PREDICTORS OF PERSISTENCE AND RESURGENCE: EVALUATION OF A
BEHAVIORAL MOMENTUM-BASED APPROACH

by

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ABSTRACT

Predictors of Persistence and Resurgence: Evaluation of a
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Utah State University, 2014

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The basic behavioral process of operant conditioning contributes to problem behaviors in psychological disorders. Escape from aversive situations in depression, the rewarding effects of drugs in substance abuse, and the receipt of caregiver attention for disruptive behavior in intellectual or developmental disabilities are just a few examples of operant reinforcement contingencies that perpetuate undesirable behavior. Behavioral treatment strategies often introduce alternative sources of reinforcement for a desirable alternative behavior. Although treatments can be effective, alternative reinforcement removal can trigger relapse of the problem behavior, called resurgence. Persistence in alternative reinforcement treatments and resurgence can be understood from the prospective of behavioral momentum theory, which predicts greater operant persistence and resurgence when there is a greater history of reinforcement associated with the context in which an operant response occurs. Shahan and Sweeney incorporated resurgence into the framework of behavioral momentum theory, and the proposed model
makes explicit qualitative and quantitative predictions that are tested in this dissertation.
Chapter 1 provides the background and significance of resurgence of operant behavior, and gives an introduction to behavioral momentum theory and the quantitative model of resurgence. Chapter 2 reports two recently published experiments that show increased time with alternative reinforcement treatment reduces subsequent resurgence in an animal model with pigeon subjects. The study presented in Chapter 3 examined how persistence and resurgence may be affected when alternative reinforcement is delivered in a novel context. This experiment, which used rat subjects, integrated and compared the animal model of resurgence with another operant relapse phenomenon, renewal, in which context change alone is known to induce relapse of a previously reduced response. Chapter 4 describes a study with college undergraduates as participants that tested the feasibility of a brief, three-alternative, forced-choice procedure as a human operant model of resurgence. Despite procedural manipulations of the length of training and probability of reward for choice of the target stimulus, resurgence was never consistently observed. Chapter 5 provides an integrative discussion of these research topics.
PUBLIC ABSTRACT

Predictors of Persistence and Resurgence: Evaluation of a Behavioral Momentum-Based Approach

by

Mary M. Sweeney, Doctor of Philosophy
Utah State University, 2014

Mary M. Sweeney, graduate student in the Experimental and Applied Psychological Sciences program at Utah State University, will complete this dissertation as part of the requirements of the degree of Doctor of Philosophy in Psychology.

One approach to reducing a behavior with a history of reward is to remove the reward for the target behavior to be reduced and introduce reward for an alternative behavior. When alternative reward is removed, though, relapse termed resurgence can occur. The broad purpose of this dissertation is to examine the variables that contribute to the persistence and resurgence of a behavior. The results of two experiments with pigeons suggest that the longer reward is removed for the target and alternative reward provided, the less resurgence should occur. Relapse can also occur when there is a change in environment or context from when the behavior was successfully reduced, called renewal. One study with rats as subjects proposed a novel methodology for studying resurgence and renewal together, and suggests alternative reward delivered in a different context does not make relapse worse than alternative reward removal or context
change alone. The final study was conducted with college undergraduates, and attempted
to develop a procedure for studying resurgence in adult humans that could easily test the
generality of resurgence studies with animals. Although the participants’ behavior was
shaped by reward, resurgence was never observed on the target beyond a control response
that was never associated with reward.
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CHAPTER 1

INTRODUCTION

Operant Behavior

Intuitively, we understand that behavior is shaped by its consequences. If a behavior gives a person access to a rewarding consequence, then we expect an increase in the frequency of that behavior. We take advantage of this understanding of behavior in our own lives in many manifestations, as parents, employers, or pet-owners, and attempt to guide desirable behavior by access to rewards. If a child completes weekly chores, the child receives an allowance. If an employee exceeds a production quota, the employee earns a monetary bonus. When a dog performs a trick, the dog earns a pat on the head or a tasty treat. Behavioral scientists understand the guiding relationship between behavior and consequences in terms of responses and reinforcers. The response is the behavior (e.g., completing chores, exceeding a quota, performing a trick) and the reinforcer is the consequence that shapes the behavior (e.g., an allowance, a monetary bonus, a treat).

