseline averages include the last 10 sessions of baseline prior to extinction for all pigeons. Standard deviations of baseline averages are presented in italics. Responses per minute in each session of extinction and reinstatement are presented. Proportion of baseline for individual sessions of extinction and reinstatement are located on the right. Food (F) and S+ reinstatement tests are presented in the order they occurred.

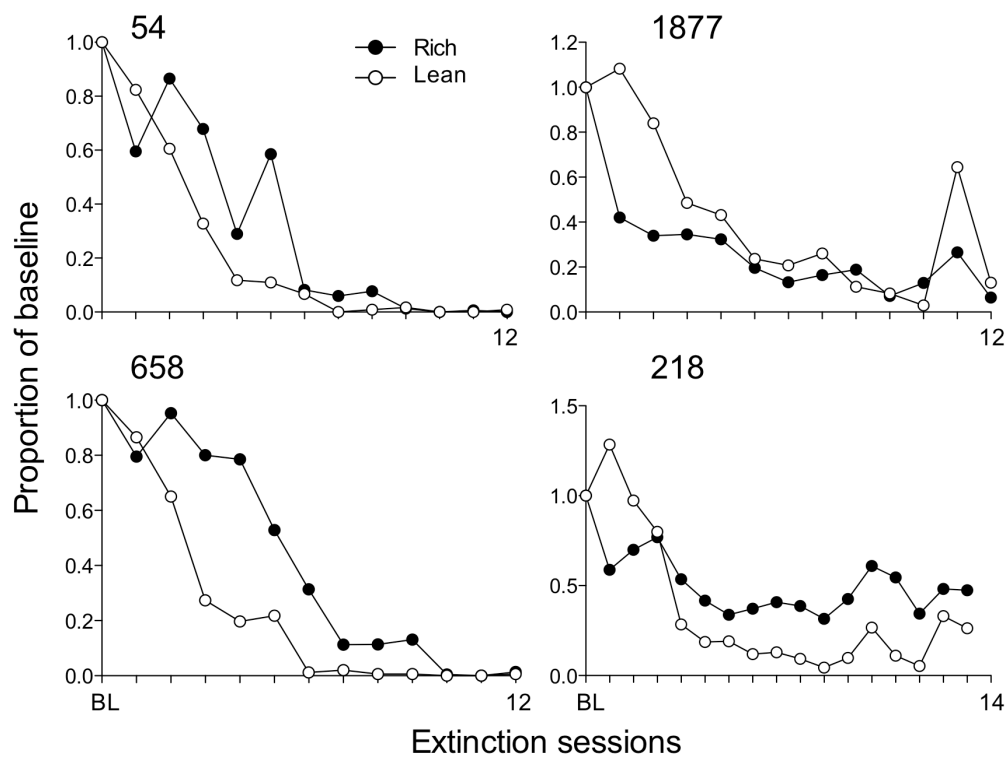


Figure 4. Mixed food-key extinction. Response rates as a proportion of baseline across consecutive sessions of extinction (EXT). Baseline is averaged across the last 10 sessions prior to extinction for all pigeons.

