TOKEN REINFORCEMENT AND RESISTANCE TO CHANGE

by

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ABSTRACT

Token Reinforcement and Resistance to Change

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Interventions based on a token economy are effective for reducing problematic

behavior. However, treatment gains commonly deteriorate once the intervention is

discontinued. Thus, it is important to better understand the persistence of behavior

maintained by token reinforcement. Conditioned reinforcement has been traditionally

accepted as the mechanism by which tokens affect behavior. Through a Pavlovian

association with primary reinforcement, neutral stimuli (e.g., coins, poker chips, lights,

signs, stickers, etc.) are said to acquire their own function to strengthen behavior.

Behavioral momentum theory suggests that resistance to change under conditions of

disruption is the most appropriate measure of response strength. However, recent animal

studies examining the resistance to change of behavior maintained by conditioned

reinforcement have shown that parameters of conditioned reinforcement affect response

rate but do not affect resistance to change. To investigate the resistance to change of

responding maintained by token reinforcement, the present dissertation developed a novel

token reinforcement procedure. Pigeons responded on a key to produce tokens displayed on a touchscreen monitor in two signaled token-production components. Tokens accumulated over the two production components prior to a common exchange component where pecks to the tokens on the touchscreen produced food reinforcement. Resistance to change of responding maintained by different rates of token reinforcement was assessed by disrupting baseline token-production responding with presession feeding. If conditioned reinforcement affected response strength, then responding in a production-component associated with a higher rate of token reinforcement was expected to be maintained at higher rates, and be more resistant to disruption relative to a component associated with a lower rate of token reinforcement. However, if conditioned reinforcement functioned to maintain behavior in a manner other than response strengthening (i.e., reinforcement), as suggested by recent research, then despite the expectation that rate of token reinforcement would affect production response rate during baseline, these parameters would not affect resistance to change. Token reinforcement rates had inconsistent effects on baseline token-production response rates. However, small, but consistent effects of token reinforcement rate on resistance to change were found at two levels of presession feeding amount. Results were contrary to both expectations, but provide weak support for a response-strengthening account of conditioned reinforcement and insightful directions for future studies of token reinforcement in related procedures.

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PUBLIC ABSTRACT

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Interventions based on a token economy effectively reduce problematic behavior. Yet, treatment gains deteriorate once an intervention is discontinued. It is important to better understand the persistence of behavior maintained by token reinforcement in simple experimental procedures. A Pavlovian association with primary reinforcement is said to endow neutral stimuli (e.g., coins, poker chips, lights, signs, stickers, etc.) with their own function to strengthen behavior as conditioned reinforcers. Behavioral momentum theory suggests that resistance to change under conditions of disruption is the appropriate measure of response strength. However, some animal studies have suggested that conditioned reinforcement may not affect resistance to change of a response. Here, a novel token reinforcement procedure was developed to investigate the resistance to change of responding maintained by token reinforcement. Pigeons responded on a key to produce tokens displayed on a touchscreen monitor in two signaled token-production components. Tokens accumulated over the two production components prior to a common exchange component where pecks to the tokens on the touchscreen produced food reinforcement. Resistance to change of responding maintained by different rates of

token reinforcement was assessed by disrupting baseline token-production responding with presession feeding. Token reinforcement rates had inconsistent effects on baseline token-production response rates. However, small effects of token reinforcement rate on resistance to change were found. Results provide weak support for a response-strengthening account of conditioned reinforcement and insightful directions for future studies of token reinforcement in related procedures.

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INTRODUCTION

One of the most enduring and effective applications of operant conditioning

research has been the token economy (Kazdin, 1977). Variations of the token economy

have been implemented in institutional (Ayllon & Azrin, 1968), educational (Matson &

Boisjoli, 2009), industrial (Fox, Hopkins, & Anger, 1987), and rehabilitative settings

(Lussier, Heil, Mongeon, Badger, & Higgins, 2006). However, the deterioration of

treatment gains following the end of treatment is a common problem encountered when

token-based interventions are applied (Prendergast, Podus, Finney, Greenwell, & Roll,

2006). Thus, it is important to better understand the variables affecting persistence of

responding maintained by token reinforcement.

Early animal studies found that neutral objects (tokens) associated with food or

other primary rewards could function as incentives for performing tasks (Cowles, 1937;

Wolfe, 1936). Traditionally, tokens have been characterized as conditioned reinforcers

(Hackenberg, 2009; Skinner, 1938). Conditioned reinforcement refers to the ability of an

initially neutral stimulus to acquire a reinforcing function through a predictive relation

with primary reinforcement (Williams, 1994a, 1994b). Responding maintained by token

reinforcement has been shown to exhibit similar patterning as responding maintained by

primary reinforcement (Kelleher & Gollub, 1962). A token-reinforcement procedure can

be conceptualized as three interconnected schedule components. Typically, one schedule

arranges a response requirement for earning tokens, while another sets the requirement

for producing an opportunity to exchange tokens for primary reinforcement, and a third

specifies how tokens are to be exchanged for primary reinforcement (Hackenberg, 2009).

Behavioral momentum theory provides an account of the strength of operant behavior based on response persistence under conditions of disruption. According to behavioral momentum theory, response rates and resistance to change are two separable aspects of operant behavior (Nevin & Grace, 2000a). The discriminated operant is considered the fundamental unit of voluntary behavior (Skinner, 1938), and specifies two important relations: (1) the response-reinforcer relation arranged by a schedule of reinforcement, which governs response rate in a manner consistent with the matching law (Herrnstein, 1970); and (2) the Pavlovian relation between the discriminative stimulus context and obtained rate of reinforcement, which governs resistance to change. Typically, when studying behavioral momentum experimentally, responding is reinforced according to a multiple schedule arranging two or more signaled periods in which different schedules of primary reinforcement operate. Once a stable baseline of responding is established, behavior is disrupted with satiation or extinction. Changes in responding in each multiple-schedule component are analyzed as a proportion of the pre-disruption baseline rate allowing for greater response strength to be indexed as a smaller change relative to baseline. Baseline conditions of primary reinforcement in a multiple-schedule component (i.e., the Pavlovian stimulus-reinforcer relation) have been shown to determine relative resistance to change across many experiments with different populations, species, and reinforcers (Nevin & Shahan, 2011)

Shahan and Podlesnik (2005, 2008a) investigated the resistance to change of responding maintained by conditioned reinforcement using a multiple-schedule of observing response procedures. An observing response procedure arranges alternating

unsignaled periods of reinforcement and extinction for one response, and a concurrent response that produces discriminative stimuli indicating which schedule is in effect (Dinsmoor, 1985; Wyckoff, 1952). Discriminative stimuli are thought to maintain observing responses through conditioned reinforcement (Dinsmoor, 1985; Fantino, 1977). While holding primary reinforcement rate constant in each component of a multiple schedule of observing-response procedures, Shahan and Podlesnik (2005) found that variations in conditioned reinforcement rate produced changes in observing response rate, but not differential resistance to change. In subsequent studies, arranging different valued conditioned reinforcers by delivering non-contingent food reinforcers and varying the probability of a food reinforcement period produced differences in observing rate, but not resistance to change (Shahan & Podlesnik, 2008a). Based on these results, there is no evidence for differential resistance to change in procedures that vary parameters of conditioned reinforcement while holding parameters of primary reinforcement constant.

The present study developed a procedure to examine the strength of responding maintained by token reinforcement within the framework of behavioral momentum theory. Token reinforcement procedures have been used extensively to study responding maintained by conditioned reinforcement (see Hackenberg, 2009 for review). Additionally, studies suggesting that conditioned reinforcement does not impact resistance to change used the observing-response procedure exclusively. If conditioned reinforcement does not strengthen responding in a manner detectible with resistance to change tests, then the results of Shahan and Podlesnik (2005, 2008a) should generalize to other procedures in which responding is maintained by conditioned reinforcement.

In the present study, pigeons responded on a key to produce tokens, represented as small boxes displayed on a touchscreen monitor. Two fixed-duration components, signaled by different key colors were arranged to allow pigeons to produce tokens according to different variable-interval (VI) schedules. An exchange period followed each set of production components. During an exchange period, pecks to the tokens on the touchscreen produced food reinforcement. Thus, the procedure was developed to investigate responding maintained by token reinforcement in a manner similar to responding in traditional multiple-schedules of reinforcement.

Tokens were delivered at different rates in the two production-components, and resistance to change was assessed by presession feeding in two replications. If responding maintained by token reinforcement has strength in a manner similar to responding maintained by primary reinforcement, then responding in a token-production component associated with a higher baseline rate of token reinforcement was expected to be more resistant to disruption than responding in a component associated with a lower rate of token reinforcement. However, based on the findings of Shahan and Podlesnik (2005, 2008a), the results of the present study had potential to demonstrate that different rates of token reinforcement do not impact response strength when measured as resistance to change. Thus, in addition to procedure development, the present study was conduced to investigate the resistance to change of responding maintained by conditioned reinforcement.

REVIEW OF THE LITERATURE

Operant conditioning provides a basis for the study of behavior maintained by its

consequences. According to Skinner (1938, 1969), the three-term contingency relating

the discriminative stimuli, the response of an organism, and the delivery of a reinforcer,

is the fundamental unit in the study of behavior. A stimulus event is termed a reinforcer if

its delivery increases or decreases the likelihood of the response that produced it in the

presence of the discriminative stimuli. Skinner defined response strength as the response

rate maintained by the presentation of the reinforcer (Skinner, 1938). Response rate and

patterning is dependent on the schedule of reinforcement, or the rule governing how and

when responses are eligible for reinforcement (Ferster & Skinner, 1957). Researchers and

practitioners have applied principles of operant conditioning as a means to affect

behavior change in a wide range of settings (see Lattal & Neef, 1996 for review). One of

the most successful and enduring applications of operant conditioning is the token

economy (Kazdin, 1977; Kazdin & Bootzin, 1972; Olmstead & Petry, 2009).

Token economies provide the basis for economic transactions in which objects or

symbols (e.g., poker chips, gold stars, coupons) are earned by performing a desired

behavior and can later be exchanged for goods, services, or other primary reinforcers

(Hackenberg, 2009). Historically, tokens in many forms have provided a medium of

exchange in ancient barter systems to modern computerized stock market transactions.

Applications of token economies are an effective means of motivating behavior change in

occupational, institutional, educational, and rehabilitative settings. Research has shown

the token economy to be among the most effective behavioral interventions for increasing

workplace productivity and safety (O'Hara, Johnson, & Beehr, 1985; Stajkovic & Luthans, 1997), promoting healthy behaviors in institutionalized populations (Ayllon & Azrin, 1968; Dickerson, Tenhula, & Green-Paden, 2005; see Kazdin, 1977 for an early review), developing skills in individuals with developmental disabilities (Matson & Boisjoli, 2009), improving classroom achievement (Boniecki & Moore, 2003; Reitman, Murphy, Hupp, & O'Callaghan, 2004; Tanol, Johnson, McComas, & Cote, 2010), and decreasing substance abuse (Dutra et al., 2008; Ghitza et al., 2008; Higgins et al., 2010; Higgins, Wong, Badger, Ogden, & Dantona, 2000; Kollins, McClernon, & Van Voorhees, 2010; Miller & Willbourne, 2002; Shoptaw et al., 2002; Silverman et al., 1996; Stitzer & Petry, 2006). Token economies have been a successful method for teaching new behaviors, maintaining behavior under long delays to primary reinforcement, and providing an alternative source of reinforcement for prosocial behavior (see Hackenberg, 2009 for review).

For example, contingency management is a token-economy based intervention for drug use in outpatient populations (Higgins, Heil, & Lussier, 2004). Typically, incentives in the form of vouchers or coupons are delivered contingent upon drug-free urine samples, and can be used to purchase items unrelated to drug use (Carroll & Onken, 2005). Clinical trials have shown contingency management interventions to be effective for reducing drug use in individuals addicted to methamphetamine, nicotine, alcohol, heroin, cocaine, as well as polydrug users (Higgins et al., 2000; Kollins et al., 2010; Miller & Willbourne, 2002; Shoptaw et al., 2002). Contingency management can also be combined with pharmacotherapy, and/or psychotherapy to further improve treatment

efficacy (Carroll & Rounsaville, 2007; Higgins et al., 2000). Higgins et al. (2004) summarized results from 16 studies that employed contingency-management based interventions to reinforce cocaine-abstinence with varying techniques, 15 reported significant increases in cocaine abstinence. Recently, Secades-Villa et al. (2011) reported a study with cocaine-dependent individuals comparing contingency-management based treatment to standard drug counseling. Of the individuals who enrolled in the study, 58.6% and 25.7% were abstinent from cocaine use following a 12-month treatment protocol in contingency management and standard counseling conditions, respectively. These results suggest that incentives in the form of non-monetary vouchers contingent on drug-abstinence significantly increase the effectiveness of treatment. However, Hackenberg (2009) has noted that research on token economy applications, including incentive-based interventions, has developed with little or no recognition of laboratory research, and could benefit from the techniques developed in laboratory preparations as a means to further improve treatment efficacy (Stitzer, Petry, & Peirce, 2010). Laboratory research on token systems has attempted to provide an empirical basis for characterizing the mechanisms underlying how token reinforcers function to change and maintain behavior.

Token Reinforcement

In laboratory settings, token reinforcement has been shown to maintain behavior in several species and populations. Early studies used primates, dogs, or cats to determine whether animals would perform a task in order to produce a token that could be

exchanged for food reinforcement (Cowles, 1937; Ellson, 1937; Smith, 1939; Wolfe, 1936). Wolfe (1936) presented a series of experiments in which chimpanzees pulled a lever to produce a token that could be deposited into a receptacle in exchange for food. Subsequent research demonstrated that chimpanzees could learn to accumulate tokens prior to an exchange opportunity, and to discriminate tokens exchangeable for food from tokens that could not be exchanged for food (Cowles, 1937).

Token reinforcement procedures have been conceptualized as a series of chained schedules (Kelleher & Gollub, 1962). For example, if 20 responses are required to produce a token [fixed ratio 20 (FR 20) token-production], and 10 tokens are required to produce an opportunity to exchange the tokens (FR 10 exchange-production), then the schedule is similar to a 10 component chained schedule with an FR 20 response requirement in each component. Indeed, token-reinforcement procedures have been shown to generate patterns of responding that resemble behavior maintained by simple chained schedules of reinforcement (Hackenberg, 2009).

Based on early studies, Kelleher and Gollub (1962) suggested that tokens are conditioned reinforcers. A conditioned reinforcer is defined as an initially neutral stimulus that, through an association with primary reinforcement, acquires its own response-strengthening function (Williams, 1994a). Procedures used to study token reinforcement separate primary and conditioned reinforcement into three interconnected schedule components. A token-production schedule specifies the response requirement for producing tokens. Additionally, an exchange-production schedule specifies the requirement for producing an opportunity to exchange tokens. Typically, the exchange-

production schedule is a ratio (i.e., tokens can be exchanged only after X tokens are earned). Finally, a token-exchange schedule sets the requirement that specifies how many tokens must be exchanged in order to receive primary reinforcement. Each of these components can be manipulated independently.

Malagodi (1967) provided evidence for a conditioned reinforcing function of tokens in an assessment of FR and VI schedules of token production. Rats responded on a lever to produce marbles (delivered into a token hopper) according to FR and VI schedules. Token production response rates under FR schedules showed a high steady rate of responding with occasional preratio pausing, which also characterizes FR responding for food. Similar results had been found with chimpanzees responding on FR schedules of token reinforcement (Kelleher, 1958). Additionally, rats' token-maintained responding on VI schedules demonstrated steady, but lower response rates, which resembled typical VI-schedule response patterning for primary reinforcement. Thus, tokens appear to function as conditioned reinforcers by maintaining similar patterns of responding as primary reinforcers (Ferster & Skinner, 1957).

Further evidence supporting a conditioned reinforcing function of tokens comes from experiments that have manipulated the exchange-production schedule while holding the token-production and token-exchange schedules constant. Webbe and Malagodi (1978) compared rats' performance when FR or variable-ratio (VR) exchange-production requirements were increased from one to six tokens required to produce an exchange period. Responding was maintained for both schedule types, but with higher production-response rates under VR schedules. Foster, Hackenberg, and Vaidya (2001) obtained

similar results with pigeons responding to produce LED light tokens. Waddell, Leander, Webbe, and Malagodi (1972) examined fixed interval (FI) exchange-production schedules in which the first token earned after the interval elapsed produced a signaled exchange period in which tokens could be exchanged for food. Like response patterning under simple FI schedules and chained schedules arranging initial-link FI schedules, token-production response rates were positively accelerated across the interval preceding an exchange opportunity.

Hackenberg (2009) suggested that, taken together, evidence from laboratory research on token reinforcement procedures suggests that tokens function to strengthen behavior as conditioned reinforcers. However, the strength of responding maintained by token reinforcement has primarily been assessed in procedures in which token-production, exchange-production, or token-exchange requirements were varied. Though these manipulations affect token-production responding in a manner characteristic of primary reinforcement, they also affect rate of primary reinforcement with an exchange-production requirement. Manipulations that affect rate of token production also affect the rate of exchange production and thus, primary reinforcement rate. A similar problem has been acknowledged when studying conditioned reinforcement using chained schedules (Dinsmoor, 1985; Williams, 1994a). However, limited evidence suggests that token-production response rate and patterning in fixed duration token-production components resembles response rate and patterning typically observed in studies of responding maintained by primary reinforcement (Kelleher, 1956).