The process by which reinforcers come to shape behavior is known as instrumental (Thorndike, 1927) or operant (Skinner, 1953) conditioning. Thorndike observed as cats improved their time to escape from a puzzle box with experience, and called the phenomenon the law of effect (Thorndike, 1898). The law of effect states that given experience in a situation, such as the puzzle box, the responses of an organism that are followed closely by satisfaction will be more likely to reoccur when the situation occurs again than those behaviors that were not rewarded. Thus, with repeated
experience in the same puzzle box, cats were faster in producing the response that satisfied them with escape. Skinner popularized the phenomenon described by the law of effect as operant conditioning. In this view, operant conditioning occurs when a response produces a reinforcer. Providing reinforcement contingent upon a particular response increases the probability that the response will occur again. In addition, the reinforcement of a response occurs within a certain context, and information about the surrounding world when reinforcement occurs is also part of operant conditioning (Skinner, 1953). Thus, operant behavior can be summarized by the following three-term contingency,

\[ S^O : R \rightarrow S^R \]

where \( S^R \) is the reinforcer contingent upon the response \( R \), and \( S^O \) is the discriminative stimulus context in which reinforcement takes place.

A common laboratory demonstration of operant conditioning is a pigeon’s behavior in a mechanical- or computer-controlled box, better known as an operant chamber. Inside the operant chamber is a wall that has one or more response keys. Say that when the key is illuminated with a red hue, the pigeon can peck at the key and is reinforced by the delivery of food into the chamber, whereas when the key is illuminated with a green hue, no food is available. One would expect the pigeon to learn that pecks in the presence of the red key produce food and those in the presence of the green key do not. This is reflected in behavior as more pecks in the presence of the red key relative to pecks in the presence of the green key. In this example, the red hue serves as the discriminative stimulus, in the presence of which the response (pecking) produces the
reinforcer (food). Similarly, the verbal command “Sit,” when given while training a dog, serves as a discriminative stimulus for the food reinforcement contingent upon the dog’s response of sitting.

**Operant Problem Behavior**

Arguments for the scientific study of operant behavior would not be particularly compelling if these phenomena were limited to the behavior of household pets and laboratory animals. Operant contingencies, however, are in place to shape a variety of human behaviors that serve as major public health concerns. For example, some researchers suggest depression can result in part from low rates of response-contingent reinforcement (Ferster, 1973; Lewinsohn, Sullivan, & Grosscup, 1980) and characterize depression symptoms of inactivity and withdrawal as avoidance behavior that provide individuals an escape from difficult situations (Jacobson, Martell, & Dimidjian, 2001). Although inactivity and withdrawal may provide temporary respite, isolation can worsen depression symptoms, perhaps by reducing the likelihood that an individual will encounter an alternative source of reinforcement for social interaction (Dimidjian, Barrera, Martell, Muñoz, & Lewinsohn, 2011). Depression is a major risk factor for suicide, which recently exceeded traffic collisions as the leading cause of injury mortality in the United States (Rockett et al., 2012). Given the lifetime prevalence for a major depressive episode is 19.2% in the United States (Kessler & Bromet, 2013), understanding the basic learning processes that may contribute to depression is important.