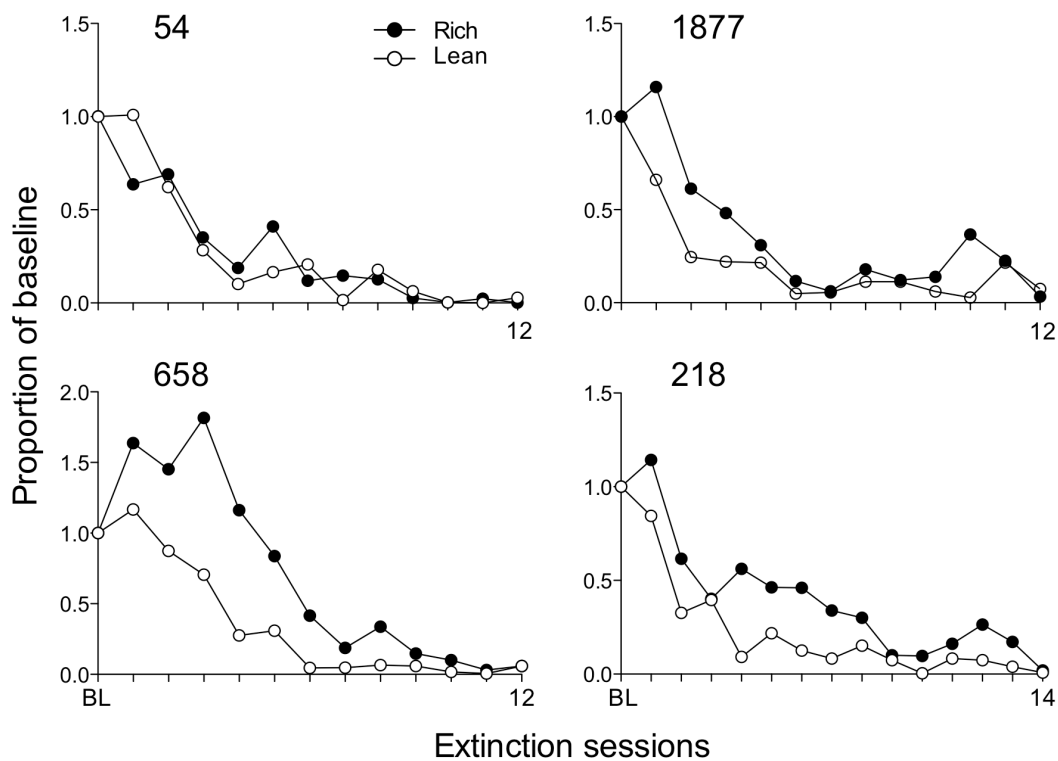


Figure 5. Observing-key extinction. Response rates as a proportion of baseline in Rich and Lean across consecutive sessions of extinction (EXT). Baseline is averaged across the last 10 sessions prior to extinction for all pigeons.

Reinstatement

Figure 6 shows food-key response rates for the last day of extinction followed by four days of reinstatement by introducing a VT 75 s schedule of food delivery as a proportion of baseline in the Rich and Lean components. Pigeons 54 and 658 were tested for reinstatement with VT 30 s free presentations of 15-s periods S+ before VT food, and showed very little food-key reinstatement by free food deliveries. Pigeons 1877 and 218 were tested for reinstatement by free food presentations first, and show nondifferential increases in food-key response rates. Pigeon 1877 responded on the food-key at a high rate in Lean in the first two days of food reinstatement. Food-key response rates in Rich from pigeons 1877 and 218 increased over the four days of food reinstatement, whereas Lean component response rates were more variable. It is possible that the order of reinstatement testing (Food then S+, versus S+ then food) was responsible for the low proportion of baseline response rates for pigeons 54 and 658. However, pigeons 218 and 1877 both responded at a higher rate, in general, and over the last three days of the EXT condition than pigeons 54 and 658.

Figure 7 presents observing-key response rates as a proportion of baseline in Rich and Lean components for the last day of extinction followed by four days of VT 75 s food reinstatement. Overall, proportion of baseline observing-response rates during reinstatement were low in both components, less than 0.4. Pigeon 658 recovered the highest proportion of baseline observing rates in both components with Lean observing rates showing greater reinstatement by free food presentations. Proportion of baseline

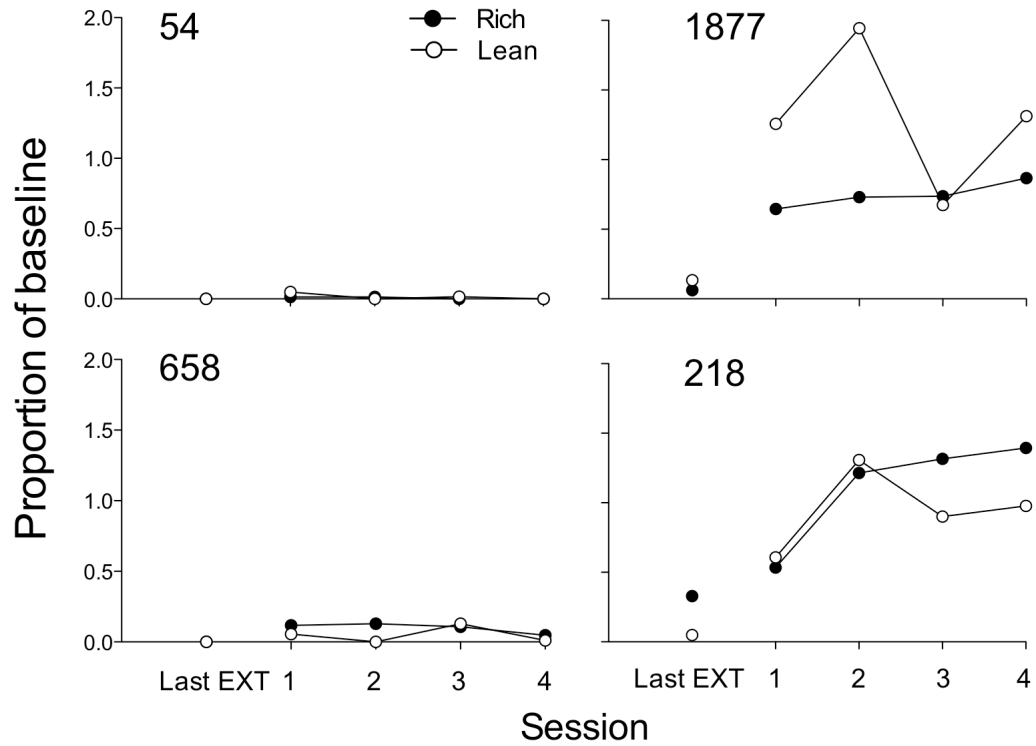


Figure 6. Food-key food reinstatement. Response rate on the food-key as a proportion of baseline in Rich and Lean components in the last day of extinction (EXT) and across four consecutive days of reinstatement by response-independent food deliveries. S+ reinstatement condition preceded food reinstatement on the left (pigeons 54 and 658), and food reinstatement occurred first on the right (pigeons 1877 and 218).