Response Strength

Traditionally, changes in response rate have been used to characterize the response-strengthening effects of token reinforcement (Hackenberg, 2009). However, behavioral persistence engendered by token reinforcement has been understudied in laboratory settings, and treatment durability is an important outcome measure for token-economy based interventions (DeFulio & Silverman, 2011; Higgins et al., 2000). Additionally, response rate may reflect factors other than the response strengthening properties of reinforcement (i.e., pacing contingencies; Nevin, 1974).

Behavioral momentum theory characterizes the strength of operant behavior as resistance to change under conditions of disruption (Nevin & Grace, 2000a). Typically, multiple-schedules of reinforcement are used to establish a baseline of responding in the presence of two or more discriminative stimuli. For example, one component of a multiple schedule may arrange a high rate of reinforcement for a response (Rich), and the other component may arrange a relatively low rate of reinforcement (Lean). Thus, responding is maintained at either a high rate or a low rate in the presence of the different component stimuli. Once stable baseline responding is established, behavior is disrupted with either presession feeding, free food delivered in the intercomponent intervals (ICI), or extinction. A large body of research suggests that resistance to disruption is greater in the component arranging a relatively higher baseline rate of reinforcement (Nevin & Grace, 2000a for review).

Several experiments have demonstrated that response rate and resistance to disruption are separable aspects of operant performance. With pigeons, Nevin, Tota,

Torquato, and Shull (1990) arranged a multiple schedule arranging signaled alternating components of VI reinforcement schedules (VI 120 s). In one component (Rich), additional reinforcers were delivered response-independently according to a variable-time schedule (VT 45 s). Thus, while the Rich component was associated with a higher rate of reinforcement, response-independent reinforcement reduced response rates relative to the Lean component. Following stable baseline responding, behavior was disrupted by delivering free food during the ICI's, and extinction. Despite maintaining a lower rate of responding relative to the Lean component, responding in the Rich component was more resistant to disruption.

Based on these results, Nevin and others (Nevin & Grace, 2000a) have suggested that within the three-term contingency that comprises the discriminated operant, the relation between the response and reinforcer determines response rate, as described by the matching law (Herrnstein, 1961, 1970), and the Pavlovian relation between the discriminative stimulus context and reinforcement rate determines resistance to disruption (Nevin et al., 1990; Nevin & Grace, 2000a). Whereas response rate may be affected by contingencies that do not affect response strength (i.e., differential reinforcement contingencies), resistance to change reflects the influence of the overall relation between the discriminative stimulus context and reinforcement rate. This has led Nevin and colleagues (Nevin & Grace, 2000a) to conclude that resistance to change is a more appropriate measure of response strength than response rate. Other experiments have provided support for this hypothesis with individuals with disabilities (Ahearn, Clark, Gardenier, Chung, & Dube, 2003; Mace et al., 1990), rats responding for alcohol

while receiving response-independent food reinforcement in one component

(Pyszczynski & Shahan, 2011; Shahan & Burke, 2004), and goldfish (Igaki & Sakagami,

2004).

In addition to responding maintained by schedules of primary reinforcement, the

behavioral momentum framework has been used to assess the strength of responding

maintained by conditioned reinforcement. Nevin, Mandell, and Yarensky (1981) used

pigeons to assess resistance to change of responding maintained in the initial links of

chained schedules. Initial link responding has been suggested to reflect the conditioned

reinforcing properties of the terminal-link stimuli (Fantino, 1977). Nevin et al. (1981)

arranged two chained schedules alternating across two response keys and signaled by

distinct discriminative stimuli. In each chained-schedule component, access to the

terminal link was arranged according to a random-interval (RI) 40 s schedule. Similarly,

each terminal link ended with primary reinforcement according to an RI 40 s schedule.

Reinforcer duration was manipulated in the terminal links such that reinforcement in one

component terminal link consisted of longer access to food. When presession feeding or

an additional source of reinforcement was introduced to disrupt responding, resistance to

change in both links of the chained schedule was positively related to reinforcement

duration in the terminal link. Although overall responding in the initial links was more

easily disrupted than terminal link responding, responding in the initial link that led to

longer duration terminal link reinforcement was more resistant to disruption. Thus,

responding maintained by a conditioned reinforcer associated with a larger magnitude

primary reinforcer was relatively more resistant to disruption.

Shahan and colleagues (Shahan, Magee, & Dobberstein, 2003; Shahan & Podlesnik, 2005, 2008a) further assessed resistance to change of responding maintained by conditioned reinforcement using the observing-response procedure. Although Nevin et al. (1981) found greater resistance to change of responding in the initial links that led to larger magnitude reinforcers, access to primary reinforcement is dependent on responding in the initial links in chained schedules, and overall reinforcement rate in the terminal link was affected by initial-link responding (Williams, 1994a). Observing-response procedures differ from chained schedules by separating the response for conditioned reinforcement from the response for primary reinforcement. Unsignaled periods of primary reinforcement alternate with periods of extinction for one response (mixed schedule), and a separate, concurrently available, response changes stimuli associated with both responses to indicate whether or not reinforcement contingencies are operating (i.e., S+ or S-; Dinsmoor, 1985; Wyckoff, 1952). Thus, responding for conditioned reinforcement does not affect rate of primary reinforcement in an observing-response procedure.

Shahan and Podlesnik (2005) investigated whether different rates of conditioned reinforcement in a multiple schedule of observing-response procedures would produce differential resistance to change. In each component of the multiple schedule of observing response procedures, unsignaled periods of RI 120 s food reinforcement and extinction alternated every 60 s on the food-key, and rate of conditioned reinforcement for responding on the observing key was varied across components. One component arranged a high rate of conditioned reinforcement by delivering S+ or S- according to a

RI 15 s schedule (Rich), while the other component delivered S+ or S- according to a RI 60 s schedule (Lean). During baseline, observing-response rates were higher in the Rich component. However, when responding was disrupted with presession feeding or extinction, resistance to change of observing did not differ between components. Shahan and Podlesnik (2005) concluded that, although differences in conditioned reinforcement rate affected observing-response rates in baseline, resistance to change of observing depended on primary reinforcement rate.

In a follow-up study, Shahan and Podlesnik (2008a) assessed whether manipulating the value of conditioned reinforcers would produce differences in resistance to change of observing. A multiple schedule of observing-response procedures arranged identical rates of S+ presentation in each component. Food-key responses were maintained on the same schedule of response-dependent primary reinforcement in both components. However, one of the components included response-independent food deliveries, which were uncorrelated with the conditions of response-dependent primary reinforcement. In this component, response-independent food reinforcement could occur during the S+ and mixed schedule stimuli. Response-independent food deliveries increased the rate of primary reinforcement, but decreased the value of S+ by degrading the predictive relation between S+ and food in the component. Following stable baseline performance, responding was disrupted with presession feeding. Results showed greater resistance to change of observing in the component arranging a higher baseline rate of primary reinforcement, even though higher baseline observing-response rates were maintained in the component arranging a higher-valued S+.

In a second experiment, the probability of a primary reinforcement period was decreased in one component relative to the other component. Thus, primary reinforcement rate was decreased, but the value of S+ was increased. Results once again showed higher observing-response rates in the component with a higher valued S+, but resistance to change of observing was greater in the component with a higher overall rate of primary reinforcement.

Finally, no differences in resistance to change of observing were found when controlling primary reinforcement rate in both components and varying conditioned reinforcement value across components in a third experiment. Shahan and Podlesnik (2008a) concluded that conditioned reinforcement value, like conditioned reinforcement rate, did not impact resistance to change of observing in any meaningful sense. Within the framework of behavioral momentum theory, there is no evidence in support of a response-strengthening interpretation of conditioned reinforcement when rates of primary reinforcement are held constant while parameters of conditioned reinforcement are varied (Shahan, 2010; Shahan & Podlesnik, 2008b).

Token Reinforcement and Resistance to Change

Token reinforcement procedures have been used extensively to study behavior maintained by conditioned reinforcement. However, response strength in token reinforcement procedures has not been assessed using the procedural framework of behavioral momentum theory. Behavioral momentum theory has provided insight into how reinforcement conditions affect response strength in a wide range of settings (Nevin

& Grace, 2000a; Nevin & Shahan, 2011). Token reinforcement-based interventions are effective in many different applications, but thorough investigation of variables affecting the durability of treatment gains once interventions are discontinued is needed. The aim of this dissertation was to develop a new procedure for examining resistance to change of responding maintained by token reinforcement using pigeons. Greater resistance to change of token-maintained responding in a multiple-schedule component associated with a relatively higher baseline rate of token reinforcement would provide evidence for a response strengthening effect of tokens. However, as data from studies using the observing-response procedure suggest (Shahan & Podlesnik, 2005, 2008a), differential rates of token reinforcement may not produce differential resistance to change, and tokens may serve to maintain behavior through a mechanism other than response strengthening.

Baseline conditions are of interest, because there have been no reported studies of token-maintained behavior in a multiple-schedule of reinforcement without an exchange-production requirement. The majority of token economy experiments have used an exchange-production schedule requirement (Bullock & Hackenberg, 2006; Foster & Hackenberg, 2004; Foster et al., 2001; Malagodi, Webbe, & Waddell, 1975; Waddell et al., 1972). Whereas fixed-duration token- and exchange-production schedules have received little attention, token-reinforcement based on response chaining has been extensively studied. However, tokens have been shown to maintain behavior in fixed-duration token production components in experiments with chimpanzees (Kelleher, 1956,

1957). Thus, baseline results are of interest for describing how VI schedules of token reinforcement maintain responding in a multiple schedule.

Following stable responding to produce and exchange tokens in fixed-duration components, rates of token production were varied to produce differential token-production response rates. Rats have been shown to discriminate multiple-schedule components arranging different schedules of token production on ratio schedules (Malagodi, 1967). Therefore, it was expected that, with pigeons, token production response rates would be higher in a component arranging a higher rate of VI token reinforcement compared to a component arranging a lower rate.

Finally, the study attempted to address whether relative resistance to change of token production is greater in a component with a higher rate of token reinforcement in a multiple-schedule arranging fixed duration production components followed by a common exchange component. Changes in motivation have been shown to impact token production in rats (Boakes, Poli, Lockwood, & Goodall, 1978). The present experiment assessed the persistence of behavior maintained by token reinforcement within the framework of behavioral momentum theory using presession feeding as a disrupter. The present study had the potential of producing results and procedural innovations important for understanding the variables affecting behavior in a token economy, as well as theoretical conceptualizations of conditioned reinforcement.

STATEMENT OF THE PROBLEM

Token-reinforcement interventions have been widely applied, but could benefit from systematic investigations of variables affecting the persistence of behavior maintained by token reinforcement. The present study developed a novel experimental preparation in order to evaluate resistance to change of responding maintained by token reinforcement with pigeons. Previous studies found that resistance to change of responding maintained by conditioned reinforcement in the observing-response procedure was not affected by different parameters of conditioned reinforcement. The present study was conducted as an attempt to assess the generality of these findings in a different, but conceptually related procedure.

Early studies of token reinforcement suggest that conditioned reinforcement strengthens responding in a similar manner as primary reinforcement. If this is true, then parameters of token reinforcement should impact resistance to change of token-production responding. However, if conditioned reinforcement does not affect resistance to change, then conclusions reached in studies using the observing-response procedure would be supported. Shahan (2010) argued that conditioned reinforcement might not serve to "strengthen" behavior in any sense. Instead, conditioned reinforcers may be thought of as a means to an end for obtaining primary reinforcers. In addition to being traditionally thought of as conditioned reinforcers, tokens are a means to an end in obtaining primary reinforcement by definition. However, it is not known whether parameters of token reinforcement affect resistance to change. Thus, the present study

aimed to evaluate the response-strengthening function of token reinforcement using the

experimental framework of behavioral momentum theory.

METHOD

Subjects

Homing pigeons experienced with operant conditioning procedures, but naïve to a touchscreen apparatus, were used. All pigeons were housed individually in a climate-controlled colony room, with a 12:12 hr light:dark cycle. Pigeons had continuous access to water in their home cage and were maintained at 80% of their ad libitum weights (+/- 15 g) by postsession feeding as needed. Care and use of pigeons was conducted according to the standards of the USU Institutional Animal Care and Use Committee guidelines.

Apparatus

Two 61 cm $\times$ 61 cm $\times$ 31 cm chambers containing an intelligence panel with one response key, a pellet receptacle, and a touchscreen monitor (acoustic; ELO touchsystems, Menlo Park, CA) were situated in a sound- and light-attenuating room (Figure 1). The intelligence panel was located on the wall opposite the chamber door. A response key was located 8 cm left adjacent to the touchscreen. A food receptacle located 10 cm below the response key (center-to-center) could be illuminated during pellet deliveries. Reinforcement consisted of activation of a pellet dispenser (Coulbourn Instruments, Whitehall, PA), allowing pigeon pellets (Bio-Serv, Frenchtown, NJ) to be delivered into the food receptacle at a rate of 1 per second. Control and recording of

experimental events were conducted using Microsoft © Visual Studio 2008 running on a dedicated computer for each chamber.

Experimental Design

The present experiment used a within-subject experimental design, allowing each subject to serve as its own control (Sidman, 1960). Data was analyzed at the individual subject level for stability preceding disruption phases via visual inspection. Data from each presession feeding condition were analyzed visually at the individual subject level, and as a group using two-way (component by session) repeated measures ANOVAs.
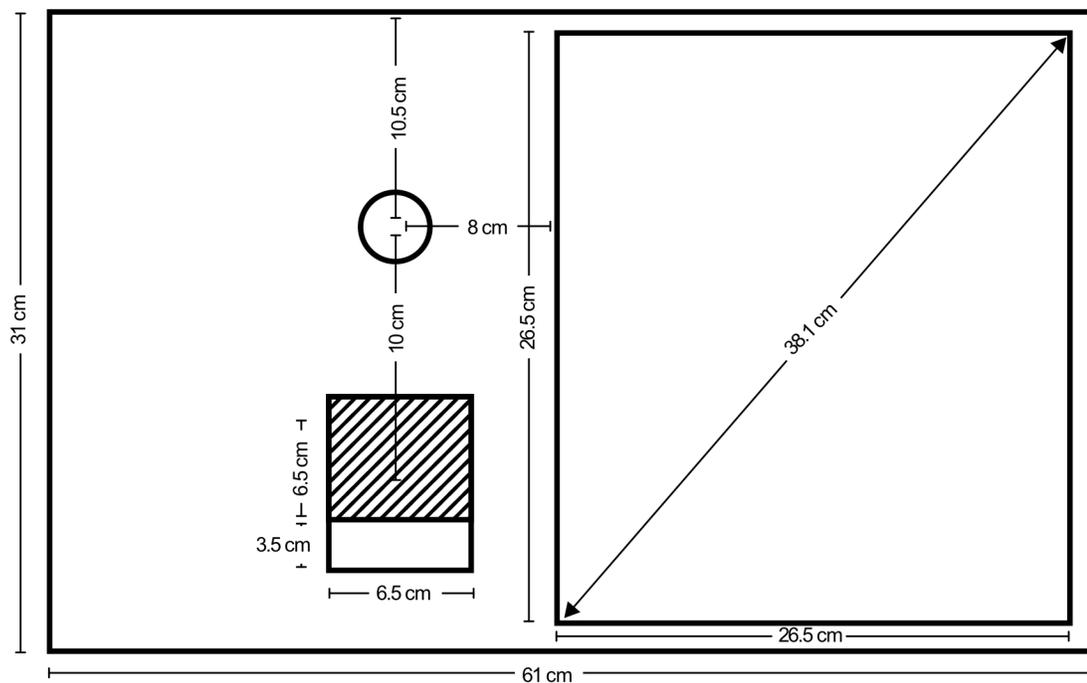

Figure 1. Schematic and dimensions of touchscreen intelligence panel.

Training

Autoshaping

Prior to introducing the response key, pigeons were shaped to respond on the touchscreen monitor with a modified autoshaping procedure (Brown & Jenkins, 1968). Autoshaping sessions consisted of 40 cycles during which a 2 cm $\times$ 2 cm yellow square was presented on the touchscreen (black background) for 6 s following a 60 s inter-trial interval. A response detected within the square during the 6 s trial resulted in the square disappearing and the immediate delivery of two food pellets. If a response was not detected during the 6 s trial, the square disappeared and food was delivered. Autoshaping sessions were conducted until pigeons responded to the square on the touchscreen on 85% or more of the trials.

Token Exchange

Prior to the introduction of the baseline procedure, pigeons were trained to respond on a lit key to produce tokens using a backward chaining procedure. Throughout all procedures, responses on the key did not produce food reinforcement. The key was illuminated yellow and a response produced a 2 cm $\times$ 2 cm yellow square (token, henceforth) on the touchscreen. An effective peck to the response key resulted in the key turning off for 0.1 s to provide visual feedback. Initially, requirements for token production and exchange were FR 1 token-production, FR 1 exchange-production, thus one response to the key produced a token on the touchscreen to be exchanged immediately (keylight turned off). An effective exchange response produced auditory

feedback, the disappearance of the token stimulus, and immediate food reinforcement. In all procedures, responses to tokens during pellet deliveries were recorded but had no programmed consequences. Throughout training and baseline procedures, the token-exchange schedule (the schedule by which tokens were exchanged for food) remained at FR 1 during an exchange opportunity. An exchange component consisted of a darkened keylight with any accumulated tokens visible on the touchscreen monitor.

The exchange-production requirement was gradually increased until pigeons were reliably producing 10 tokens (FR 10; arrayed horizontally across the touchscreen) prior to an exchange opportunity. Once pigeons reached stability on the FR 10 exchange-production schedule, the exchange-production schedule was reduced to FR 5 and the token-production schedule was increased across sessions according to a VR, initially, and then according to VI schedule.