In individuals with intellectual or developmental disability, problem behaviors
such as aggression, self-injury, property destruction, and disruption may also be
maintained in part by contingent reinforcement (Carr & Durand, 1985; Iwata, Dorsey,
Slifer, Bauman, & Richman, 1994). For example, Schmidt, Drasgow, Halle, Martin, and
Bliss (2013) treated problem behavior in a nine-year-old boy with autism and profound
intellectual disability. He engaged in aggression (forceful hitting, kicking, pushing, and
pinching or throwing objects at others) because engaging in acts of aggression allowed
him to escape unpleasant tasks. Another 15-year-old participant diagnosed with autism,
severe intellectual disability, depressive disorder, and psychotic disorder (not otherwise
specified) cursed and made sexual statements and was aggressive in order to gain access
to caregiver attention (Schmidt et al., 2013). Two recent studies that systematically
assessed the presence of challenging behaviors in samples with autism suggest that
challenging behavior can occur at rates as high as 96% in these populations (Jang,
Dixon, Tarbox, & Granpeesheh, 2011; Kozlowski, Matson, & Rieske, 2012). Because
intellectual and developmental disabilities are prevalent (Boyle et al., 2011), and problem
behaviors occur at higher levels in these populations, it is important to develop effective
treatment strategies that take into account an understanding of the operant contingencies
that may affect the frequency of challenging behavior.

Substance abuse is also maintained in part by the basic behavioral processes of
operant conditioning (Higgins, Silverman, & Heil, 2008; O’Brien, Childress, Ehrman, &
Robbins, 1998). Drug use is shaped by its consequences, whether it is the positive
hedonic effects of drugs or the alleviation of withdrawal symptoms (Everitt & Robbins,
2005). The 2010 National Survey on Drug Use and Health conducted by the Substance
Abuse and Mental Health Services Administration (SAMHSA, 2010) estimated that 8.7% (22.1 million) of the U.S. population aged 12 or older were classified as substance dependent or substance abusers according to the DSM-IV criteria (American Psychiatric Association, 2000). More than 1.9 million Americans were admitted to substance abuse treatment in 2009 alone (SAMHSA). Drug abuse not only negatively affects the health of drug users, but also burdens our society through loss of productivity, health expenses, and the cost of drug-related crimes. From an economic standpoint, the National Drug Intelligence Center (NDIC, 2011) estimated that in 2007 alone, illicit drug abuse cost the United States more than $193 billion. To put this number in perspective with other major health issues, drug use costs the U.S. more money than diabetes ($174 billion) or obesity ($147 billion).

**Treatments Using Alternative Reinforcement**

Given the contributions of basic behavioral processes in perpetuating problem behavior in psychological disorders, behavioral treatments often incorporate aspects of operant conditioning. One strategy to reduce operant problem behavior is the introduction of an alternative source of reinforcement. In such alternative reinforcement treatments, the function of the problem behavior is identified, and an alternative, socially acceptable behavior or source of reinforcement is introduced. For example, behavioral treatments of depression such as behavioral activation make efforts to increase engagement in positive activities associated with the experience of pleasure or mastery (Dimidjian et al., 2011) as well as focus on the function of avoidance behavior (Carlbring
et al., 2013; Dimidjian et al., 2006). Another example of alternative reinforcement intervention is contingency management treatment of substance abuse. In an effort to compete with the reinforcing effects of drugs, contingency management provides reinforcement such as vouchers for goods and services (Lussier, Heil, Mongeon, Badger, & Higgins, 2006) or access to employment (DeFulio, Donlin, Wong, & Silverman, 2009) contingent upon drug abstinence. To combat problem behavior in individuals with intellectual or developmental disabilities, the reinforcer maintaining the problem behavior is assessed with a functional assessment, and then that reinforcer is introduced contingent upon a socially appropriate alternative behavior. This approach is called differential-reinforcement of alternative behavior, and has been demonstrated to effectively reduce the operant problem behavior in many cases (Lloyd & Kennedy, 2014; Petscher, Rey, & Bailey, 2009).

**Resurgence**

Although behavioral treatments can be effective when the interventions are in place, problem behavior can relapse when alternative reinforcement is removed or reduced post-treatment (Dobson et al., 2008; Higgins et al., 2007; Volkert, Lerman, Call, & Trosclair-Lasserre, 2009). In operant conditioning, relapse following the removal of alternative reinforcement is called resurgence (Epstein & Skinner, 1980). Often, the resurgence phenomenon is studied in laboratory animal models using pigeons (e.g., Leitenberg, Rawson, & Mulick, 1975, Experiment 3; Podlesnik & Shahan, 2009, Experiment 2) or rats (e.g., Leitenberg, Rawson, & Bath, 1970; Leitenberg et al., 1975,
Experiments 1, 2, & 4; Sweeney & Shahan, 2013; Winterbauer & Bouton, 2010; Winterbauer, Lucke, & Bouton, 2013).