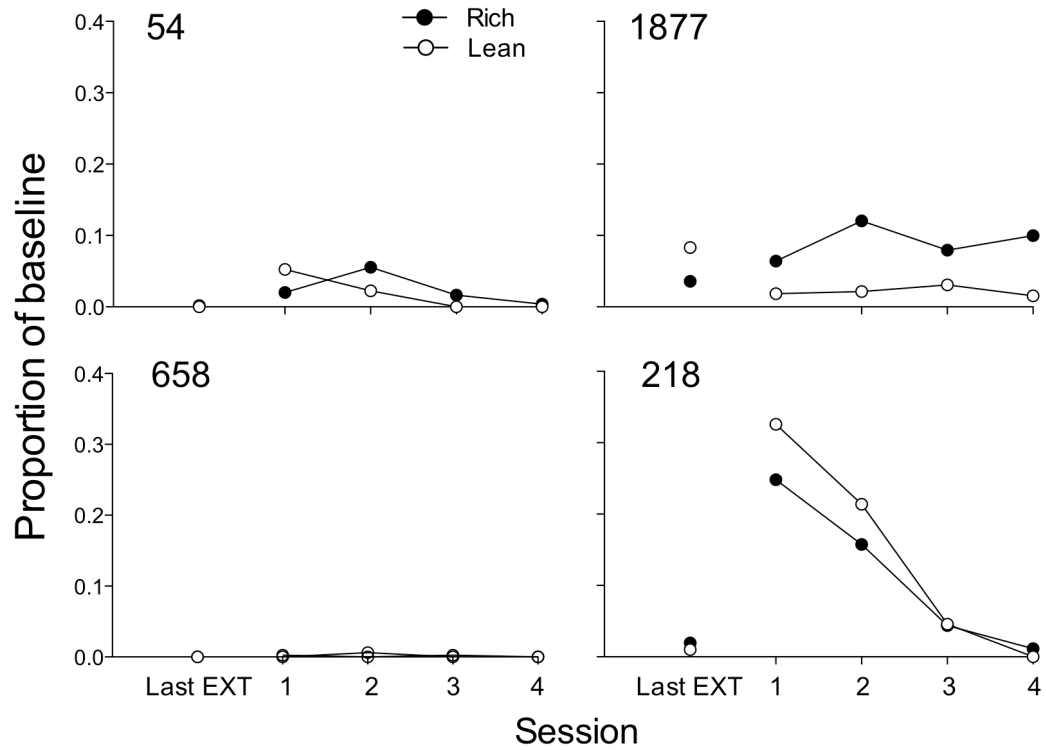


Figure 7. Observing-key food reinstatement. Response rates as a proportion of baseline in Rich and Lean components in the last day of extinction (EXT) and across four consecutive days of reinstatement by response-independent food presentations. S+ reinstatement condition preceded food reinstatement for pigeons in the left column (54 and 658), and Food reinstatement occurred first for pigeons in the right column (1877 and 218).

response rates on the observing and food-key showed no systematic reinstatement by free food presentation in Rich or Lean components.

The left column of Figure 8 shows food key response rates as a proportion of baseline in Mixed for Rich and Lean components for the last extinction session and four days of VT 30 s S+ reinstatement. Proportion of baseline food key response rates increased for all pigeons relative to the last day of extinction in both components. Response rates were highest in the first day of S+ reinstatement, and decreased thereafter. Rich component response rates increased to a greater degree than Lean for all pigeons.

The right column of Figure 8 presents food-key response rates as a proportion of baseline during S+ in Rich and Lean components for the last extinction sessions and four days of VT 30 s S+ reinstatement. For all pigeons, proportions of baseline food-key response rates in multiple schedule stimuli (S+) were higher in the Rich component during S+ reinstatement. Response rates were highest on the first day of reinstatement and decreased over the subsequent days. Pigeons 658, 1877, and 218 responded above 50% of baseline in Rich and Lean on the first day of reinstatement, and pigeon 54 responded at 30% and 20% in Rich and Lean, respectively. Reinstatement by VT 30 s presentations of S+ periods produced greater increases in proportion of baseline response rates in the Rich component.