Following stable token- and exchange-production responding, fixed duration token-production and token-exchange components were introduced (i.e., the exchange-production requirement was removed). Pigeons responded to produce tokens in a 60 s token-production component, which was immediately followed by a 60 s exchange component. Token-production VI schedule values were adjusted to maintain production-response rates according to a VI 10 s schedule.

Multiple Schedule of Token Production

Following reliable responding to produce tokens on the fixed-duration token reinforcement schedule, the baseline multiple schedule of token production was introduced**.** Early stages of multiple-schedule training arranged a multiple schedule

consisting of cycles of two 30 s production components, followed by a 60 s exchange component. Initially, an attempt was made to increase VI values to 30 s and 120 s. However, through several conditions of lengthening and shortening of VI values, reliable responding could not be maintained in the majority of pigeons. Thus, component length and VI values were decreased to shorter durations, and reinforcement magnitude was increased from to 2 to 4 pellets in order to maintain consistent levels of production-key responding.

In the final procedure, sessions consisted of 30 cycles of a three-component multiple schedule. Two 15 s token-production components alternated prior to a 30 s exchange component (excluding reinforcement time) and were separated by a 2 s ICI. An ICI consisted of a darkened keylight and any accumulated tokens hidden by a black screen. Sessions began with a 2 s blackout followed by the presentation of a token-production component with p=0.5. One production-component (i.e., Rich or Lean) was selected randomly at the beginning of a session, and following each exchange component. This arrangement allowed for an equal number of transitions from each production-component to the exchange component. One production component was signaled by a distinctive keylight color (e.g., red), and the other production component was signaled by a different keylight color (e.g., green). Tokens accumulated in one component were masked during the following component (Figure 2). The touchscreen display (black background) was separated into two 12.75 cm X 26.5 cm halves vertically by a 1 cm white line. Tokens were selected to display randomly on 3 rows of 5 horizontal
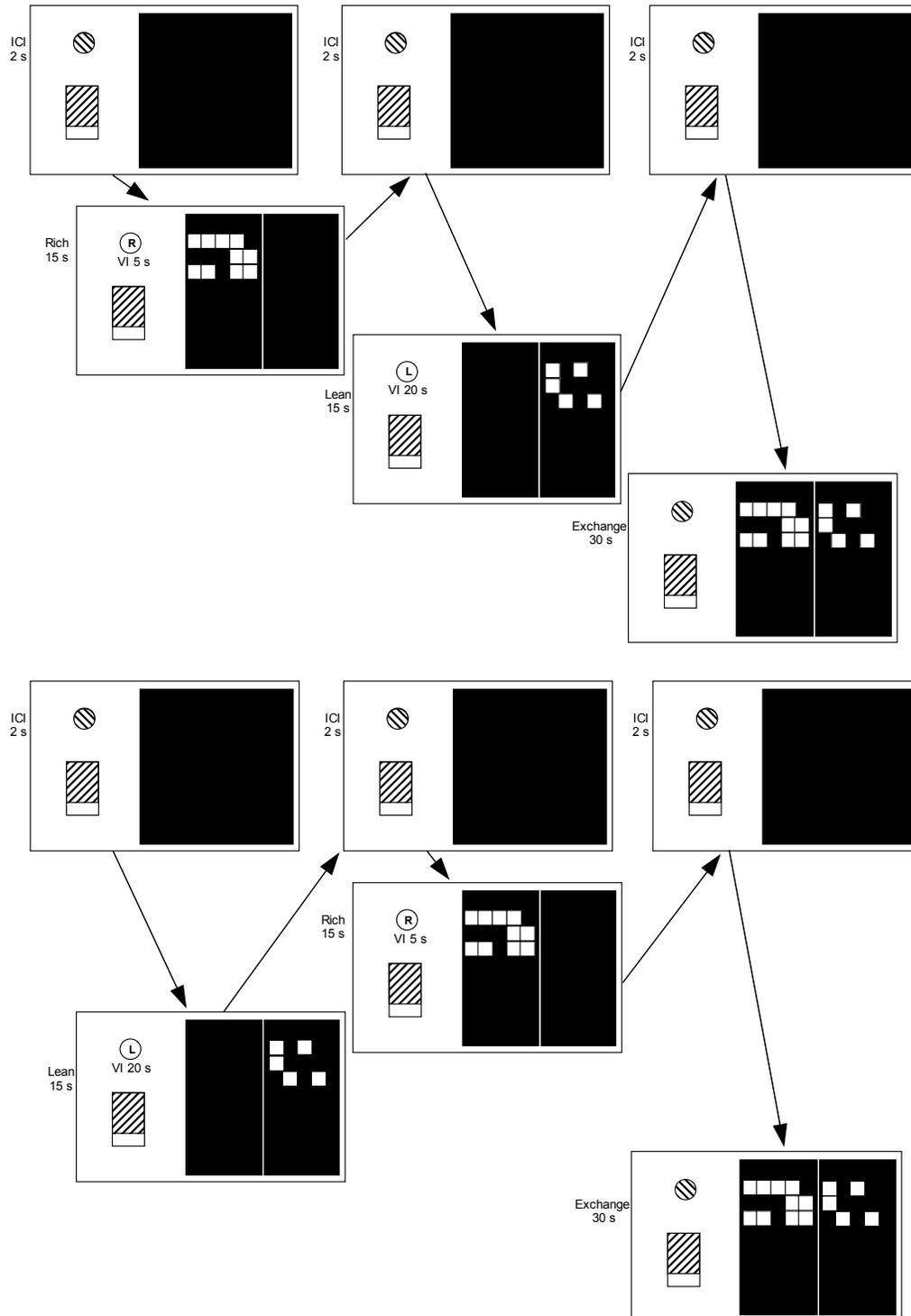
Figure 2. Schematic of component presentation in the multiple-schedule of token reinforcement.

positions, allowing a maximum of 30 tokens prior to an exchange component (i.e., 15 on each side of the screen; Figure 2).

Once responding was established to a VI 10 s token-production schedule in each component, token reinforcement rate was reduced in one of the components and increased in the other. Adjustments in schedule and component length were made until pigeons were responding reliably on a VI 5 s schedule in one production component (Rich), and according to a VI 20 s schedule in the other production component (Lean). Key colors, and location on the touchscreen where tokens accumulate for each component were counterbalanced across pigeons (e.g., Rich tokens produced by pecking the green key displayed on right side; Table 1).

Initial baseline training was conducted for 20 sessions, followed by 5 sessions of disruption (Condition 1). Following the first disruption, schedule values were changed to VI 12.5 in both components for 15 sessions in order to provide a comparison of component behavior under nondifferential token reinforcement conditions (Condition 2) to behavior in Conditions 1 and 3. Resistance to change was not assessed in Condition 2. In Condition 3, Rich VI 5 s and Lean VI 20 s schedules were reintroduced, but keylight stimuli and token locations were reversed in comparison to the first phase. Training proceeded for 15 sessions prior to disruption.

Table 1

Assignment of Stimuli

Conditions 1 & 2	Key color		Side	
Pigeon	Rich	Lean	Rich	Lean
11	Red	Green	Right	Left
46	Green	Red	Left	Right
121	Red	Green	Left	Right
224	Red	Green	Left	Right
289	Green	Red	Right	Left
1133	Red	Green	Right	Left
1188	Green	Red	Right	Left
4748	Red	Green	Left	Right
49864	Red	Green	Left	Right
Condition 3				
Pigeon				
11	Green	Red	Left	Right
46	Red	Green	Right	Left
121	Green	Red	Right	Left
224	Green	Red	Right	Left
289	Red	Green	Left	Right
1133	Green	Red	Left	Right
1188	Red	Green	Left	Right
4748	Green	Red	Right	Left
49864	Green	Red	Right	Left

Disruption

Following stable responding, defined as the absence of trend over 5 sessions, the effects of home-cage presession feeding one hour prior to a session was examined in the first and third phases. In the first phase, pigeons were fed 12% of their running weights for five consecutive sessions. Following presession feeding, running weights were reestablished prior to the next baseline condition. In the final phase, pigeons were fed 8% of their running weights for five consecutive sessions.

Statistical Analysis

Differences in production-component response rates, and token reinforcement rates, in the last five sessions of each baseline were compared using paired t-tests. Resistance to change data were analyzed as a proportion of baseline response rate. Proportion of baseline for each session of disruption was calculated as the response rate in the production component divided by the average response rate over the last five sessions of baseline in that component. Each disruptive manipulation was analyzed in a 2 (Component) $\times$ 5 (Session) repeated-measures ANOVA.

RESULTS

Baseline

Mean response rates and obtained token rates for each baseline and prefeeding condition are listed in Table 2. Figure 3 shows mean baseline response rates on the production key and on the touchscreen in Rich and Lean components for each pigeon. The top row displays response rates for Condition 1. Baseline production-key response rates tended to be higher in the Lean component [$t(8)=4.15$, $p=0.003$]. Touchscreen response rates were variable across pigeons, and did not tend to differ across components [$t(8)=2.052$, $p=0.074$]. However, Pigeons 121, 289, and 4748 tended to respond at a higher rate than on the production key, and at a higher rate in the Rich component than in the Lean component. The middle row displays response rates in Condition 2, in which programmed token reinforcement rates were equal. Production-key response rates tended to be higher in the Lean component (i.e., the multiple schedule component associated with a relatively lower rate of token reinforcement in Condition 1; $t(8)=3.11$, $p=0.014$). Touchscreen response rates were variable across pigeons with a tendency to be higher in the Rich component [$t(8)=2.509$, $p=0.036$], and decreased overall with the exception of Pigeon 121. The bottom row displays response rates in Condition 3. In comparison to Conditions 1 and 2, production-key response rates tended to be lower. Production-key response rates in the Rich component tended to be marginally higher than in the Lean component [$t(8)=0.16$, *ns*], with the exception of Pigeons 289, 4748, and 49864.

Table 2

Response Rates, Reinforcement Rates, and Number of Sessions in Each Condition.
Conditions are presented in the order they occurred. Baselines (BL) are indicated by the
following disrupter, or reinforcement rate (equal reinforcement rate [1:1], presession
food [PF], 12% of running weight [PF 12%], 8% of running weight [PF 8%]). Response
rates and token reinforcement rates are mean rates from the final five sessions of
baseline prior to disruption or condition change. Response rates from individual sessions
of disruption are presented. SD s are in italics.

Pigeon	Condition	Session	Response Rates		Token Rates	
			Rich	Lean	Rich	Lean
11	PF 12% BL	20	15.30	31.74	3.44	2.09
			1.17	*3.06*	*0.42*	*0.22*
	PF 12%	1	5.25	9.24	1.38	0.63
	PF 12%	1	8.63	8.53	3.10	1.07
	PF 12%	1	14.27	21.25	3.16	1.50
	PF 12%	1	11.52	26.50	3.29	1.75
	PF 12%	1	13.13	20.97	2.75	1.64
	BL (1:1)	15	21.79	42.26	2.41	2.86
			4.83	*3.09*	*0.26*	*0.14*
	PF 8 % BL	15	18.24	13.58	3.64	1.57
			2.06	*2.41*	*0.42*	*0.16*
	PF 8%	1	14.63	9.87	3.50	1.52
	PF 8%	1	17.33	13.35	2.67	1.89
	PF 8%	1	13.48	6.67	2.43	1.33
	PF 8%	1	13.07	8.36	2.93	1.75
	PF 8%	1	8.40	4.58	2.27	1.35
46	PF 12% BL	20	27.09	28.56	4.32	1.68
			9.54	*3.62*	*0.43*	*0.42*
	PF 12%	1	4.50	2.15	1.00	0.51
	PF 12%	1	0.13	0.00	0.13	0.00
	PF 12%	1	6.84	3.55	1.71	0.98
	PF 12%	1	8.00	6.74	3.47	1.48
	PF 12%	1	7.83	6.00	1.89	0.88
	BL (1:1)	15	34.30	44.39	2.72	2.84
			4.17	*8.97*	*0.47*	*0.34*

Pigeon	Condition	Session	Response Rates			Token Rates	
			Rich	Lean		Rich	Lean
	PF 8% BL	15	21.99	17.51		3.38	1.81
			4.58	*5.88*		*0.30*	*0.83*
	PF 8%	1	4.93	4.45		1.20	1.08
	PF 8%	1	4.56	3.13		1.27	0.75
	PF 8%	1	8.49	7.20		2.29	0.53
	PF 8%	1	19.15	9.07		2.29	0.93
	PF 8%	1	17.72	17.30		2.32	0.85
121	PF 12% BL	20	11.68	17.45		3.88	1.78
			2.04	*2.04*		*0.47*	*0.33*
	PF 12%	1	7.73	7.96		3.87	1.62
	PF 12%	1	0.76	0.50		0.51	0.25
	PF 12%	1	0.27	0.00		0.27	0.00
	PF 12%	1	0.38	0.25		0.38	0.25
	PF 12%	1	0.13	0.00		0.13	0.00
	BL (1:1)	15	18.00	24.72		2.17	2.93
			4.59	*4.05*		*0.27*	*0.21*
	PF 8% BL	15	12.19	9.36		3.42	1.62
			1.87	*0.55*		*0.23*	*0.52*
	PF 8%	1	7.71	6.25		3.28	1.38
	PF 8%	1	4.94	2.25		2.03	0.63
	PF 8%	1	2.93	1.48		1.47	0.27
	PF 8%	1	0.51	0.25		0.13	0.00
	PF 8%	1	0.00	0.00		0.00	0.00
224	PF 12% BL	20	9.55	10.88		3.39	1.57
			3.43	*4.94*		*0.39*	*0.48*
	PF 12%	1	0.00	0.13		0.00	0.13
	PF 12%	1	3.28	2.00		1.64	0.75
	PF 12%	1	0.00	0.00		0.00	0.00
	PF 12%	1	0.00	0.00		0.00	0.00
	PF 12%	1	0.00	0.00		0.00	0.00
	BL (1:1)	15	6.66	6.92		1.53	2.15
			2.84	*3.08*		*0.34*	*0.89*
	PF 8% BL	15	13.16	9.47		4.01	1.64
			1.85	*2.80*		*0.33*	*0.14*

Pigeon	Condition	Session	Response Rates		Token Rates	
			Rich	Lean	Rich	Lean
	PF 8%	1	4.43	4.88	2.41	0.38
	PF 8%	1	4.25	1.39	1.25	0.13
	PF 8%	1	3.25	0.89	1.00	0.13
	PF 8%	1	4.67	1.62	1.47	0.13
	PF 8%	1	7.06	3.10	1.05	0.39
289	PF 12% BL	20	18.45	42.89	3.57	1.95
			5.32	*5.94*	*0.22*	*0.38*
	PF 12%	1	0.00	0.00	0.00	0.00
	PF 12%	1	0.00	0.00	0.00	0.00
	PF 12%	1	0.00	0.00	0.00	0.00
	PF 12%	1	0.00	0.00	0.00	0.00
	PF 12%	1	7.63	6.96	2.13	1.01
	BL (1:1)	15	28.33	37.51	2.49	2.69
			4.95	*4.21*	*0.22*	*0.36*
	PF 8% BL	15	17.06	20.49	3.59	1.72
			3.02	*3.63*	*0.39*	*0.19*
	PF 8%	1	14.83	11.87	4.18	1.73
	PF 8%	1	0.40	0.40	0.13	0.13
	PF 8%	1	9.38	7.85	3.00	1.14
	PF 8%	1	0.88	3.29	0.25	0.00
	PF 8%	1	6.67	5.93	2.00	1.35
1133	PF 12% BL	20	16.17	33.73	3.73	2.34
			4.82	*7.84*	*0.39*	*0.33*
	PF 12%	1	1.38	1.39	0.50	0.38
	PF 12%	1	4.83	10.43	0.57	0.82
	PF 12%	1	3.44	13.55	1.07	1.21
	PF 12%	1	2.54	12.12	0.36	1.10
	PF 12%	1	4.60	18.94	1.09	1.34
	BL (1:1)	15	14.11	51.80	1.90	3.30
			5.64	*4.83*	*0.20*	*0.12*
	PF 8% BL	15	17.63	3.41	4.51	0.98
			0.69	*4.17*	*0.30*	*0.53*
	PF 8%	1	7.01	0.53	3.51	0.13
	PF 8%	1	6.27	0.00	1.33	0.00
	PF 8%	1	6.25	0.00	1.88	0.00

(Continued)

Pigeon	Condition	Session	Response Rates		Token Rates	
			Rich	Lean	Rich	Lean
	PF 8%	1	7.59	0.13	2.28	0.00
	PF 8%	1	4.93	0.78	2.27	0.13
1188	PF 12% BL	20	12.89	18.43	3.30	1.89
			1.86	*4.75*	*0.35*	*0.24*
	PF 12%	1	0.86	0.50	0.12	0.13
	PF 12%	1	1.75	1.60	0.81	0.27
	PF 12%	1	0.80	1.08	0.67	0.40
	PF 12%	1	0.27	0.81	0.27	0.13
	PF 12%	1	0.67	0.93	0.54	0.00
	BL (1:1)	15	12.62	21.41	1.95	2.74
			3.20	*4.10*	*0.20*	*0.48*
	PF 8% BL	15	14.93	7.35	4.07	1.61
			1.91	*2.59*	*0.38*	*0.44*
	PF 8%	1	1.50	2.15	1.38	0.13
	PF 8%	1	0.27	0.00	0.27	0.00
	PF 8%	1	1.63	0.13	0.88	0.00
	PF 8%	1	1.48	0.27	0.54	0.13
	PF 8%	1	0.00	0.00	0.00	0.00
4748	PF 12% BL	20	31.67	49.51	4.36	1.80
			5.53	*15.29*	*1.05*	*0.40*
	PF 12%	1	8.99	7.63	1.77	0.88
	PF 12%	1	0.00	0.00	0.00	0.00
	PF 12%	1	2.43	0.80	1.21	0.00
	PF 12%	1	0.40	0.27	0.40	0.00
	PF 12%	1	0.00	0.13	0.00	0.00
	BL (1:1)	15	48.66	58.85	2.82	3.04
			10.62	*5.10*	*0.27*	*0.09*
	PF 8% BL	15	25.57	53.43	3.78	2.06
			14.48	*5.02*	*0.57*	*0.23*
	PF 8%	1	11.60	26.29	3.07	2.43
	PF 8%	1	3.47	11.33	1.07	0.94
	PF 8%	1	8.00	15.32	2.00	1.14
	PF 8%	1	10.38	27.50	2.41	1.25
	PF 8%	1	13.79	31.64	2.68	2.27
49864	PF 12% BL	20	20.49	32.37	4.61	1.85
			1.50	*6.97*	*0.56*	*0.26*

Pigeon	Condition	Session	Response Rates			Token Rates	
			Rich	Lean		Rich	Lean
	PF 12%	1	1.33	1.48		0.80	0.54
	PF 12%	1	1.89	0.80		1.21	0.00
	PF 12%	1	8.61	9.38		2.41	1.38
	PF 12%	1	8.67	5.66		3.87	1.08
	PF 12%	1	10.25	8.67		3.78	1.20
	BL (1:1)	15	28.45	30.48		2.47	3.35
			7.48	*2.60*		*0.29*	*0.32*
	PF 8% BL	15	15.39	15.77		3.87	1.47
			6.78	*4.94*		*0.20*	*0.93*
	PF 8%	1	4.04	7.73		3.24	2.13
	PF 8%	1	2.83	7.07		1.62	0.80
	PF 8%	1	1.89	4.25		1.01	0.38
	PF 8%	1	5.13	5.57		0.63	0.38
	PF 8%	1	9.17	6.93		2.02	1.20

Touchscreen response rates tended to increase in Condition 3, but were nondifferential across pigeons. Pigeons responding to the production-key and touchscreen tended to occur at similar rates [$t(8)=0.779$, $p=0.458$], with the exception of Pigeons 121 and 289, who responded at a relatively higher rate on the touchscreen within token production components.