A laboratory animal model of resurgence generally consists of three distinct experimental phases. Phase I involves the training of an operant target response. For example, the target response for a pigeon would be to peck a lit key in an operant chamber to receive food—for a rat, the target response may be to press a particular lever in an operant chamber to receive a food pellet delivery. After the subject emits the target response regularly, or after a fixed period of time, Phase II, or simulated alternative reinforcement treatment, is introduced. In Phase II, reinforcement is not available for the target response (also called extinction of a response) and introduced for an alternative response. For a pigeon, pecks to the target key would no longer produce food, but pecks to a different key would produce reinforcement. For a rat, presses to the target lever would not result in the delivery of a food pellet, but a new response such as pulling a chain provides an alternative source of reinforcement. In Phase II, target response rate decreases and alternative response rate increases. Phase III of the laboratory model is a probe for the effect of alternative reinforcement removal on the target response. During Phase III, alternative reinforcement is removed and extinction of the target response remains in place such that no response will produce reinforcement. It is during Phase III that resurgence of the suppressed target response can occur. In addition to food reinforcement, laboratory studies with rats have also shown resurgence of alcohol- (Podlesnik, Jimenez-Gomez, & Shahan, 2006) and cocaine-seeking (Quick, Pyszczynski, Colston, & Shahan, 2011) following the removal of alternative, non-drug reinforcement.
Because the introduction of alternative reinforcement is an important component of many behavioral treatments, it is important to understand variables that contribute to the persistence and resurgence of operant behavior in the face of alternative reinforcement treatments. Shahan and Sweeney (2011) have developed a quantitative model of resurgence that asserts important predictors of persistence of the target response during treatment and resurgence magnitude when a treatment lapse occurs. Because the model directly extended behavioral momentum theory to incorporate findings in the resurgence literature, the basic tenets of behavioral momentum theory will be summarized before the predictions of the quantitative model of resurgence are discussed in detail.

**Behavioral Momentum Theory**

According to behavioral momentum theory, the three-term contingency of operant behavior can be broken into two key parts: response rates and resistance to change (Nevin, Mandell, & Atak, 1983). Rate of an operant response is determined by the response-reinforcer relationship, whereas the resistance to change of an operant response is determined by the stimulus reinforcer relationship of the context. The stimulus-reinforcer relationship is a function of history of reinforcement associated with that context. This is illustrated in the following schematic, where all terms are as described previously,
The higher the rate of reinforcement previously experienced in the context, the more resistant that operant behavior will be to disruption. The reinforcement experienced in the context includes all sources of reinforcement, regardless of whether they are contingent upon the target response, independent of the target response, or even contingent on an alternative response (Nevin, Tota, Torquato, & Shull, 1990).

The effect of history of reinforcement on subsequent persistence is consistent across different types of disruption, including satiation (e.g., Nevin, 1974) and distraction (Mace et al., 1990), but the most studied disruptor is the removal of reinforcement for the operant response, or extinction. Nevin and Grace (2000) quantified behavioral momentum theory’s predictions regarding resistance to extinction for an operant response in a quantitative model known as the augmented-extinction model:

$$\log \left( \frac{B_t}{B_0} \right) = -\frac{t(c + dr)}{r^b}$$

This equation predicts proportion of baseline response rates at a given time \( t \) in extinction. The equation suggests there are two primary disruptors in extinction. First, parameter \( c \) represents the disruptive impact of the broken contingency between the response and the reinforcer. In addition, the removal of baseline reinforcement is disruptive because the absence of reinforcement distinguishes extinction from baseline contingencies and makes generalization of the response to extinction more difficult. This is known as the generalization decrement, and is captured in the augmented model by \( dr \). The parameter \( d \) scales the disruptive impact of the removal of baseline reinforcement in reinforcers per hour, \( r \). Opposing the disruptive impact of the broken response-reinforcer
contingency and the removal of baseline reinforcement is the stimulus-reinforcer relationship of the context, which is operationalized by the denominator: $r$ (baseline reinforcement rate) and qualified by an organism’s sensitivity to reinforcement rate ($b$). Thus, a high rate of reinforcement in the context during baseline would mean a stronger stimulus-reinforcer relationship of the context, reflected in a larger value of $r$ relative to a low rate of reinforcement in the context. A higher value of $r$ in the denominator formalizes the prediction of greater resistance to change following a high rate of reinforcement relative to a low rate of reinforcement.

**A Model of Resurgence**

In resurgence, reinforcement is not only introduced during baseline, but is also present during extinction of the target response and reinforcement of the alternative response. Therefore, we extended the augmented extinction model to incorporate the role that alternative reinforcement plays in persistence and resurgence (Shahan & Sweeney, 2011). The model states,

$$ \log \left( \frac{B_t}{B_o} \right) = \frac{-t(kR_a + c + dr)}{(r + R_a)^b} $$

(2)

where all terms are as in Equation 1, with the addition of $kR_a$. The rate of reinforcement for the alternative response, $R_a$, is scaled by parameter $k$. We suggest that $R_a$ has a disruptive impact on the target response when it is in place, but that it also contributes to the overall strength of the stimulus-reinforcer relationship of the context. Therefore, when alternative reinforcement is removed, there is a release from disruption and the
resurgence of the target response is a function of the stimulus-reinforcer relationship of the context. The model operationalizes this relationship as the combination of baseline rate of reinforcement and alternative reinforcement rate, which is consistent with behavioral momentum theory’s contention that all reinforcement, whether response dependent, response independent, or contingent on another response, contributes to the persistence of a response that occurs in that context (e.g., Nevin et al., 1990).

Equation 2 makes several predictions that have been tested empirically. One is that higher rates of alternative reinforcement will be associated with faster response elimination during extinction plus alternative reinforcement, but cause more resurgence when removed. In contrast, low rates of alternative reinforcement ought to result in slower response elimination (less disruption) during extinction plus alternative reinforcement, but cause less resurgence when removed. At least two studies provide empirical support for this prediction (Leitenberg et al., 1975, Experiment 3; Sweeney & Shahan, 2013). The role of alternative reinforcement rate in persistence and resurgence will be discussed in more detail in the general discussion, Chapter 5.

Because Equation 2 predicts that the disruptive impact of the breaking of the response-reinforcer contingency and the removal of baseline reinforcement increases as a function of time in extinction, the release from disruption that occurs when alternative reinforcement is removed ought to cause less resurgence when extinction has been in place longer and more resurgence when extinction has been in place briefly. It is this prediction change in resurgence magnitude as a function of time in extinction and repeated resurgence tests that is examined in Chapter 2.
Purpose

The purpose of this work is to test the direct quantitative and broad theoretical predictions of behavioral momentum theory on operant response persistence and resurgence. In the next chapter, two experiments that test the effect of time in extinction in an animal model of resurgence are presented. Chapter 3 presents an experiment designed to assess the role of alternative reinforcement context in subsequent relapse. Chapter 4 presents data collected in an attempt to develop a simple, time- and cost-effective laboratory model of resurgence that could test the generality of basic animal research findings in human research participants. Chapter 5 integrates the discussion of this research into known predictors of resurgence in the literature, and states the implications of these predictors for a behavioral momentum-based approach to the topic of resurgence.
CHAPTER 2