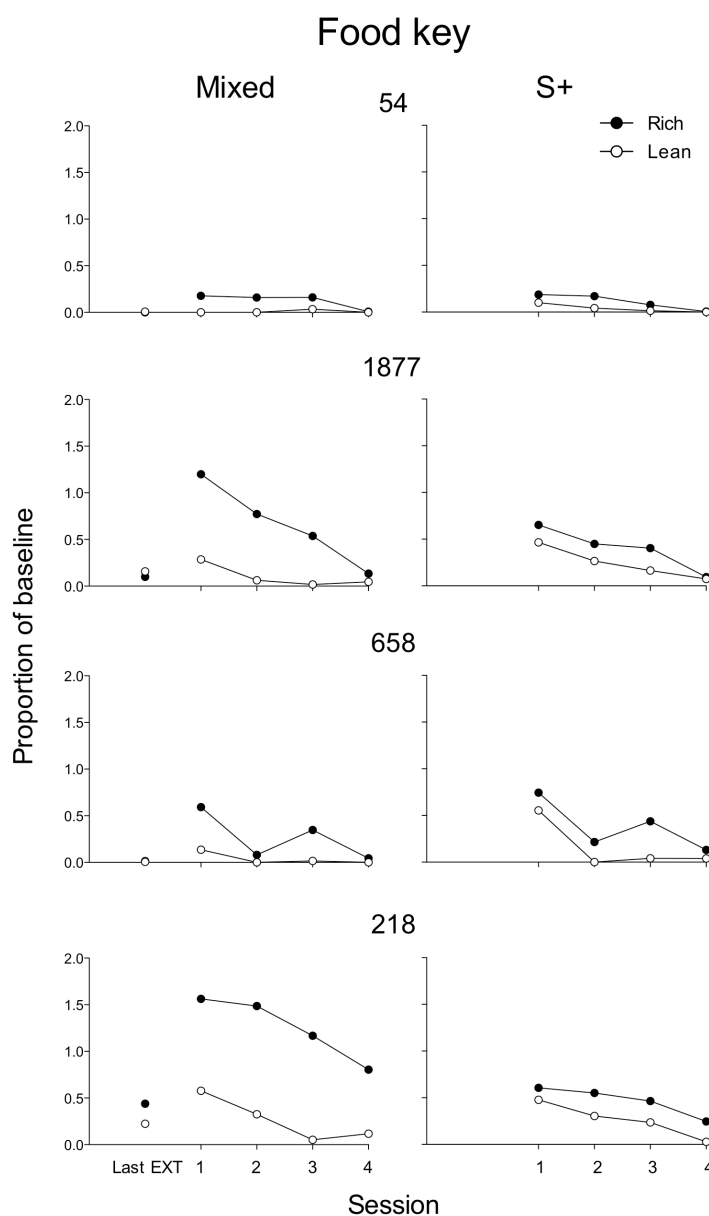


Figure 8. Food key S+ reinstatement during mixed schedule stimuli (left column) and S+ periods (right column). Food-key response rates in the presence of mixed-schedule stimuli (MIX) as a proportion of baseline in Rich and Lean components in the last day of extinction (EXT) and across four consecutive days of reinstatement by response-independent presentations of S+ (left column), and food-key response rates during S+ periods (S+) as a proportion of baseline in Rich and Lean components across four consecutive days of reinstatement by response-independent presentations of S+ (right column). S+ reinstatement condition preceded food reinstatement for pigeons 54 and 658, and food reinstatement preceded S+ reinstatement for pigeons 1877 and 218.

Figure 9 shows observing response rates as a proportion of preextinction baseline for Rich and Lean components in the last day of extinction and four subsequent days of VT 30 s S+ reinstatement. Observing-response rates increased less than food-key response rates. However, for all pigeons, observing-response rates increased to around 30% of baseline in the Rich component. For pigeons 54, 658, and 1877, proportion of baseline observing-response rates increased more in Rich relative to the last day of extinction on the first day of reinstatement and decreased thereafter. For pigeon 218, observing-response rates increased over the four days of S+ reinstatement in Rich and Lean components. Observing-response rates increased to a lesser extent in Lean over the four days of S+ reinstatement for all pigeons. Overall, free S+ presentations increased observing-response rates more in the Rich component than the Lean component.

Absolute response rates and proportion of baseline for individual extinction sessions, food reinstatement sessions and S+ reinstatement sessions for food- and observing-key responses during mixed- and multiple-schedule stimuli are presented in Table 2. Baseline observing-response rates were higher in the Rich component for pigeons 218, 1877, and 54. Pigeon 658 had slightly higher observing-response rates in the Lean component during baseline. Baseline food-key response rates were higher during S+ periods for all pigeons, except 658, who responded more on the food-key during mixed-schedule stimuli in the Rich component. In food reinstatement, pigeons 218 and 1877 showed increases in absolute observing- and food-key response rates compared to the last day of extinction. This increase in absolute response rate was smaller in the pigeons (658 and 54) that experienced S+ reinstatement prior to food reinstatement.