Figure 4 shows mean obtained token reinforcement rates in Rich and Lean components for each pigeon. The top panel displays obtained token rates for Condition 1. Token reinforcement rates were higher in the Rich component [$t(8)=10.29$, $p<0.001$]. The middle panel displays token reinforcement rates for Condition 2, in which programmed token reinforcement rates were equal. Obtained token reinforcement rates tended to be higher in the component associated with the Lean schedule of token reinforcement in Condition 1 [$t(8)=4.44$, $p=0.002$]. The bottom panel displays token reinforcement rates Condition 1 [$t(8)=4.44$, $p=0.002$]. The bottom panel displays token reinforcement rates

obtained in Condition 3. Obtained token reinforcement rates were higher in the Rich

component than the Lean component in Condition 3 [$t(8)=11.11$, $p<0.001$]. In Condition
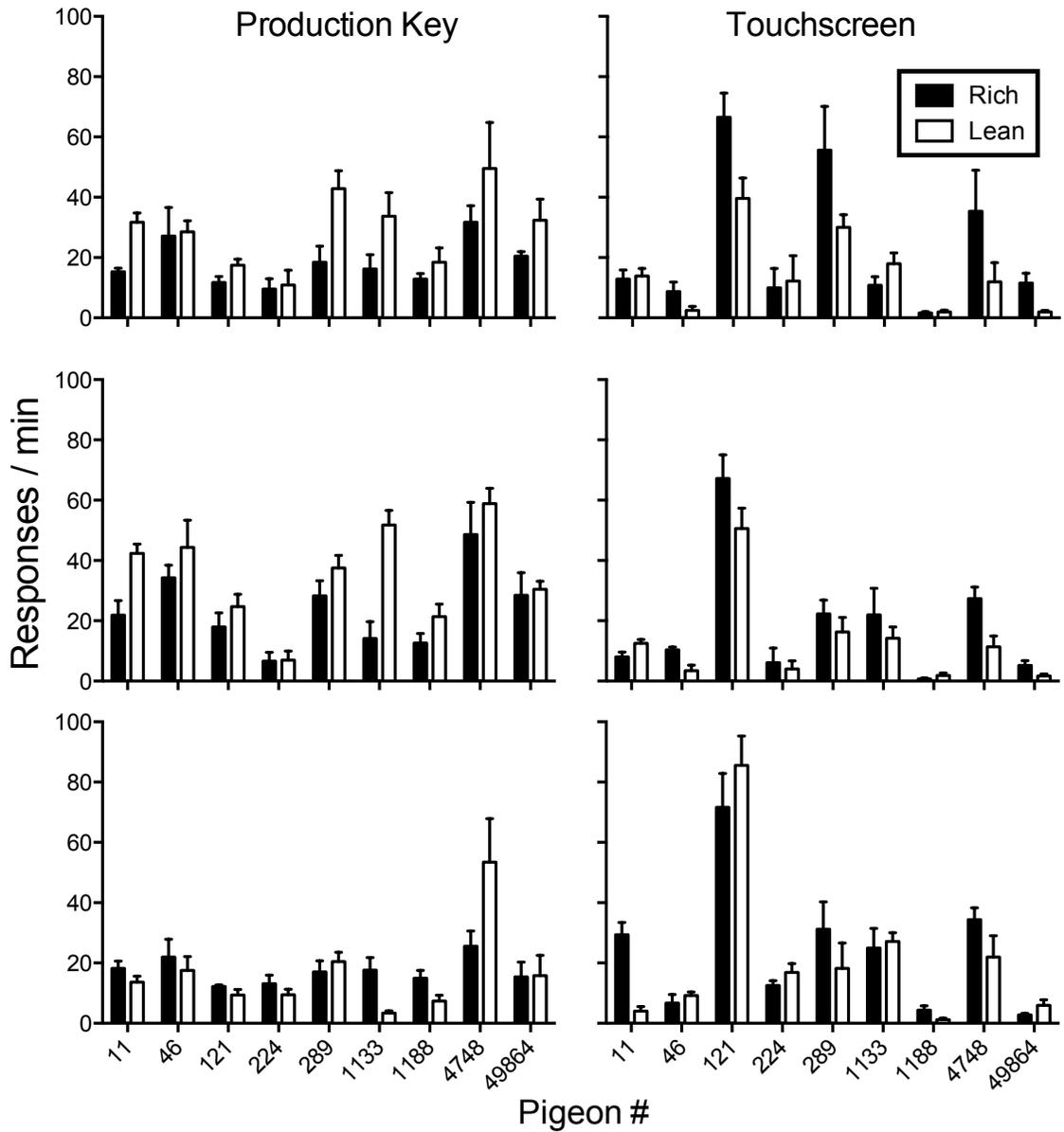

Figure 3. Baseline response rates on production key and touchscreen. Each bar represents the mean of the last five sessions of baseline. Error bars represent +1 *SD*. Rows represent Conditions 1-3 in descending order.
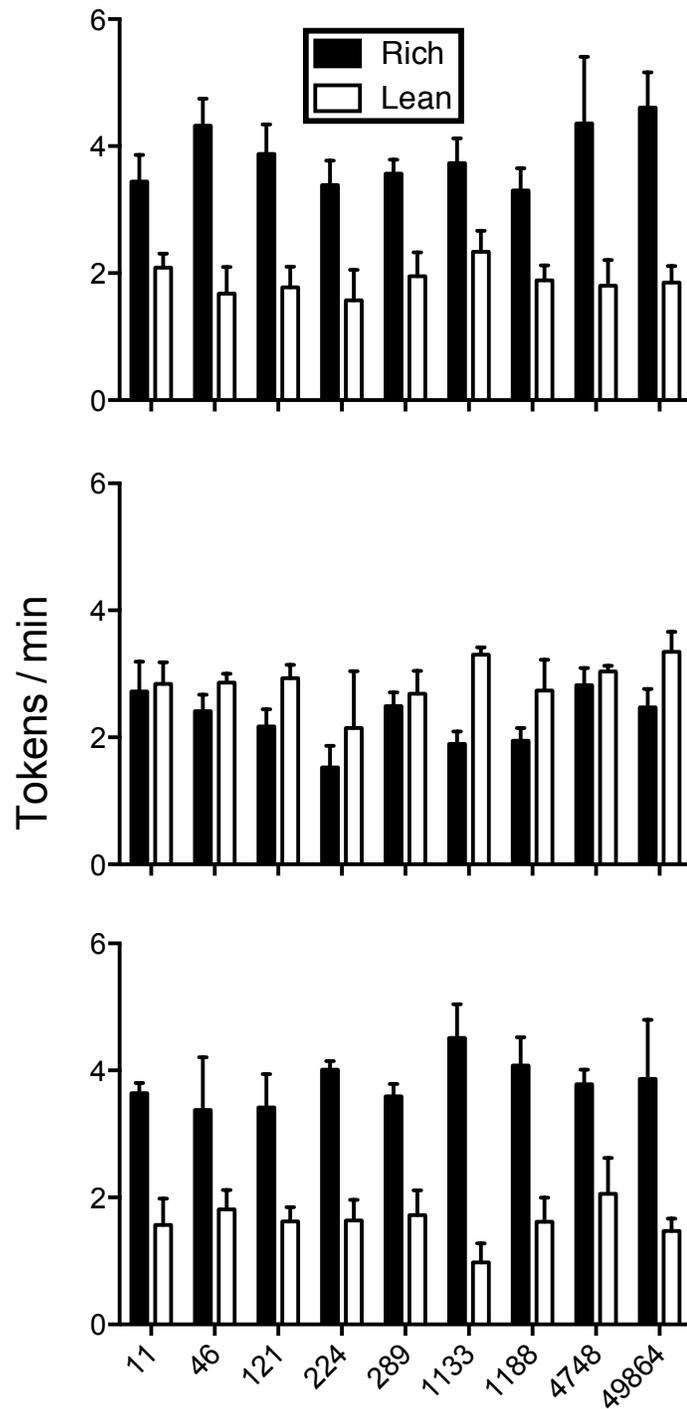
Figure 4. Obtained token reinforcement rates. Each bar represents the mean of the last five sessions of baseline. Error bars represent +1 *SD*. Panels represent Conditions 1-3 in descending order.

1, the average obtained token reinforcement rates in Rich and Lean components (M=3.84, SD=0.48; M=1.88, SD=0.23, respectively) did not approximate their programmed values of 12 per min in the Rich component and 3 per min in the Lean component, despite being in the direction of their programmed values. The same was true of obtained token rates in Rich and Lean components in Condition 3 (M=3.81, SD=0.36; M=1.61, SD=0.29, respectively). Analyses of responding to the production key and touchscreen within production components were conducted to assess potential sources of the discrepancy between programmed and obtained token rates. Pigeon 1188 was not included in visual, nor statistical, within-component analyses due to a recording error. Visual analyses of production-key and touchscreen responding for the last five sessions of each condition suggest that pigeons often responded on the production key until a token was earned, and then responded on the touchscreen for the remainder of the component. If pigeons earned a token in the first component, responding would shift from the key to the token displayed on the touchscreen until the component terminated, and then resume on the key in the subsequent component. If pigeons earned a token in the second component, responding would often shift from the key to the token until the component terminated and the exchange period began. However, pigeons' production-component touchscreen responding did not differ in the two production-components, and thus did not differentially impact production-key responding in either component.

The analysis in Figure 5 was conducted to assess whether touchscreen responding impacted response rates in one production-component to a greater extent than the other. Figure 5 shows the log ratio of average production-key response rates (Rich/Lean) in the

last five sessions of baseline plotted as a function of the log ratio of average touchscreen

response rates in the last five sessions of baseline for each baseline condition. There was

no tendency for production key response ratios to change as a function of touchscreen

response ratio in any of the three conditions. The tendency for off-key behavior is further

explored in analyses of exchange-period behavior.
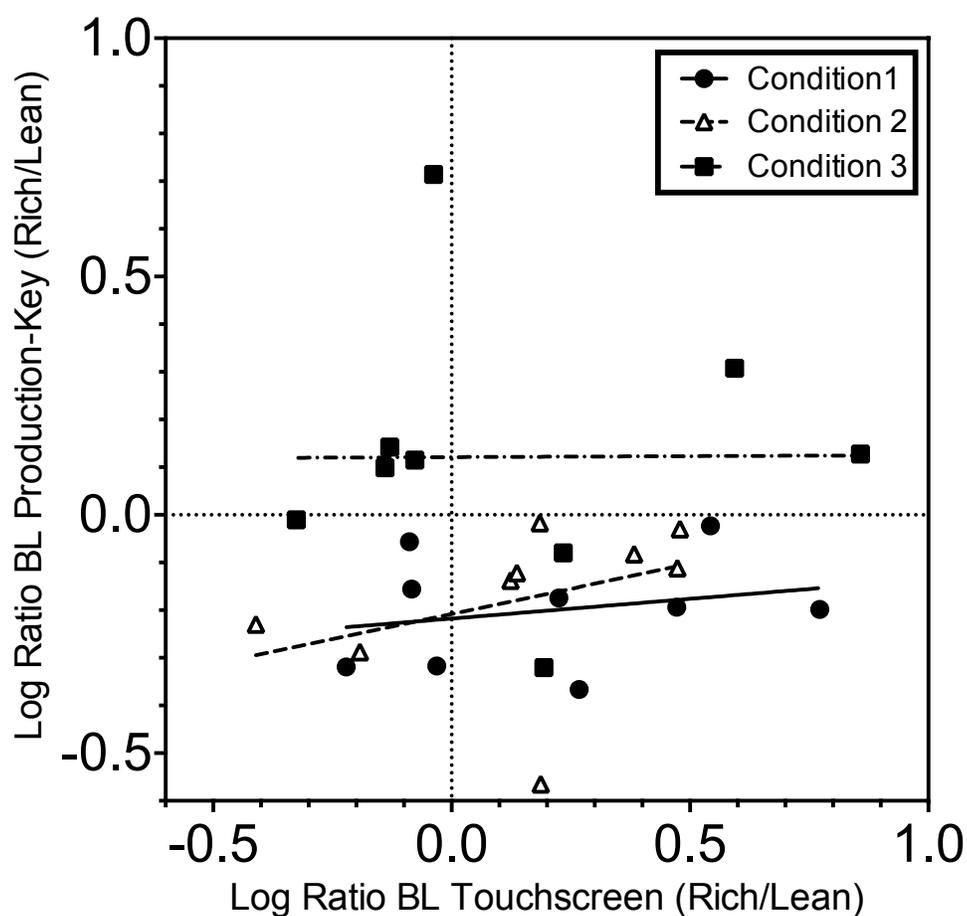
In exchange periods, pigeons tended to exchange the token displayed closest to

Figure 5. Production-key and touchscreen responding in baseline. Log ratio of baseline (BL) production-key response rates (Rich/Lean) plotted as a function of log ratio of BL touchscreen response rates (Rich/Lean). Each point represents the mean of the last five sessions of a baseline condition for an individual pigeon.

the response key and feeder first in exchange periods where tokens were available on both sides of the touchscreen (Figure 6). Across conditions, the average number of exchange periods in which tokens were available on both sides of the screen and the token on the left side of the screen was exchanged first was consistently greater than the number of exchange periods in which the token on the right side was exchanged first. A repeated-measures ANOVA found a significant main effect of component [$F(1, 7)$=6.46, p=0.039], as well as condition [$F(2, 14)$=4.67, p=0.028] suggesting that while the token on the left side of the screen was chosen first more frequently, the difference between first token location changed across conditions. However, a lack of interaction [$F(2, 14)$=1.10, p=0.360], and follow-up paired samples t-tests suggest the difference in location of initial token exchanged decreased across conditions, but remained in the same direction [Condition 1: $t(7)$=2.89, p=0.023; Condition 2: $t(7)$=2.17, p=0.066; Condition 3: $t(7)$=1.94, p=0.094].