RESURGENCE AND TIME IN EXTINCTION

Introduction

Resurgence is relapse that occurs following the removal of alternative reinforcement introduced during the extinction of an operant response. Resurgence has practical implications for treatments using alternative reinforcement to reduce problem behaviors, because it suggests that the removal or reduction of alternative reinforcement following treatment can result in an increase in the problem behavior. Many popular behavioral treatments involve alternative reinforcement, such as contingency management for substance abuse (e.g., Higgins et al., 2010; Silverman et al., 2007) and differential reinforcement of alternative behavior (DRA) in individuals with intellectual or developmental disabilities (Petscher et al., 2009). Although treatments that use alternative reinforcement are often effective at reducing problem behavior during treatment, the risk of relapse when alternative reinforcement is reduced or removed has led to a recent revival in basic (Lieving & Lattal, 2003; Quick et al., 2011; Winterbauer & Bouton, 2010) and applied (Volkert et al., 2009) research on resurgence (see Lattal & St. Peter Pipkin, 2009, for a review).

Chapter 2 of this dissertation proposal was adapted from, “Behavioral momentum and resurgence: Effects of time in extinction and repeated resurgence tests,” by M. M. Sweeney and T. A. Shahan, 2013, Learning & Behavior, Volume 4, Issue 4, p. 414-424, with kind permission from Springer Science and Business Media. A copy of the license agreement can be seen in Appendix I.
Behavioral momentum theory has been useful for understanding the persistence (e.g., Nevin et al., 1983) and relapse (Podlesnik & Shahan, 2010) of operant behavior—as such, the application of behavioral momentum theory to resurgence could shed light on important determinants of resurgence magnitude. In an effort to integrate resurgence into behavioral momentum theory, Shahan and Sweeney (2011) proposed a quantitative model of resurgence based on the augmented-extinction model (Nevin & Grace, 2000). The augmented extinction model suggests that experience with higher rates of reinforcement within a discriminative-stimulus context prior to extinction renders an operant response more resistant to the disruptive effects of extinction. The model suggests:

\[ \log\left(\frac{B_t}{B_0}\right) = \frac{-t(c + dr)}{r^b} \]  

(1)

where \( B_t \) is the response rate at time \( t \) in extinction and \( B_0 \) is the baseline response rate before extinction, \( c \) is the suppressive effect of breaking the response-reinforcer contingency, \( d \) scales suppression associated with elimination of reinforcers from the situation (i.e., generalization decrement), \( r \) is the rate of reinforcement within the context in baseline, and \( b \) is sensitivity to reinforcement rate. As time in extinction increases, the disruptive impact increases (in the numerator), but is counteracted by previous experience with higher reinforcement rates in the discriminative context (in the denominator). Reinforcement experienced in the context includes all sources of reinforcement, regardless of whether they are contingent upon the target response, independent of the target response, or even contingent on an alternative response. This prediction stems from behavioral momentum theory’s suggestion that resistance to disruption is governed by the Pavlovian discriminative-stimulus reinforcer relation, which has been supported by
research with species ranging from fish to humans (e.g., Ahearn, Clark, Gardenier, Chung, & Dube, 2003; Cohen, 1996; Igaki & Sakagami, 2004; Nevin et al., 1990; Shahan & Burke, 2004). Nevin, McLean, and Grace (2001) have shown that the c and d parameters are independent, vary as expected with experimental manipulations, and combine additively as suggested by the model. Equation 1 also accounts for the partial reinforcement extinction effect because at very high rates of reinforcement the stimulus change associated with removal of reinforcers from the situation (i.e., generalization decrement—$dr$) serves as a larger disruptor than removal of reinforcers arranged on a schedule of partial reinforcement (Nevin & Grace, 2005). Equation 1 has provided a successful account of extinction of operant behavior in basic research and in applied settings (Nevin & Shahan, 2011, for review).