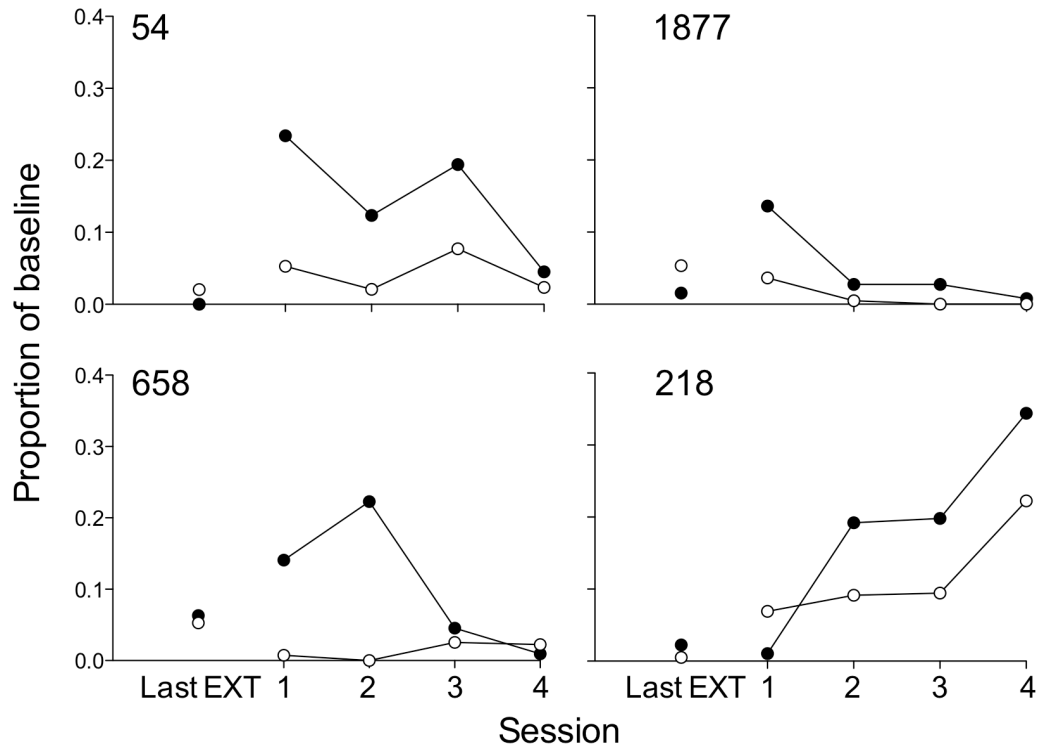


Figure 9. Observing-key S+ reinstatement. Response rates as a proportion of baseline in Rich and Lean components in the last day of extinction (EXT) and across four consecutive days of reinstatement by response-independent S+ presentations. S+ reinstatement condition preceded food reinstatement on the left (pigeons 54 and 658), and Food reinstatement occurred first on the right (pigeons 1877 and 218).

DISCUSSION

The present results replicate previous findings and extend the observing response procedure to an animal model of relapse. As expected, responding on the observing key was more resistant to extinction in the component associated with a higher primary reinforcement rate (Shahan et al., 2003). Food-key responding was also more resistant to extinction in the component associated with higher primary reinforcement rate for three of the four pigeons. Following extinction, reinstatement tests produced different results for deliveries of food and S+ periods. In the food reinstatement phase, response-independent food deliveries did not have a systematic effect on food key or observing response rates relative to the last day of extinction. However, in the S+ reinstatement phase, food key and observing response rates increased when S+ stimuli were presented response-independently. Consistent with previous results, both food- and observing-key responding increased relatively more in the component arranging a higher baseline rate of primary reinforcement (Podlesnik & Shahan, 2009). Interestingly, food-key responding increased to a higher rate relative to baseline than observing-key responding during the S+ reinstatement condition. These effects of baseline reinforcement rates on resistance to extinction and relapse replicate results obtained with simple operant responding (Podlesnik & Shahan, 2009, 2010), and extend an established animal model of relapse to responding maintained by the production of cues associated with differential reinforcement (Shahan et al., 2003).

Reinstatement by response-independent presentations of S+ periods resulted in increases in observing- and food-key responding. This result is consistent with several

experiments that have demonstrated cue-induced reinstatement of extinguished drug-seeking behavior in rats (Alleweireldt et al., 2001; Ball et al., 2007; Hollander & Carelli, 2007; Weiss et al., 1999). The present results show that extinguished cue-maintained behavior increased following the presentation of cues associated with reinforcement. As an animal model of attending to cues associated with differential reinforcement, the present results suggest that attending to cues and behavior maintained by primary reinforcement are susceptible to the same relapse conditions. The present findings, and those of Podlesnik and Shahan (2009, 2010), show that relatively better stimulus-reinforcer relations in baseline increase the persistence of behavior and the magnitude of relapse relative to baseline response rates.

During the S+ reinstatement condition, increases in food- and observing-key responding were relatively greater in the Rich component. Overall, food-key responding increased more than observing. Responding maintained by the production of S+ (observing) may have been “weaker” than responding maintained by the production of the primary reinforcer (Shahan & Podlesnik, 2008b). If observing is weaker than responding maintained by primary reinforcement, then it would be expected that observing would relapse to a lesser extent relative to food-key responding in both reinstatement conditions. However, there was not a consistent effect on either response in the food reinstatement condition. A possible explanation for the different findings across reinstatement conditions can be found by examining procedural details.