The number of exchange periods in which one or more tokens were available on one side of the touchscreen, and no tokens had been earned on the other side, changed across conditions (Figure 6; bottom panel). A repeated-measures ANOVA revealed significant main effects of component [$F(1)$=336.13, p<0.001], condition [$F(2)$=36.07, p<0.001], as well as a significant interaction [$F(2)$=37.27, p<0.001], confirming that changes in token reinforcement rate across conditions were accompanied by changes in the number of exchange periods in which token were available on one side

of the touchscreen. Follow-up *t*-tests found differences in Conditions 1 and 3 [$t(7)=24.05$, $p<0.001$; and $t(7)=12.01$, $p<0.001$, respectively], as well as no difference in Condition 2 [$t(7)=0.418$, *ns*].
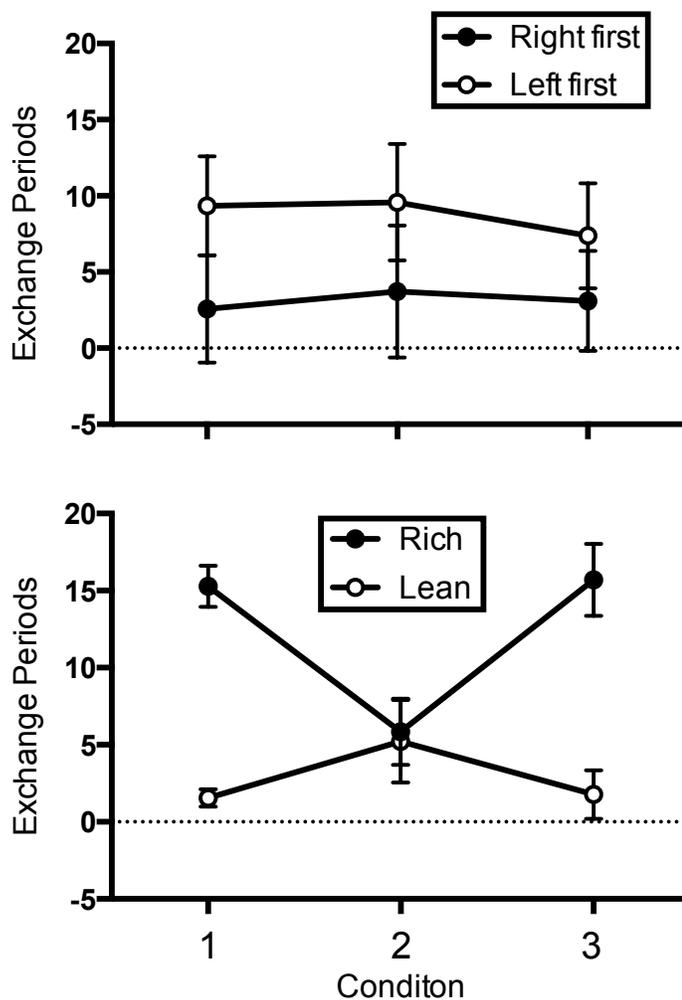

Figure 6. Exchange period responding across components. Mean number of instances in which a token from the left and right where exchanged first when tokens were available to be exchanged on both sides of the touchscreen across conditions (Top). Mean number of instances in which only one token was available to be exchanged from Rich and Lean components across conditions (Bottom; Rich and Lean denote keylight stimuli previously associated with differential reinforcement rates in Condition 2). Error bars represent ±1 *SD*. Note that *y*-axis starts at -5.

Prefeeding

Figure 7 shows mean proportion of baseline response rates for each session of disruption for Conditions 1 and 3 (12% and 8%, respectively). Proportion of baseline response rates are plotted on the top row, and log proportion of baseline response rates are plotted on the bottom row. Previous studies have used both expressions to assess resistance to change (Nevin & Shahan, 2011; Quick & Shahan, 2009). Separate two-way repeated measure ANOVAs for each prefeeding condition assessing proportion and log proportion of baseline were conducted to assess differences in component response rate as a function of session of disruption. For the proportion of baseline in the 12% prefeeding condition (top left panel), an ANOVA found no significant main effects of component [$F(1, 8)$=3.109, p=.116] or session [$F(4, 32)$=0.663, p=.643], and no interaction [$F(4, 32)$=0.614, p=.656]. For the proportion of baseline in the 8% prefeeding condition (top right panel), an ANOVA found no significant main effects of component [$F(1, 8)$=2.327, p=.116] or session [$F(4, 32)$=1.481, p=.231], and no interaction [$F(4, 32)$=1.078, p=.384]. For log proportion of baseline data in the 12% prefeeding condition (bottom left panel), an ANOVA found no significant main effects of component [$F(1, 8)$=1.019, p=.387] or session [$F(4, 32)$=2.818, p=.073], and no interaction [$F(4, 32)$=2.719, p=.080]. Finally, for the log proportion of baseline response rates for the 8% prefeeding condition (bottom right panel), an ANOVA found no significant main effects of component [$F(1, 8)$=0.076, p=.794] or session [$F(4, 20)$=1.976, p=.137], and no interaction [$F(4, 20)$=0.524, p=.719].

Figures 8 and 9 show individual-subject proportion of baseline response rates from presession feeding tests in Conditions 1 and 3, respectively. Proportion of baseline response rates from Condition 1 (12%; Figure 8) show a large amount of inter-subject variability. But, with the excep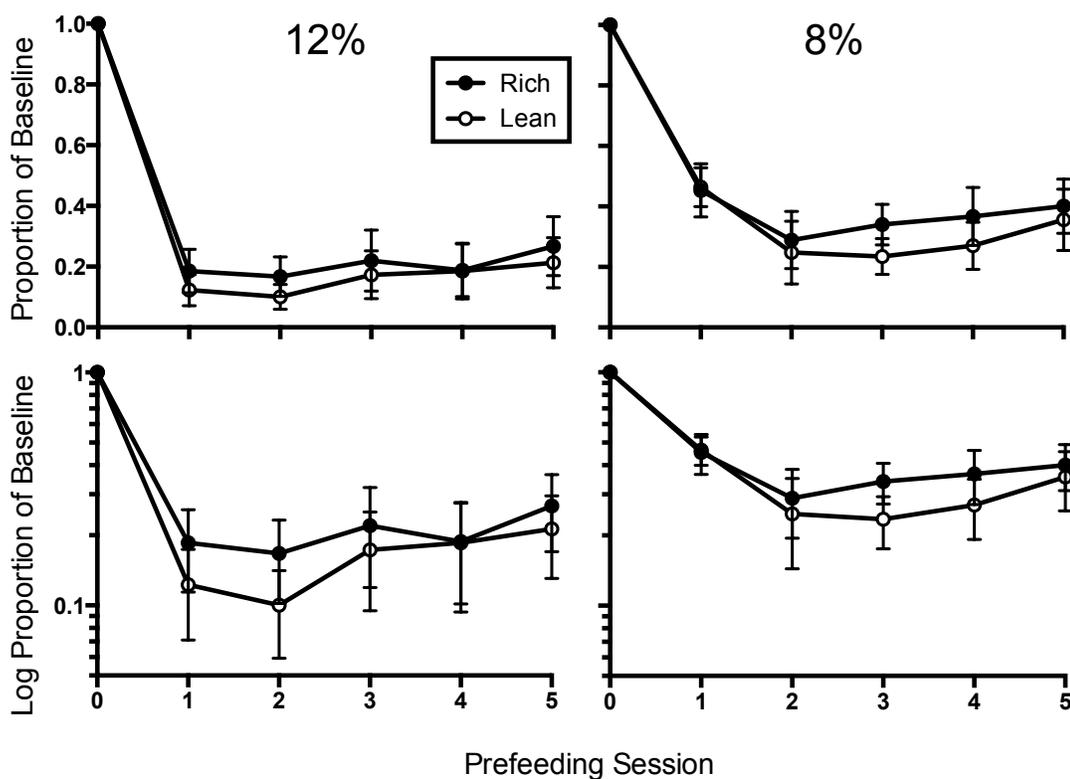tion of Pigeon 1133, response rates tended to be more resistant to change in the rich component. Proportion of baseline response rates from Condition 3 (8%; Figure 9) also show a large amount of inter-subject variability.

Figure 7. Average proportion baseline and log proportion baseline. The top row shows average proportion of baseline for all pigeon over sessions of prefeeding in 12% and 8% prefeeding conditions. The bottom row shows average log proportion of baseline for all pigeons over sessions of each prefeeding condition. Error bars indicate *SEM*.
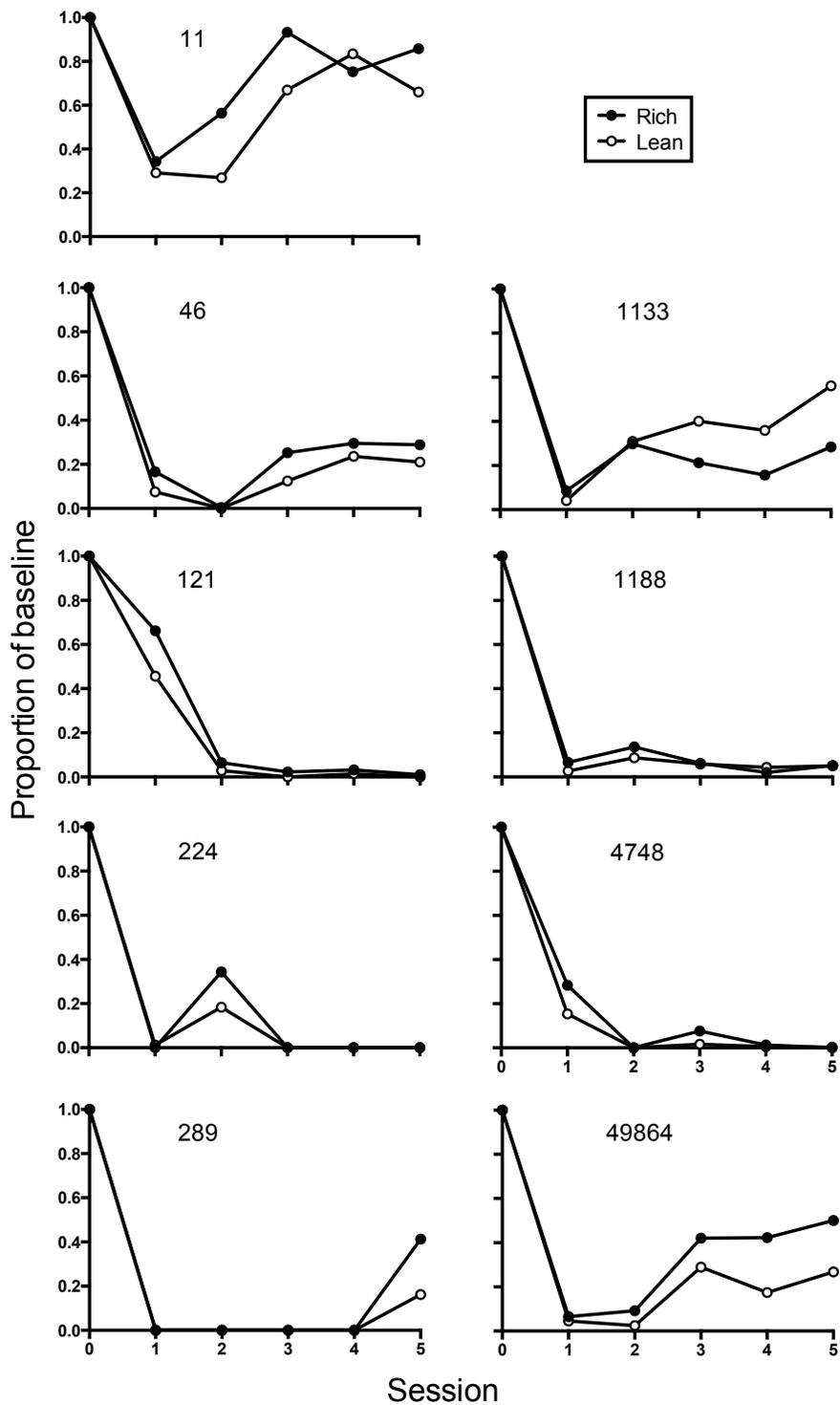
Figure 8. Proportion of baseline – Condition 1. Proportion of baseline response rates for each 12% prefeeding session in Conditon 1 for individual pigeons.
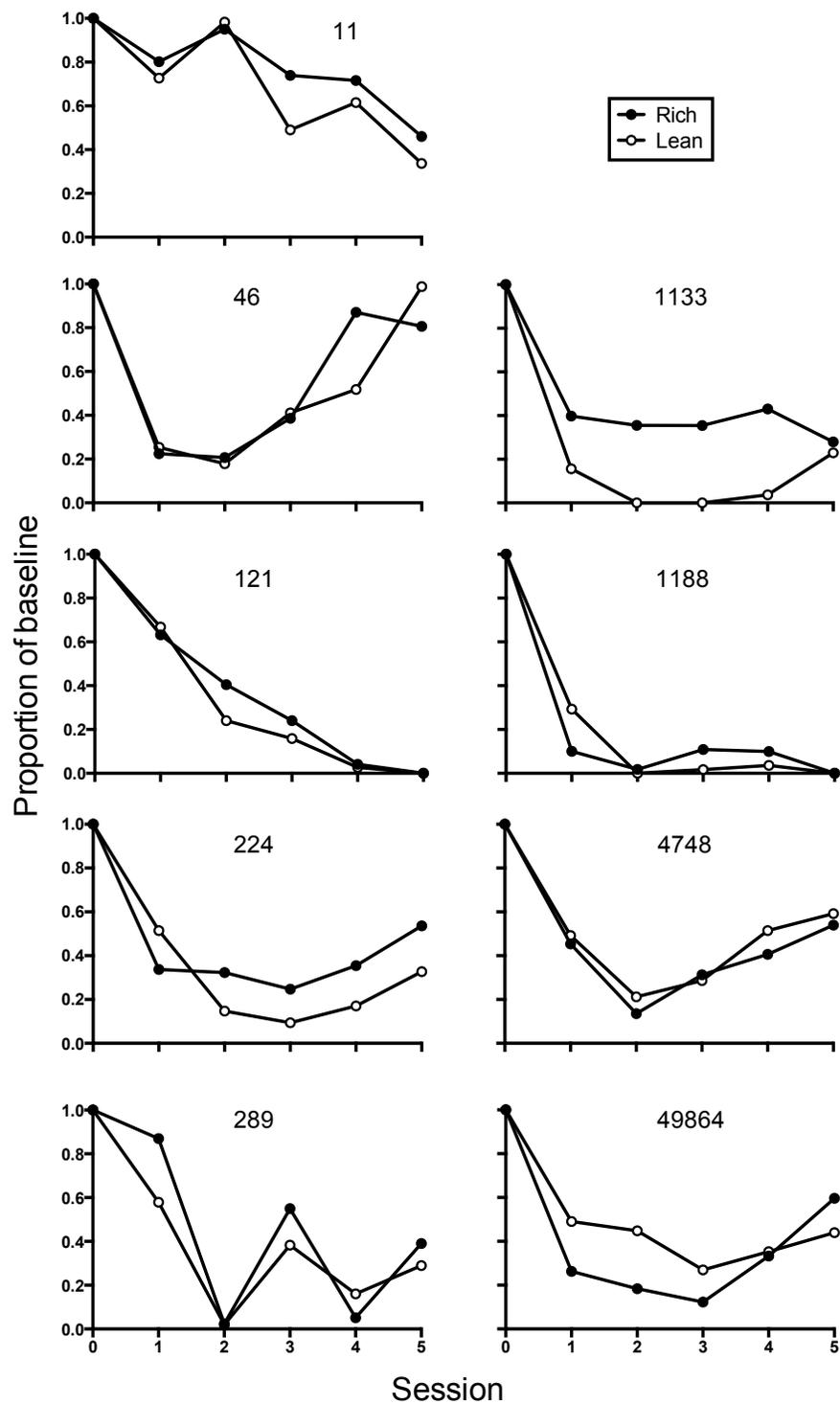
Figure 9. Proportion of baseline – Condition 3. Proportion of baseline response rates for each 8% prefeeding session in Conditon 3 for individual pigeons.

With the exception of Pigeons 1133 and 4748, response rates tended to be more resistant
to change in the Rich component. Despite a lack of statistical significance, individual
subject data suggest small differences in resistance to change in the direction of greater
resistance to change in the Rich component across sessions of prefeeding.

Figure 10 shows log proportion of baseline response rates as a function of
presession feeding amount for individual pigeons, and for the mean of all pigeons. There
was a large amount of inter-subject variability. However, log proportion of baseline
response rates tended to be higher in the Rich component across prefeeding conditions,
with the exception of Pigeons 1133, 4748, and 49864. Mean log proportion of baseline
response rates was higher in the Rich component in the two prefeeding conditions. The
small difference in mean log proportion of baseline was also present in the 12%
prefeeding condition, with the exception of Pigeons 1133 and 1188. A two-way repeated
measures ANOVA (prefeeding-by-component) on mean log proportion of baseline
response rates found significant main effects of prefeeding condition [$F(1, 8)=1.225$,
$p=0.020$] and component [$F(1, 8)=32.675$, $p<0.001$], and no significant interaction [$F(1,
8)=0.464$, $p=0.515$]. Thus, systematic differences in resistance to change were present
across the two disruptions, with responding in the Rich component tending to be more
resistant to change than in the Lean component.

Figure 11 shows the difference in mean log proportion of baseline response rates
for each pigeon for the five sessions of each prefeeding condition. Positive values
indicate greater relative resistance to change in the Rich component. Overall, resistance
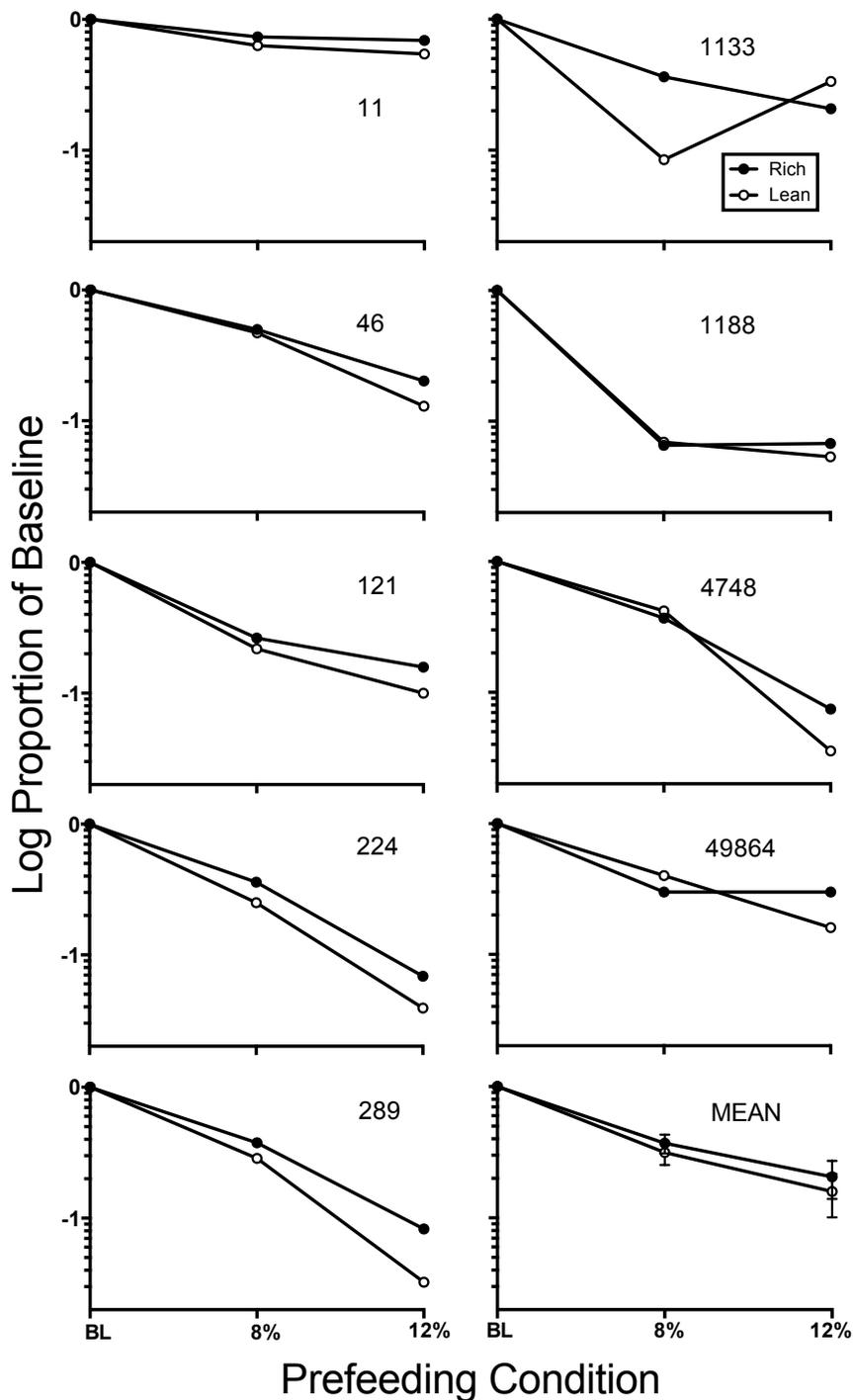to change tended to be greater in the Rich component. The top panel of Figure 11 shows

Figure 10. Mean log proportion baseline across conditions. Mean log proportion of baseline response rates plotted as a function of prefeeding amount for individual pigeons and the mean (*SEM*). Data points represent the log average proportion of baseline for Rich and Lean in each condition.
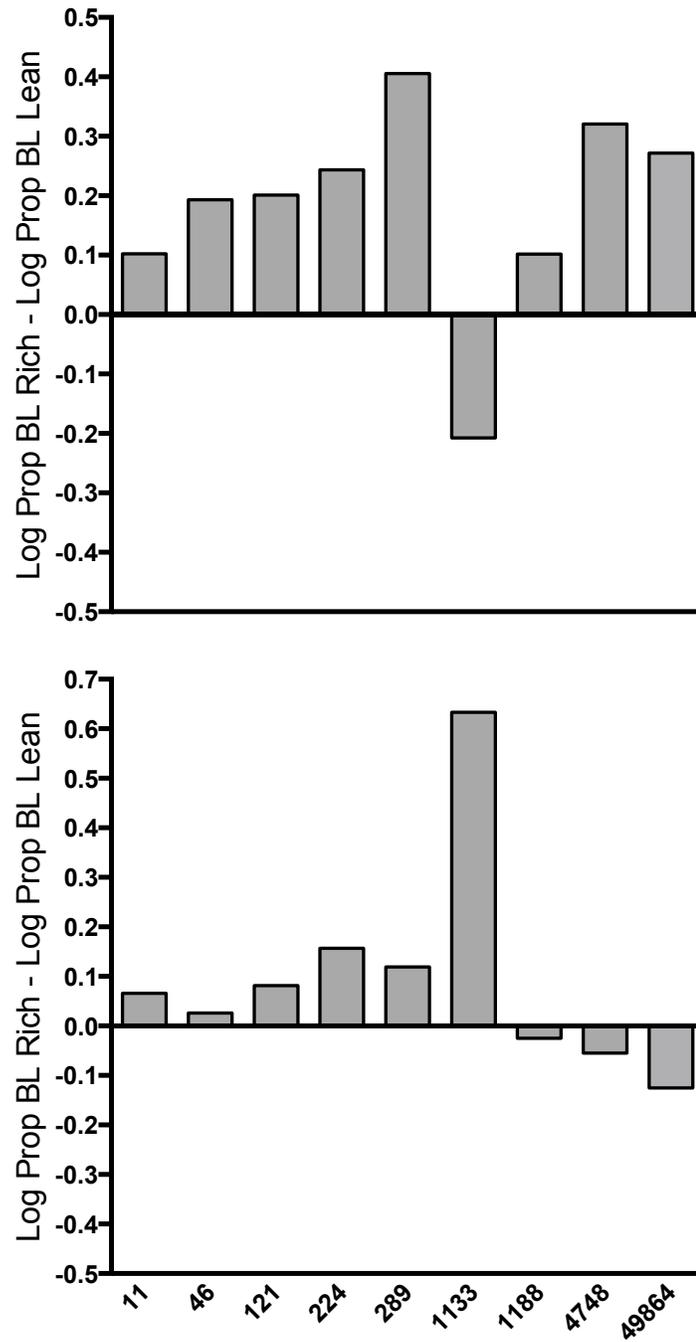
Figure 11. Relative resistance to change. The top panel presents the difference of log mean proportion baseline response rates in Rich and Lean components for all pigeons in the 12% prefeeding condition. The bottom panel presents the difference of log mean proportion baseline response rates in Rich and Lean components for all pigeons in the 8% prefeeding condition.

relative resistance to change results from the 12% prefeeding condition. With the exception of Pigeon 1133, resistance to change was greater in the Rich component for all pigeons. A nonparametric Wilcoxon signed-rank test found that the median difference in log (z=-0.201; p=0.039) proportion of baseline response rates was significantly different from zero. The bottom panel of Figure 11 shows relative resistance to change results from the 8% prefeeding condition. With the exception of Pigeons 1188, 4748, and 49864, resistance to change tended to be greater in the Rich component. Differences in log proportion of baseline were smaller in the 8% prefeeding condition in comparison to the 12% prefeeding condition, with the exception of an extreme value from Pigeon 1133. Indeed, a Wilcoxon signed-rank test showed that the difference in median log proportion of baseline did not differ from zero (z=-0.066; p=0.203).

Although Conditions 1 and 3 arranged identical reinforcement rates, there was variability in obtained token reinforcement rates (Figure 12). In order to determine if relative resistance to change was a function of relative obtained token reinforcement rates Figure 10 shows the difference in average log proportion of baseline response rates in Rich and Lean components in the two prefeeding conditions for each pigeon expressed as a function of the log ratio of average baseline obtained token reinforcement rates. Data points falling above zero indicate greater relative resistance to change in the Rich component. Of the 18 data points, four fall below zero. Linear regression slopes indicate a positive relation between relative resistance to change and relative token reinforcement rates for the 12% (1.268) and the 8% (1.448) prefeeding conditions. The slope of the regression line relating relative resistance to change to obtained token reinforcement rate

for the 8% prefeeding condition differed from zero [$F(1, 7)=11.780$, $p=0.011$], whereas

the slope for the 12% condition did not [$F(1, 7)=3.495$, $p=0.104$]. The two most extreme

data points come from Pigeon 1133. A follow up analysis in which Pigeon 1133 was

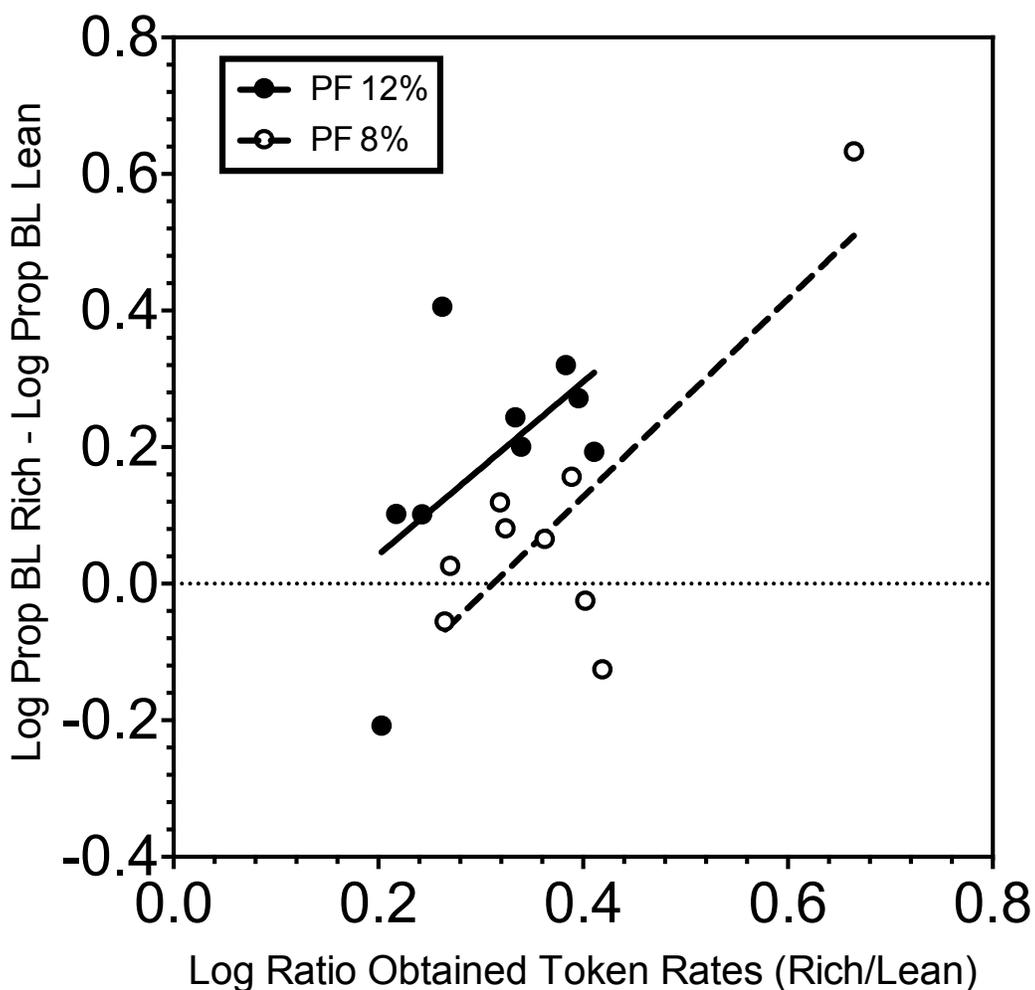excluded from the analysis in Figure 12 showed that linear regression slopes relating

Figure 12. Relative resistance to change and obtained token rates. The difference in log
proportion of baseline response rates for 8% and 12% prefeeding disruptions is plotted as
a function of the ratio of obtained log token reinforcement rates averaged for the last five
sessions of baseline in Rich and Lean components. Data points represent average log
proportion baseline for the five sessions of disruption in each prefeeding condition.

relative resistance to change to obtained token reinforcement rate no longer differed

significantly from zero (Figure 13).

Previous studies have shown reliable evidence of marginally greater resistance to

change when response rates are lower and all other variables are controlled (Nevin &

Grace, 2000b; Nevin, Grace, Holland, & McLean, 2001). Figure 14 shows the difference

in average log proportion of baseline response rates in Rich and Lean in the two

disruption conditions plotted as a function of the log ratio of the average response rates

from the five sessions prior to disruption. Data points falling above zero on the *y*-axis

indicate greater relative resistance to change in the Rich component. Data points falling

below zero on the *x*-axis indicate greater relative baseline response rates in the Lean

component. Of the 18 data points, four fall below zero on the *y*-axis and 12 fall below

zero on the *x*-axis. In Condition 1, response rates were reliably lower in the Rich

component, yet there was a weak positive relation across the limited range of response

rate difference. Linear regression slopes indicate a weak positive relation between

relative resistance to change and baseline response rates for the 12% prefeeding condition

despite the limited range of response rate difference {0.248; did not differ from zero

[$F(1, 7)=0.197, p=0.670$]}. Importantly, for the 8% prefeeding condition there was a

reliable positive relation {0.610; different from zero [$F(1, 7)=11.270, p=0.012$]}. Thus,

small differences in resistance to change above were not likely due to lower baseline

response rates in the Lean component alone. Finally, when extreme values from Pigeon

1133 were excluded in a follow-up analysis of Figure 14, data no longer provided

evidence in favor of a positive relation between relative resistance to change and log ratio

of baseline response rates in Condition 1 (Figure 15). Instead, the relation in Figure 15

suggests that resistance to change in the Rich component tended to decrease as relative

response rate increased in the Rich component. Thus, the significant difference in

resistance to change in Condition 1 may be attributed to lower baseline response rates in
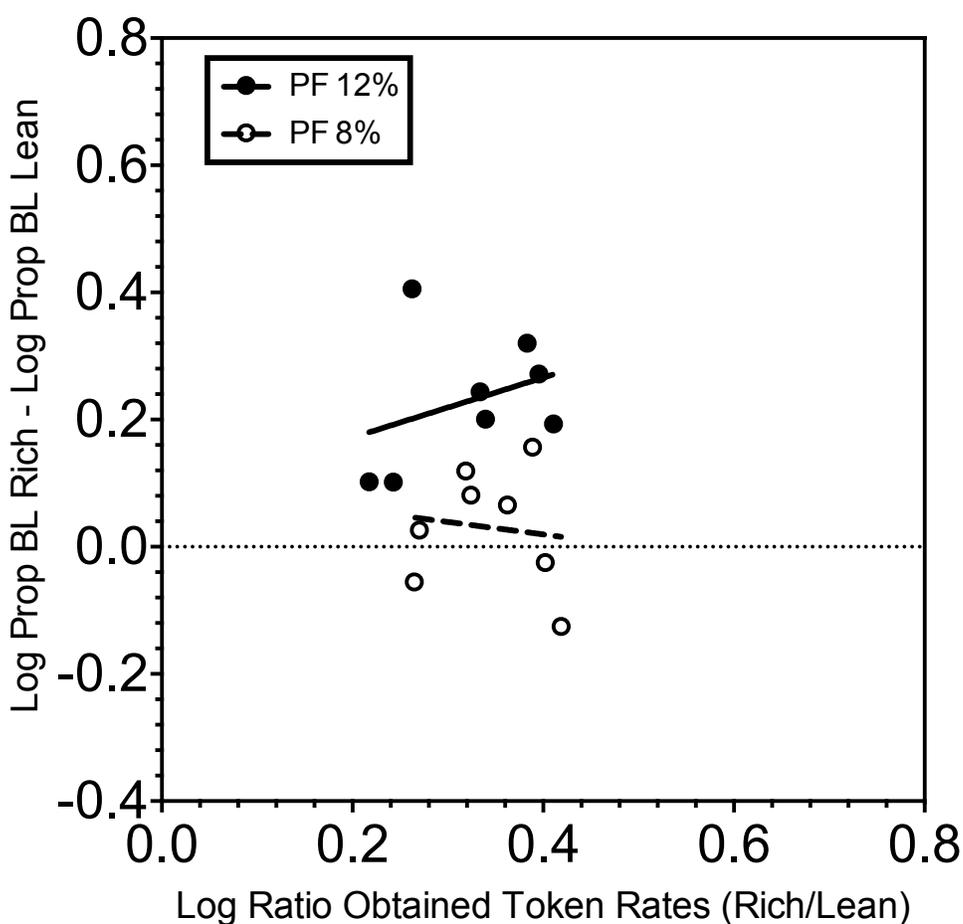
the Rich component.