During baseline, observing-responses produced S+ only when a period of VI reinforcement was operating on the food-key (VI component of the mixed-schedule).

During extinction, responding on the food-key had no consequence, and observing did not change mixed-schedule stimuli to signal VI periods. Disruption of food-directed and stimulus-directed responding was accomplished in extinction by removing primary reinforcement and S+ presentations, and not by devaluing the consequence (i.e., satiation of the primary reinforcer or pairing the stimulus with non-reinforcement). According to behavioral momentum theory, disruption during extinction is the result of terminating the contingency between response and reinforcer, and generalization decrement resulting from the absence of reinforcement (Nevin, McLean, & Grace, 2001). In addition to terminating the response-reinforcer contingency, the response-stimulus contingency for observing was also terminated. Thus, food-key responding was not extinguished in the presence of S+ stimuli. By comparing the results from the two reinstatement conditions, the greater increase in food-key responding in the S+ reinstatement condition suggests that S+ functioned as a better predictor of food reinforcement for food-key responding than food itself. During baseline, food deliveries in the absence of S+ occurred rarely, and thus may not have been as predictive of further primary reinforcement as S+.

The observing-response procedure may be considered analogous to chained schedules of reinforcement where responding in the presence of the initial-link stimulus is maintained by the transition to a terminal-link stimulus indicative of primary reinforcement. Previous experiments examining behavioral momentum in chained schedules found resistance to change of responding in the terminal-link to be greater than in the initial-link (Nevin, Mandell, & Yarensky, 1981). The observing-response in the present experiment may be thought of as an initial-link in which responding produces the

terminal-link stimulus, S+. Previous studies have shown responding to persist longer in extinction when S+ is presented than in extinction in the absence of S+ (Shahan, 2003; Shahan & Jimenez-Gomez, 2006). In the present study, extinction consisted of removing food and S+ periods for food-key and observing-key responding, respectively. Thus, the predictive relation between S+ stimuli and the availability of primary reinforcement was not explicitly extinguished. The large increase in food-key responding during S+ reinstatement may be due to the predictive relationship between S+ stimuli and the availability of primary reinforcement for responding on the food key.

The failure to obtain systematic relapse of either response in the response-independent food reinstatement condition may have resulted from the inability of noncontingent food deliveries to reestablish the instrumental relationship between food-key responding and food delivery. It remains to be seen whether observing- and food-key responding would relapse to a greater extent if reinstatement were conducted with response-dependent food deliveries (Podlesnik & Shahan, 2009). However, the present study represents a first report of relapse of responding maintained by the production of conditioned reinforcement (i.e., observing/attending), as well as differential cue-induced reinstatement of responding maintained by primary and conditioned reinforcement. It should be noted that, with respect to the traditional concept of conditioned reinforcement, the present study was not designed to evaluate whether or not S+ functions to reinforce (i.e., strengthen) observing responses. While not relevant in the discussion surrounding recent challenges to the traditional concept of conditioned reinforcement (see Shahan,

2010), the present study examined effects of primary reinforcement context on relapse in an established animal model of attending to reinforcement cues (Dinsmoor, 1985).

The present study is limited by the design of the reinstatement testing conditions. Different reinstatement results may have been obtained if reinstatement conditions were conducted with a return to baseline and replication of extinction conducted between conditions. However, the aim of the present study was to extend the observing-response procedure to a previously reported reinstatement procedure that included additional days of extinction between reinstatement tests (Podlesnik & Shahan, 2009). Additionally, several other reports of cue-induced reinstatement have used a similar testing arrangement (Gracy et al., 2000; Liu, Caggiula, Palmatier, Donny, & Sved, 2008; Rescorla & Heth, 1975; Weiss et al., 1999). Given the traditional methods of reinstatement testing, future studies may benefit from a replication of baseline and extinction conditions before each test of reinstatement or between-groups designs to minimize potential carryover effects.

Small sample size may have also contributed to the present results. It is difficult to have confidence in broad conclusions and generalizability from a sample of only four pigeons. However, the design of the experiment resulted in stable performance and minimal intersubject variability. As a demonstration of relapse in an animal model of attending to reinforcement cues, the present study replicated earlier extinction results with the observing-response procedure and extended the procedure to an established animal model of relapse. Despite limited sample size, S+ presentations resulted in clear increases in extinguished observing-response rates for all pigeons.

Future Directions

Relapse of Attending to Cues

The present results provide evidence that behavior maintained by the production of reinforcement cues (i.e., cue-seeking) is susceptible to relapse. Additionally, cue-induced reinstatement of responding maintained by primary and conditioned reinforcement depended on the baseline rate of primary reinforcement in the stimulus context (i.e., the stimulus-reinforcer relation). Based on the present results and previous work examining relations between behavioral momentum and relapse, future research can apply the observing-response procedure to other animal models of relapse. Additionally, the present experimental approach could be extended to existing animal models of attending to drug-associated stimuli (Shahan, 2002; Shahan & Jimenez-Gomez, 2006). Thus, there is potential to develop a more complete picture of environmental factors influencing relapse of attending in the observing-response procedure, and assess the applicability of the present approach to animal models of drug taking.