Figure 13. Relative resistance to change and obtained token rates excluding Pigeon 1133.
The difference in log proportion of baseline response rates for 8% and 12% prefeeding
disruptions is plotted as a function of the ratio of obtained log token reinforcement rates
averaged for the last five sessions of baseline in Rich and Lean components. Data points
represent average log proportion baseline for the five sessions of disruption in each
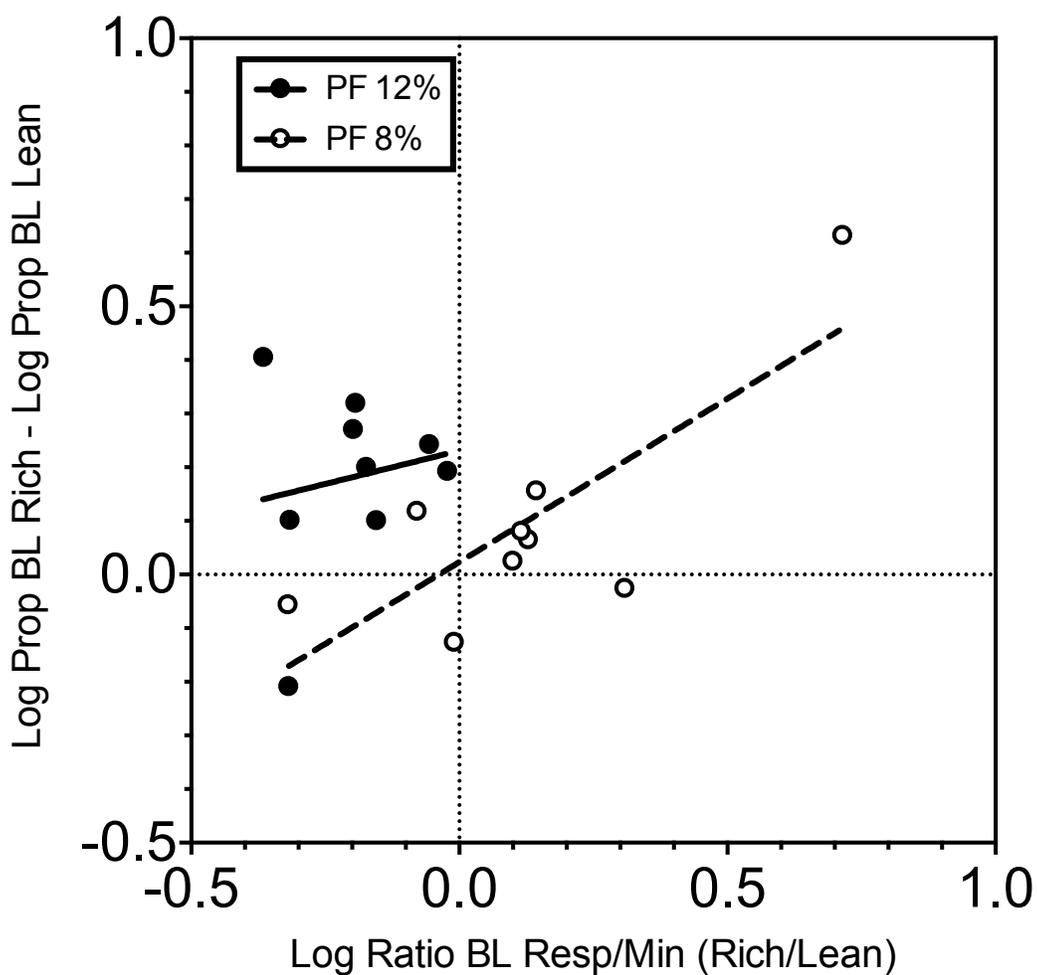prefeeding condition for all pigeons, with the exception of Pigeon 1133.

Figure 14. Relative resistance to change and relative baseline response rates. The difference in log proportion of baseline response rates for 8% and 12% prefeeding disruptions plotted as a function of the log ratio of baseline (BL) response rates averaged for the last five sessions of baseline in Rich and Lean components. Data points represent average log proportion baseline for the five sessions of disruption in each prefeeding condition.
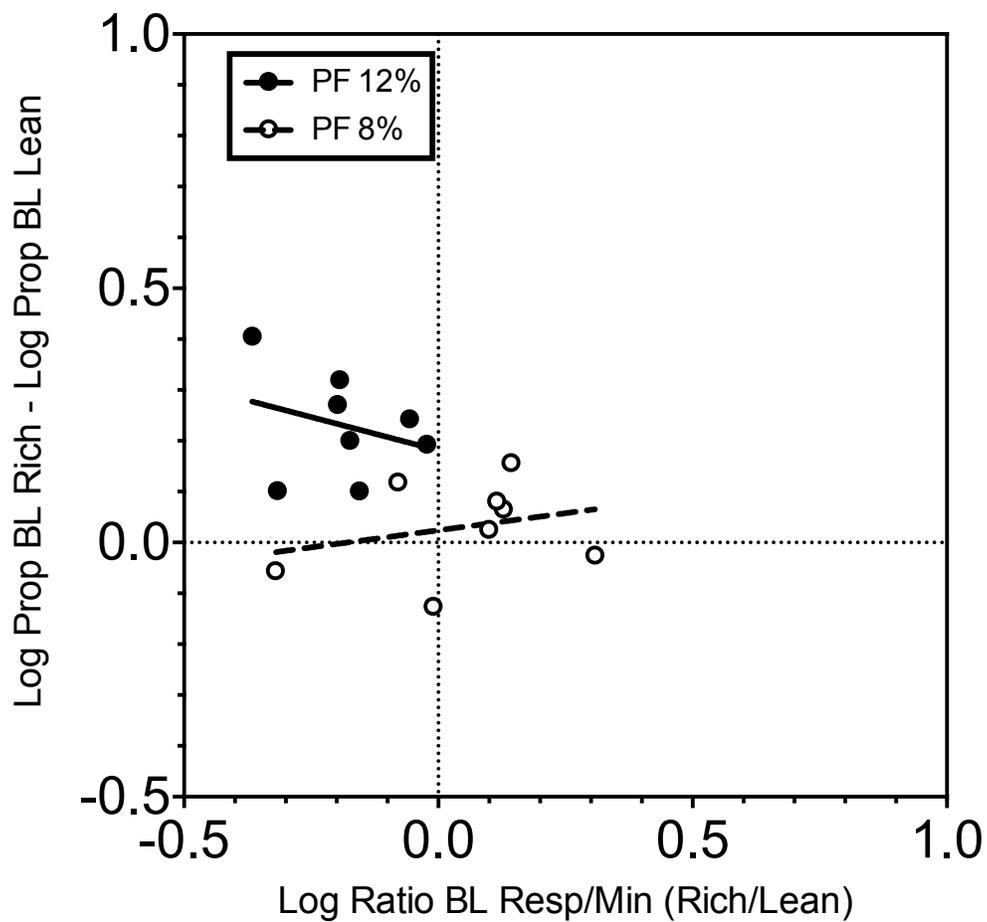
Figure 15. Relative resistance to change and relative baseline response rates excluding Pigeon 1133. The difference in log proportion of baseline response rates for 8% and 12% prefeeding disruptions plotted as a function of the log ratio of baseline (BL) response rates averaged for the last five sessions of baseline in Rich and Lean components for all pigeons, with the exception of Pigeon 1133. Data points represent average log proportion baseline for the five sessions of disruption in each prefeeding condition.

DISCUSSION

The present research was conducted as an attempt to develop a novel procedure for studying the persistence of behavior maintained by conditioned reinforcement in pigeons. Previous studies showed higher rates of conditioned reinforcement, either tokens or S+, to maintain higher rates of responding in a manner predicted by the matching law (Herrnstein, 1970). However, studies of the resistance to change of responding maintained by conditioned reinforcement have produced mixed results.

With pigeons responding on chained schedules of reinforcement, Nevin et al. (1981) found greater resistance to change in an initial link associated with higher magnitude terminal link reinforcement. However, rate of terminal-link primary reinforcement was dependent on rate of initial-link responding. With the observing response procedure, Shahan and Podlesnik (2005) found no differences in resistance to change despite differences in baseline observing rates. Yet, conditioned and primary reinforcement were presented in the same component stimulus context.

The present multiple-schedule of token reinforcement procedure was developed as a novel approach to the analysis of resistance to change of responding maintained by conditioned reinforcement. Rate of primary reinforcement was not affected by production-component response rates, and primary reinforcement was never delivered in a token-production component. Thus, the present study was an attempt to improve on limitations of prior studies in order to assess potential response-strengthening effects of conditioned reinforcement (Shahan, 2010).

Higher rates of token production were expected to maintain higher production-response rates. Previous studies of token reinforcement have shown higher token production rates to maintain higher response rates (Hackenberg, 2009; Kelleher, 1957). Additionally, higher rates of conditioned reinforcement have been shown to maintain higher response rates in the observing-response procedure (Shahan & Podlesnik, 2005; Shahan et al., 2006). However, the present study found higher production-response rates in a component arranging a relatively lower rate of token production when programmed rates differed in Condition 1.

Baseline production response rates in Condition 1 were unexpected given the prevailing body of research on conditioned reinforcement showing that relatively higher rates of conditioned reinforcement maintain higher response rates (Shahan & Podlesnik, 2005; Shahan et al., 2006). In Condition 2, token reinforcement rates were equated to assess whether higher response rates in the Lean component in Condition 1 were due to the differences token reinforcement rate. Response rate differences decreased in Condition 2, yet the tendency for higher response rates in the formerly Lean component was present in three of nine pigeons. However, once differential token reinforcement rate was reinstated in Condition 3, response rates tended to be higher in the Rich component.

However, response rate data from Condition 3 suggest a tendency for pigeons to respond at a higher rate in the presence of one keylight color. Production component stimuli in Condition 3 were reversed such that keylight color signaling Rich in Condition 1 signaled Lean, and vice versa. For the majority of pigeons (11, 46, 121, 224, 1133, and 1188), response rate was higher in the presence of one of the keylight stimuli across all

conditions, which may account for higher response rates in the Lean component in Condition 1 and response rate differences in Condition 2. For other pigeons, response rates tended to show control by token reinforcement rate in the direction of higher response rates in the Lean component in Conditions 1 and 3 (289 and 4748), or become nondifferential across conditions (49864). Keylight colors may have influenced response rates such that the majority of pigeons responded at a higher rate in the presence of one color across conditions, suggesting that token reinforcement rates had little impact on response rates. There are several potential explanations for these findings.

The only report that may inform the tendency for higher baseline response rates in the Lean component in Condition 1 is a study of preference in pigeons responding on concurrent-chain schedules (Schuster, 1969). In Schuster's study, pigeons were presented with a choice between two response keys. Completing the schedule requirement on either key would result in access to a terminal link where food reinforcement could be earned according to a VI schedule. In one terminal link, responses produced stimuli (blue light and buzzer) paired with food reinforcement, whereas in the other terminal link responses produced the same stimuli paired with food, plus additional stimulus presentations that were not followed by food according to an FR 11 schedule. Stimuli were presented more frequently in the terminal link with added stimulus presentations. If the stimuli functioned as conditioned reinforcers, pigeons would be expected to prefer the terminal link with additional stimuli. However, the results showed that the pigeon preferred the terminal link in which the stimulus was paired with the primary reinforcer. These findings have been interpreted in favor of a functional view of conditioned reinforcement.

According to the functional view, a stimulus will function as a conditioned reinforcer only when it reliably predicts a primary reinforcer (Rachlin, 1976; Shahan, 2010). Otherwise, stimuli lacking functional utility or informativeness with respect to primary reinforcement may not serve to maintain behavior, or be preferred in comparison to stimuli with functional relevance.

The present study arranged a token economy in which tokens were exchangeable for the same primary reinforcement and consisted of identical stimulus properties, but were earned at different rates in two components. The results from Condition 1 clearly show a higher rate of token-production responding in the component arranging a lower rate of token reinforcement. Superficially, these results suggest that less frequent conditioned reinforcement maintained higher response rates, in line with Schuster's functional analysis. Yet, this interpretation is flawed on two accounts; more frequent tokens directly translated to more primary reinforcement, and further within-component analyses suggest that the presence of tokens on the touchscreen interfered with responding to produce tokens.

The present procedure was designed to isolate conditioned reinforcement from primary reinforcement. Previous studies of the resistance to change of responding maintained by conditioned reinforcement have either allowed parameters of primary and conditioned reinforcement to vary together (Nevin et al., 1981), or primary and conditioned reinforcement to be delivered in the same stimulus context (Shahan & Podlesnik, 2005, 2008a). Both preparations allow for explanation of the presence or absence, respectively, of a response-strengthening effect of conditioned reinforcement in

terms of variations of primary reinforcement. The present procedure arranged separate stimulus contexts and responses for conditioned and primary reinforcement; responding for conditioned reinforcement did not affect the delay to primary reinforcement, and primary reinforcement was never delivered as a consequence for the response that delivered conditioned reinforcement. However, while avoiding limitations of previous studies, this arrangement allowed for interaction between the two responses by providing visual feedback in the form of token accumulation on the touchscreen monitor during production components.

Pigeons demonstrated a preference for exchanging the token closest to the response key and pellet receptacle first when tokens could be exchanged from either side of the touchscreen. However, this preference was not absolute, and varied across pigeons. Analyses of within-component behavior to the response key and touchscreen revealed that once a token was produced (i.e., visible on the left or right portions of the touchscreen), pigeons began responding on the token. Instances of the first token exchanged coming from the right side (far, with respect to the pellet receptacle) of the touchscreen occurred, almost exclusively, when a token was present on the right side of the touchscreen in the component immediately preceding an exchange component. Since tokens were delivered at a higher rate in the Rich component, tokens were often produced earlier. By switching to respond on the touchscreen, pigeons effectively reduced production-key response rates and limited obtained token reinforcement in both token production components.

Yet, despite the competing behavior to the touchscreen, obtained token reinforcement rates differed in the two production components, and token reinforcement occurred at a higher rate in the presence of the Rich component stimuli. In addition, competing behavior to the touchscreen did not impact production-key responding differentially in the two components. According to behavioral momentum theory, the Pavlovian relation between component stimuli and reinforcement determines resistance to change (Nevin & Grace, 2000a). The impact of response-reinforcer relations and stimulus-reinforcer relations are separable, and thought to determine response rate and resistance to change independently (Nevin et al., 1990). Thus, results from presession feeding tests suggest whether token reinforcement in the presence of production-component discriminative stimuli affected response strength.

Tokens tended to be earned earlier in Rich production components, allowing more time for behavior to the touchscreen to interfere with production-key responding. Also, when token-reinforcement rate was varied, many exchange periods consisted of only Rich tokens available for exchange. Yet, primary reinforcement was delivered only in exchange periods, and despite a lack of effect of token reinforcement rate on production-key response rates, production-key responding tended to be more resistant to change in the component arranging a higher baseline rate of token reinforcement. Results from disruption tests in Condition 1 support a response-strengthening account of conditioned reinforcement on the individual subject level. However, this apparent difference in resistance to change was not consistent across measures. When mean proportion of baseline response rates were compared across sessions, response rates did

not differ in the two components. Once extreme values from Pigeon 1133 were removed, there was no evidence of a positive relation between token reinforcement rate and resistance to change.

Token reinforcers in the present study differed from tokens typically studied in token economies with animals, and conditioned reinforcers generally, in several important ways: (1) Earning a token did not affect delay to primary reinforcement; (2) The number of tokens earned did not affect delay to exchange; and (3) Tokens earned in the two components were identical in every stimulus dimension aside from the rate at which they were earned and location on the screen. Thus, on average, on the individual-subject level, and in the absence of variables often conflated in prior studies (Nevin et al., 1981; Shahan & Podlesnik, 2005, 2008a), the present results provide support for the notion that token reinforcement rate impacted response strength, as indexed by resistance to change.

However, differences in resistance to change were small. Additionally, pigeons responded on the touchscreen at varying rates during each component. Indeed, pigeons could have earned a token in a production-component and responded on the token for the remaining duration of the prior to the exchange component, and effectively changed the token-reinforcement procedure into a chained-schedule of reinforcement. This possibility was not controlled for, and may be attributed to the effort to maintain response rates by employing short component durations. Importantly, early training conditions using longer durations were not effective at maintaining production-key response rates. Suggesting

that, in order to maintain behavior, the short delay between production and exchange in the terminal baseline may have had to necessarily function as a response chain.

Shahan and Podlesnik (2008b) noted that a failure of second-order conditioning might account for the absence of an effect of conditioned reinforcement rate and value on resistance to change in observing studies. In the observing response procedure, observing behavior is established through a first-order Pavlovian association between S+ and food. Thus, resistance to change, which depends on the association between component stimulus context and reinforcement (Nevin & Grace, 2000a), would depend upon a second-order Pavlovian association between component stimulus context and S+. Thus, due to a hypothesized lack of sensitivity of measures, Shahan and Podlesnik (2005, 2008a, 2008b) suggested that the framework of behavioral momentum theory might not provide an appropriate assessment of conditioned reinforcement strength.

In the context of this hypothesis, the present study attempted to arrange no such first-order Pavlovian association between tokens and food in the presence of production-component stimulus contexts, which would have necessarily arranged a first-order Pavlovian association between component stimulus context and obtained rate of token reinforcement. According to this hypothesis, tokens were first-order conditioned stimuli with respect to the response for food during exchange components; the keylight colors were first-order conditioned stimuli with respect to token reinforcement rate in the presence of production component stimuli. Therefore, the present study had the potential to suggest two predictions for the study of response strength maintained by conditioned reinforcement: (1) Resistance to change is an appropriate measure of response strength

when only first-order Pavlovian relations are arranged; and (2) In the case of resistance to change of responding maintained conditioned reinforcement, a second-order relation in the case of observing-response procedures, resistance to change may be overshadowed in the presence of a first-order relation (i.e., a response maintained by primary reinforcement; Pearce & Hall, 1978; Williams & Dunn, 1991). However, the seeming inability of tokens *themselves* to maintain responding prevents strong predictions.

Applied significance

The present procedural developments have potential utility for investigating several variables commonly found to affect outcomes of contingency-management based interventions. Studies have found that differences in value produce differences in treatment outcomes (Garcia-Rodriguez et al., 2009; Higgins et al., 2007; Petry et al., 2004; Silverman, Chutuape, Bigelow, & Stitzer, 1999). Additionally, studies have shown differences in treatment outcomes when using probabilistic incentives, with higher probability incentive conditions yielding a greater percentage of cocaine-free urine samples (Ghitza et al., 2008). The role of contingency is also important in increasing drug abstinence in contingency management interventions (DeFulio, Donlin, Wong, & Silverman, 2009; Ghitza et al., 2008; Higgins et al., 2000; Roll, Reilly, & Johansen, 2000). For example, Higgins et al. (2000) compared cocaine-dependent individuals who received vouchers contingent on drug-negative urine samples to individuals who received noncontingent vouchers. Individuals in the contingent-voucher condition maintained drug-abstinence longer than individuals in the noncontingent condition (approximately

45% at 8 weeks compared to 30%, 38% at 12 weeks compared to 10%, and 20% at 16 weeks compared to 10%). Posttreatment assessments found 20% of individuals in the contingent group to be drug-abstinent compared to 5% in the noncontingent group at 18 months. The present procedure improves on the flexibility of earlier procedures for studying token reinforcement in pigeons (Hackenberg, 2009). Basic studies of token reinforcement using arrangements informed by the present study could further investigate these variables, and generate useful predictions for treatment studies.

The present results suggest that higher rates of incentive delivery may impact treatment effectiveness. This prediction is consistent with previous incentive studies that varied delivery schedules. Ghitza et al. (2008) reported that cocaine-dependent individuals in a prize-based intervention with a high probability of winning were more likely to remain abstinent than a similar group of individuals who experienced a lower probability of winning. Despite similar results with respect to rate of token/prize delivery, similar token-related behavior would not be expected for humans and pigeons. Species differences in token-related behavior between humans and pigeons make direct comparisons impossible. Yet, it is important to note that, despite a large amount of intrusion from pigeons' instinctive behavioral repertoires in the present study, small but inconsistent differences in resistance to change present during both disruptions were consistent with findings in human studies.

Limitations

Tokens were visible during components and attracted considerable amounts of behavior. Previous studies of token-reinforcement with pigeons arranged an array of LED lights as tokens that illuminated sequentially (Bullock & Hackenberg, 2006; Foster & Hackenberg, 2004; Lagorio & Hackenberg, 2010; Pietras & Hackenberg, 2005; Raiff, Bullock, & Hackenberg, 2008). Also, the procedures used in the studies of Hackenberg and colleagues effectively prevented pigeons from interacting with token reinforcers by making exchange contingent on responses to a key, and not on responses to tokens themselves.

The ability of reinforcement-related stimuli to attract the behavior of pigeons is a well-known phenomenon (Brown & Jenkins, 1968). Intrusion of instinctive behavioral repertoires is a well-documented phenomenon in token reinforcement procedures with non-humans as well (Boakes et al., 1978; Breland & Breland, 1961). In the present study, touchscreen responding in production components reduced time allocated to responding on the production key, as well as obtained token-reinforcement rates. Off-key behavior differed from earlier studies that found interference by instinctual behavioral patterns in that overall rate of token production, not delay to exchange, was effected by handling tokens. However, early training phases with longer component durations were ineffective for maintaining production key behavior, and by decreasing the component durations pigeons may have been able to bridge delays to primary reinforcement. Experimental events were periodic, though a low rate of production key responding was required to earn reinforcement. Thus, the prevalence of off-key behavior may also be a result of an

interaction of the tendency of pigeons to sign-track and the periodicity of the arranged schedule of experimental events (Falk, 1966). If a pigeon were responding on a token during a production-component immediately preceding an exchange period, the token would disappear during the 2 s ICI and reappear to be exchanged for the next peck. Thus, some token-directed behavior during production components was possibly due to adventitious reinforcement (see Killeen & Pellón, 2013 for review). Whether the results of the present study would have been different if pigeons' interactions with tokens were prevented warrants further investigation.

The difference in baseline response rates found in Condition 1 was not replicated in Condition 3. This failure to replicate suggests that higher response rates in the Lean component may have been influenced by prior training conditions or been an artifact of the tendency for tokens to be earned sooner in a Rich component, instead of an aversive aspect of higher rate of conditioned reinforcement (Rachlin, 1976; Schuster, 1969). Generally, there was a large amount of variability in baseline response rates across pigeons that could be attributed to pigeons' off-key behavior within components. Future studies could investigate methods for reducing off-key behavior, such as punishment contingencies for within-component touchscreen behavior, or manipulations of token appearance during components.

Presession feeding is the most common disrupter used for assessing resistance to change (Nevin, 1974; Nevin & Grace, 2000a). Similar results would be expected if behavior in the present procedure were to be disrupted with extinction, or ICI food, and replication is desirable given the concerns raised by the prevalence of within-component

behaviors. The flexibility of the present procedure allows for flexibility in disruptive manipulations. Extinction would be especially interesting; extinction could be conducted by discontinuing token reinforcement in production components, or by preventing tokens from being exchanged. A hallmark finding in conditioned reinforcement studies is that conditioned reinforcers act to prolong extinction (Kelleher, 1961; Kelleher & Gollub, 1962). This finding has been replicated in a multiple schedule of observing-response procedures arranging different rates of primary reinforcement (Thrailkill & Shahan, 2012), but has not been studied when conditioned reinforcement rate is varied in a multiple schedule. Resistance to change tends to be consistent across types of disruption (Nevin & Grace, 2000a), yet whether similar results would be observed with different extinction methods or ICI food in the present procedure warrants further investigation.

Training phases of the present study found that early versions of the present procedure would not maintain high response rates when production components were 30 s or 60 s. Thus, while comparatively higher production-response rates were maintained, production components were brief in comparison to multiple-schedule component length typically reported (e.g., Shahan & Podlesnik, 2005, 2008a). The length of the components could have influenced whether pigeons would respond to the key or on the touchscreen in such a manner that a token may have signaled a delay to primary reinforcement and functioned as a bridging stimulus (Williams, 1994a). Indeed, tokens attracted considerable behavior when present on the touchscreen during a production component. However, earlier variations of the procedure were unable to generate sufficient behavior for meaningful analysis, and pigeons' obtained rates of token

reinforcement were higher in the Rich component in Conditions 1 and 3. Thus, whether tokens functioned to bridge delays, their presence did not affect delay to primary reinforcement, but could have effectively functioned as a response chain. Once a token was earned, pigeons often switched to respond on the touchscreen for the remainder of the component, and because the ICI was short, could have exchanged the token by continuously responding on the touchscreen. Future research should address further improvements to the present procedure to maintain sufficient behavior, while controlling off-key behavior to allow pigeons' obtained token reinforcement rates to approximate programmed rates.

Future Directions

Pigeons' behavior to the touchscreen during production components limited obtained token reinforcement rate. In typical studies of resistance to change with different rates of response-dependent primary reinforcement, there is a positive relation between baseline response rates and resistance to change (Nevin, 1974). Different rates of conditioned reinforcement also maintain different rates of responding (Kelleher, 1956; Shahan & Podlesnik, 2005). Clearer differences in baseline production-response rates would be expected to produce clearer differences in resistance to change, and strengthen the conclusion that conditioned reinforcement rate impacts response strength. Thus, it is important for future studies to explore methods of demonstrating control by baseline production-response rates by token reinforcement rates.

One potential solution to the problem of token reinforcement rates maintaining different response rates during production components is to provide feedback in the form of brief token presentations. Tokens earned in a production component could be presented briefly as feedback for responding, but then be made invisible until the exchange component. Brief stimuli are known to be effective in maintaining responding in chained schedules (Williams, 1994a, 1994b).

Another approach would be to enforce a punishment contingency for touchscreen responding during components. A response cost contingency could be introduced as a training condition to reduce within-component touchscreen behavior. For example, a response-cost contingency would punish a response to a token during a production component by subtracting that token when a response is detected. Response-cost punishment contingencies have been found to be effective in suppressing behavior maintained by conditioned reinforcement (Pietras & Hackenberg, 2005; Raiff et al., 2008), and the present procedure has potential utility for future investigations of the putative function of token-loss as a conditioned punisher.

Physical characteristics of tokens were controlled in the present study, the appearance of tokens produced in each component were identical during production- and exchange-components. The only cues to whether tokens were earned in a Rich or Lean component were the keylight color and position of the tokens on the touchscreen. Future studies could manipulate token size, color, or shape to provide a broader range of discriminative stimuli. Thus, studies could investigate control by discriminative properties of the tokens other than location on the touchscreen. For example, tokens

earned could be presented as a different shape and/or color in the production components (e.g., circle/blue), and change to a different color and/or in the exchange component (e.g., square/yellow). Such a manipulation would provide additional discriminative stimuli for when tokens are eligible to be exchanged and potentially mitigate within-component touchscreen behavior by providing a stimulus that is never associated with primary reinforcement. The present procedure is extremely flexible in terms of ability to program different stimuli to be presented on the touchscreen (e.g., size, color, photographs, shape, and movement). Thus, these are several routes of future study to ensuring token production-response rates reflect programmed token reinforcement rates.

In addition, the present procedure allows for interesting manipulations of properties of token reinforcers that may impact resistance to change. Voucher magnitude has been shown to influence abstinence in contingency-management based treatments (Silverman et al., 1999). The present procedure could be adapted to arrange tokens associated with different magnitude primary reinforcers. Additionally, similar results with tokens associated with primary reinforcers of different magnitude would provide a systematic replication of results found by Nevin et al. (1981) with chained schedules in a procedure in which delay to primary reinforcement would not vary with responding for conditioned reinforcement.

Finally, the present procedural arrangement and, perhaps, token reinforcement in general may be better suited for study in human participants. While the present study was aimed at extending study of resistance to change to token reinforcement procedures in animal subjects, whom are the typical subject involved in basic behavioral research. The

innate behavioral repertoire of pigeons introduced limitations in performance and interpretation. Indeed, there is growing support for procedures designed to take into account, and concern for results in studies that conflict with organisms' innate behavioral tendencies (Gallistel, 2012; Timberlake & Lucas, 1985). Importantly, despite these concerns and without measures taken to interfere with pigeons' repertoires, the present study was not able to provide equivocal evidence for or against a response-strengthening account of conditioned reinforcement. Future studies are needed to address whether the introduction of punishment contingencies on sign-tracking, or added discriminative stimuli, would either decrease variability in the result, or produce different results entirely. The present study provides a basis for comparison.

Conclusion

The present dissertation developed a novel procedure for investigating behavior maintained by token reinforcement in a touchscreen apparatus. The procedure was designed to address procedural limitations in prior studies, and was successfully implemented with pigeons. However, there were shortcomings to be addressed in future studies. Tokens are a means to an end in obtaining primary reinforcement, by definition. Tokens in the present study differed from stimuli that are traditionally thought of as conditioned reinforcers in that they neither signal conditions of primary reinforcement, nor signal a decrease in delay to primary reinforcement. However, delays separating the delivery of a token and the opportunity to exchange were small. Additionally, interactions with the conditioned reinforcer were required in order to produce primary reinforcement,

thus pigeons interacted with tokens to the extent that overall reinforcement was decreased. Although the goal of finding unequivocal support, or lack thereof, of the influence of conditioned reinforcement rate on resistance to change of token-maintained responding was not met, a small difference in resistance to change suggests that token reinforcement rate may have affected response strength. Token-maintained behavior tended to be more persistent in the presence of stimuli associated with a relatively higher rate of token reinforcement, but the potential of the present procedural arrangement to function as a chain schedule prevented firm conclusions. Future studies are needed to address within-component competition between token-production and touchscreen responding. Response cost punishment and stimulus manipulation have the potential to decrease production-component response competition, increase obtained token-reinforcement rate, and allow for further assessments of resistance to change of responding maintained by conditioned reinforcement. This procedure has great potential for further refinement, providing a flexible testing ground for basic behavioral processes, and for providing useful insights for existing treatment approaches.

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PUBLICATIONS

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(7) **Thrailkill, E. A.,** & Shahan T. A. (2012). Resistance to change and relapse of
        observing. *Journal of the Experimental Analysis of Behavior, 97,* 279-302.
 (6) Podlesnik, C. A., **Thrailkill, E. A.**, & Shahan, T. A. (2012). Differential
        reinforcement and resistance to change of divided attention performance. *Learning
        & Behavior, 40,* 158-169.

(5) Podlesnik, C. A., Jimenez-Gomez, C., **Thrailkill, E. A.,** & Shahan, T. A. (2011). Temporal context, preference, and resistance to change. *Journal of the Experimental Analysis of Behavior, 96,* 191-213.

(4) Barker, D. J., Sanabria, F., Lasswell, A., **Thrailkill, E. A.,** Pawlak, A. P., & Killeen, P. R. (2010). Bright light as a practical aversive stimulus for the albino rat. *Behavioural Brain Research, 214,* 402-408.

(3) Sanabria, F., **Thrailkill, E. A**., & Killeen, P. R. (2009). Timing with opportunity cost: Concurrent schedules improve peak timing. *Learning & Behavior, 37*, 217-229.

(2) Sanabria, F., & **Thrailkill, E.** (2009). Pigeons (*Columba livia*) approach Nash Equilibrium in Experimental Matching Pennies Competitions. *Journal of the Experimental Analysis of Behavior, 91*, 169-183.

(1) Killeen, P. R., Posadas-Sanchez, D., Johansen, E. B. & **Thrailkill, E. A.** (2009). Progressive ratio schedules of reinforcement. *Journal of Experimental Psychology: Animal Behavior Processes, 35,* 35-50.

In Preparation

Thrailkill, E. A., & Shahan, T. A. Extinction, relapse, and behavioral momentum II: Novel stimuli, incubation, and spontaneous recovery.

Thrailkill, E. A., & Shahan, T. A. Resistance to change of responding maintained by token reinforcement

Thrailkill, E. A., & Shahan, T. A. Resistance to change and renewal of ethanol self-administration in rats

Thrailkill, E. A., & Shahan, T. A. Resistance to change of sign-tracking

Thrailkill, E. A., & Shahan, T. A. Resurgence of extinguished cocaine-seeking in non-deprived rats

Thrailkill, E. A. & Shahan, T. A. Temporal information and appetitive pavlovian conditioning.

RESEARCH INTERESTS
- Conditioned reinforcement
- Animal models of relapse
- Drug self-administration
- Behavioral momentum theory
- Pavlovian conditioning

PRESENTATIONS

Chaired symposia
Conditioned Reinforcement. (2010, May) Symposium held at the annual meeting of the Association for Behavior Analysis International, San Antonio, TX.

Paper presentations

Thrailkill, E. A. & Shahan T. A. Extinction, relapse, and behavioral momentum II: Novel stimuli, incubation, and spontaneous recovery. Paper presented at the annual meeting of the Association for Behavior Analysis International, Minneapolis, MN.

Thrailkill, E. A. & Shahan T. A. Resistance to change and renewal of rats' alcohol self-administration. Paper presented at the 2011 Intermountain Graduate Research Symposium, Logan, UT.

Thrailkill, E.A. & Shahan T. A. Resistance to change and relapse of observing. Paper presented at the annual meeting of the Association for Behavior Analysis International, San Antonio, TX.

Thrailkill, E. A. & Shahan T. A. Reinstatement, renewal, and resurgence of observing: Analogs of relapse of attending. Paper presented at the 2010 Intermountain Graduate Research Symposium, Logan, UT.

Poster presentations

Thrailkill, E. A. & Shahan, T. A. (2012, May). Behavioral momentum and disinhibition of extinguished operant responding. Poster presented at the meeting of the Society for Quantitative Analysis of Behavior, Seattle, WA.

Thrailkill, E. A., Podlesnik, C. A., & Shahan, T. A. (2010, May). Resistance to change of divided attention performance. Poster presented at the meeting of the Society for Quantitative Analysis of Behavior, San Antonio, TX.

Thrailkill, E.A., & Shahan T.A. (2010, April). Resistance to change of Pigeon sign tracking behavior. Poster presented at the meeting of the Four Corners Association for Behavior Analysis, Park City, UT.

Thrailkill, E.A., Podlesnik, C.A., & Shahan, T.A. (2009, March). Divided attention and the matching law: Compound sample performance is sensitive to variations in relative reinforcement experienced with the elements alone. Poster presented at the 2009 Intermountain Graduate Research Symposium, Logan, UT. (Awarded Best Poster Presentation)

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TEACHING

Undergraduate
      Psy 3400: Analysis of Behavior: Advanced, Spring 2013
      Psy 3400: Analysis of Behavior: Advanced, Fall 2012
      Psy 3400: Analysis of Behavior: Advanced, Spring 2012

PROFESSIONAL ACTIVITIES

<u>Editorial Activities</u>
 Ad Hoc Reviewer for:
  Journal of the Experimental Analysis of Behavior
  Psychology & Neuroscience
<u>Mentorship</u>
 2006 *Mentor,* Barrett Summer Scholars Program
   Arizona State University, Tempe, AZ
<u>Undergraduate Research Supervision</u>
 Spring, 2013 – Christina Stacey, Psy 3400 laboratory assistant, Psy 4950
 Spring, 2013 – Brianna Fernandez, Psy 3400 laboratory assistant, Psy 4950
 Spring, 2013 – Jordan Tait, Psy 3400 laboratory assistant, Psy 4950
 Fall, 2012 – Andrew Adams, Psy 3400 laboratory volunteer
 Fall, 2012 – Jordan Hansen, Psy 3400 laboratory assistant, Psy 4950
 Fall, 2012 – McKay Mattingly, Psy 3400 laboratory assistant, Psy 4950
 Summer, 2012 – Lance Hinton, Psy 3400 laboratory assistant, Psy 4950
 Summer, 2012 – Eric Milman, Psy 3400 laboratory volunteer
 Spring, 2012 – Ashley Humphries, Psy 3400 laboratory volunteer
 Spring, 2012 – Melissa Ballard, Psy 3400 laboratory assistant, Psy 4950
 Fall, 2011 – Eric Richardson, Psy 3400 laboratory assistant, Psy 4950
 Fall, 2008 – Bistra Bogoev, Psy 3400 laboratory assistant, Psy 4950
<u>Member</u>
 Association for Behavior Analysis International
 Society for the Quantitative Analysis of Behavior

REFERENCES

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