Podlesnik and Shahan (2009) assessed relapse of simple operant responding in several procedural relapse analogs that have straightforward applicability to the multiple schedule of observing-response procedures. Aside from reinstatement, context renewal has been the most extensively studied animal model of relapse (Bouton, 2002). Context renewal experimental designs usually consist of three phases. First, a response is trained to produce reinforcement in the presence of one set of contextual stimuli (Context A), then extinction occurs in the presence of a different set of contextual stimuli (Context B).

In the third phase, relapse is typically observed when the organism is returned to Context A, while extinction remains in effect. For example, Podlesnik and Shahan (2009) showed that relative relapse of pigeons' responding for food reinforcement on a multiple schedule was greater in a component arranging a relatively higher overall rate of reinforcement. During baseline, pigeons responded on a two-component multiple schedule of variable-interval food reinforcement in the presence of a steady house light (Context A). One component arranged a better stimulus-reinforcer relation by delivering additional response-independent reinforcement on a variable-time schedule (VI+VT). Following baseline, extinction occurred in the presence of a blinking house light (Context B). In the final condition, the house light was changed back to steady while extinction remained in effect (return to Context A). This approach could be directly applied to the procedure in the present study to examine context renewal of observing. Based on the results of Podlesnik and Shahan (2009), a reasonable prediction would be greater relative relapse of observing- and food-key responding in the component associated with a higher rate of primary reinforcement during baseline.

Context renewal and reinstatement procedures are similar because stimuli present during baseline are re-introduced after extinction. In contrast, a third type of relapse model, resurgence, has been developed to study reinforcement loss as a different potential source of relapse (Epstein & Skinner, 1980; Podlesnik, Jimenez-Gomez, & Shahan, 2006). The typical resurgence procedure consists of removal of reinforcement for a target response while an additional response is introduced and reinforced. Relapse is evidenced by an increase in the target response when the alternative response is also extinguished.

Applying the resurgence paradigm to the multiple schedule of observing-response procedure is complex because there are two responses and two sources of reinforcement. However, several questions could be addressed: Does observing show relapse after an alternative response for food is introduced and food and S+ reinforcement for the original responses is removed? If an alternative observing-response that produces the same S+ is introduced and food key reinforcement remains, does the original observing-response relapse after the alternative observing-response is extinguished? Similarly, does relapse of the original observing-response occur after an alternative observing-response that produces different stimuli associated with food periods is introduced and extinguished? The present results suggest that the relationship between the presence of S+ and the availability of primary reinforcement is an important variable. The resurgence model allows manipulation of the source and type of S+ without changing the conditions of primary reinforcement. Extensions to other relapse models may help identify potential sources of relapse of observing, effects of baseline reinforcement context, and effects of the presence or absence of S+ in extinction. Aside from applying other animal models of relapse to the present procedure, the present procedure can be applied to study relapse in other animal models that employ different species and type of reinforcers.

Typical studies of relapse in animal models employ rats responding for drugs as reinforcers, and drug delivery, drug-associated cues, or stress as operations to induce relapse (Shaham et al., 2003). The present results suggest that extinguished cue-maintained responding is susceptible to these relapse manipulations. Previous studies have shown drug-associated stimuli to maintain responding in the observing-response

procedure (Shahan, 2002). Shahan and Jimenez-Gomez (2006) found that the rate of extinction of rats' observing to produce alcohol cues depended on the rate of alcohol delivery during the cues in baseline. The same approach could be used to investigate relapse of extinguished observing behavior in rats self-administering alcohol and potentially other drugs. Further investigation of resistance to change and relapse of responding maintained by contact with drug-associated cues in rats can potentially allow for study of the neural mechanisms involved, and application of targeted pharmacological interventions that may reduce relapse.

In summary, the present study has straightforward applicability to established animal models of relapse and attending to drug-associated stimuli. Future studies have the potential to further clarify the generality of the present results in relation to the body of research on animal models of relapse. The observing-response procedure has been demonstrated as a useful preparation for studying rats' attending to drug-associated cues. However, it remains to be seen whether rats' attending to drug-associated cues is susceptible to cue-induced relapse. The present results, along with previous studies, provide clear predictions to guide future research with the observing-response procedure as an animal analog of attending to cues.

Attentional Biases and Safety Signals

Attentional biases to threat-related stimuli are common in individuals with anxiety disorders (general anxiety disorder; social anxiety disorder; panic disorder; obsessive-compulsive disorder; post-traumatic stress disorder; Bryant & Harvey, 1995; Koster, Crombez, Verschuere, & De Houwer, 2006; MacLeod & Mathews, 1985; MacLeod et al.,

1986; Mobini & Grant, 2007). The present study found that attending to stimuli associated with reinforcement is susceptible to relapse. Also, the magnitude of relapse of observing was greater in the component arranging a higher rate of primary reinforcement. Further research is necessary in order to demonstrate whether these findings generalize to a model of attending to stimuli associated with avoidance of aversive events. An extension of the present experimental approach to aversive stimuli has translational utility for modeling the effects of reinforcement context on extinction and relapse of attending to stimuli associated with negative reinforcement.

Pigeons have been shown to respond to produce stimuli associated with the absence of a schedule of punishment. In a series of experiments, Dinsmoor, Flint, Smith, and Viemeister (1969) showed that only stimuli associated with the absence of shock (safe signals) maintain observing responses. In their experiments, pigeons could respond on an observing key to produce stimuli associated with alternating periods of VI food reinforcement (food-only) or conjoint VI food and fixed ratio shock (food+shock) for responding on a food key. In three conditions, pigeons' responding on the observing key produced stimuli during food-only, food+shock, or both periods. Results showed observing rates were highest during the food-only condition, lowest during the food+shock condition, and intermediate when producing stimuli associated with both periods. Based on these results, Dinsmoor (1985, 2001) argued that only stimuli associated with the absence of punishment maintain observing responses, and that these stimuli function as safety signals (i.e., conditioned negative reinforcers). Thus, a stimulus that signals the absence or postponement of an aversive event (i.e., safety) maintains

responding in a similar manner to stimuli associated with a positive event (food). This approach can be modified to extend the observing response procedure to study resistance to change and relapse of responding maintained by stimuli associated with negative reinforcement as a model of persistence and relapse of attending to safety signals.

In order to remove food and substitute a negatively reinforcing event, an avoidance procedure could be arranged in which rats respond to cancel shock on a mixed schedule of alternating unsignaled periods of unpredictable shock and extinction. During a shock period, a response on one lever during an interval preceding a shock delivery can cancel the shock (avoidance lever). However, no feedback stimuli are provided for responding on the avoidance lever. A response on a second lever (observing lever) could produce a stimulus signaling a shock period and the opportunity to effectively avoid shock. During an extinction period, both responding on the avoidance- and observing-lever have no consequence. It would be expected that responding on the observing lever would be maintained by the association between the presence of the stimulus and effective avoidance of shock deliveries. This approach is similar to a procedure in which rats have been shown to respond to produce signaled periods associated with the absence of an avoidance contingency (timeout from avoidance), but separates the response that produces stimuli from the response that avoids shock (Perone & Galizio, 1987). Previous research has demonstrated that rats prefer signaled over unsignaled schedules of avoidance when allowed to respond to produce stimuli associated with avoiding shock (Badia, Culbertson, & Lewis, 1971). This procedure could be further modified into a multiple schedule of observing-response procedures to allow for initial assessment of

resistance to change of observing maintained by conditioned negative reinforcement, as well as effects of baseline primary reinforcement on magnitude of relapse of observing and avoidance responding.

Future studies could assess extinction, and stimulus- and shock-induced relapse of observing for stimuli associated with avoidance of aversive events. Further research is needed to determine whether the above procedural approach is fruitful. However, previous studies demonstrating reinstatement and context renewal of fear responses (i.e., freezing, suppression of ongoing responding) to stimuli predictive of electric shock, suggest that rats' avoidance responding may also be susceptible to relapse (Rescorla & Heth, 1975; Woods & Bouton, 2006). Rats have been shown to respond in order to produce stimuli associated with the presence of (signaled over unsignaled), opportunity to terminate (escape), or opportunity to postpone (avoid) electric shock (Badia, Harsh, & Abbott, 1979; Brennan, Beck, & Servatius, 2003; Kinsman & Bixenstine, 1968). Thus, there is potential, along with other human-subject approaches (See, MacLeod, & Bridle, 2009), to provide a useful animal analog of attending to threatening stimuli for addressing clinically relevant questions concerning the role of primary reinforcement context in maintenance, persistence, and relapse of attentional biases to aversive stimuli.

Conclusion

This study found greater resistance to change and relapse of responding maintained by the production of stimuli associated with primary reinforcement in a context of a higher preextinction rate of primary reinforcement in a multiple schedule of

observing-response procedures. Reinstatement of observing occurred only when response-independent S+ periods were delivered. Extinguished food-key responding relapsed to a greater degree than observing during the S+ reinstatement condition. Greater food-key reinstatement may reflect the different discriminative properties of S+ and food in the observing-response procedure. The results are consistent with previous work extending the framework of behavioral momentum theory to animal models of relapse using simple schedules of reinforcement. As an animal model of attending, results from the present study suggest that attending to discriminative cues is susceptible to relapse. However, these conclusions remain tentative in light of further investigation of environmental parameters affecting relapse of observing in other animal models of relapse, species, and stimulus dimensions.

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