Shahan and Sweeney (2011) extended Equation 1 to resurgence by suggesting that alternative reinforcement during extinction of a target behavior has two effects. First, alternative reinforcement further disrupts the target behavior. Second, alternative reinforcement contributes to the strength of the target behavior by serving as an additional source of reinforcement in the context. Thus, the model suggests:

$$\log\left\{\frac{B_t}{B_o}\right\} = \frac{-t(kR_a + c + dr)}{(r + R_a)^b}$$

where all terms are as in Equation 1. The added variable $R_a$ is the rate of alternative reinforcement during extinction and the added parameter $k$ scales the disruptive impact of the alternative reinforcement during extinction. The inclusion of $kR_a$ increases the suppressive impact in the numerator, with higher rates of alternative reinforcement producing more suppression of the target behavior. When alternative reinforcement is removed, $kR_a$ is zero and
the target behavior increases as a result of the decrease in disruption. In addition, because $R_a$ is included in the denominator, alternative reinforcement experienced in the context during extinction also contributes to the future strength of the target behavior.

Equation 2 describes several known findings in the resurgence literature and fits existing data well (Shahan & Sweeney, 2011). One such finding is that less resurgence occurs following longer exposure to extinction plus alternative reinforcement (Leitenberg et al., 1975, Experiment 4). Equation 2 captures the effect of extended exposure to extinction plus alternative reinforcement through its use of time in extinction as a factor that increases the impact of disruption over time. As time in extinction increases, $t$ becomes larger, and consequently the larger numerator predicts that the removal of alternative reinforcement after extended periods of extinction will result in less resurgence.

A related prediction of Equation 2 is that resurgence should decrease across repeated tests. In other words, when subjects are not returned to baseline contingencies of reinforcement for the target response, $t$ continues to grow as exposure to extinction plus alternative reinforcement increases, and thus the model predicts that resurgence should decrease across each removal of alternative reinforcement. Figure 2.1 shows a simulation of this prediction using the exponentiated version of Equation 2, which avoids logarithmic transformation of response rates and permits the inclusion of zero values. The exponentiated version is,

$$\frac{B_t}{B_0} = 10 \left(\frac{-t(kR_a+c+dr)}{(r+R_a)^b}\right)$$

(3)
where all terms are as in Equation 2. This simulation in Figure 2.1 is supported by evidence from two studies, Quick et al. (2011) and Wacker et al. (2011). Quick et al. investigated resurgence of cocaine seeking in rats following the removal of alternative food reinforcement for nose pokes during extinction. They introduced and removed alternative food reinforcement twice while keeping the extinction of cocaine seeking in place. Relapse during the second resurgence test was significantly smaller than the first resurgence test—consistent with the predictions of Equation 3. In an applied study with children with developmental disabilities, Wacker et al. alternated extinction of problem behavior with extinction plus alternative reinforcement in the form of functional

![Graph](image)

**Figure 2.1.** Simulation produced by Equation 3 using baseline reinforcement rates of variable-interval (VI) 60 seconds and alternative reinforcement rate of VI 30 seconds and repeated introductions (Rₐ) and removals (No Rₐ) of alternative reinforcement. Reprinted from Shahan and Sweeney (2011) with permission from the Journal of the Experimental Analysis of Behavior).
communication training (FCT). Resurgence of problem behavior that occurred following FCT generally decreased with each removal of alternative reinforcement. In fits of Equation 3 to the data, Wacker et al. found that the model accurately described the decreased resurgence seen following repeated FCT. Although the percentage of variance accounted for was relatively low compared to fits of the model to data from basic laboratories, the fits were compelling given the variability inherent in the dataset collected in children’s homes with their mothers serving as therapists.

The purpose of the present experiments was to examine resurgence across repeated tests under conditions explicitly designed to test Equation 3. Experiment 1 was designed to establish that resurgence decreases across repeated tests with simple food-maintained behavior in a manner consistent with the predictions of Equation 3 and existing data from more complex situations (Quick et al., 2011; Wacker et al., 2011). Though the data from Quick et al. and Wacker et al. are consistent with the predictions of Equation 3 displayed in Figure 2.1, there are no data comparing a condition with repeated resurgence tests to a condition with constant alternative reinforcement. Equation 3 predicts that not only should resurgence decrease across repeated resurgence tests as time in extinction increases, but resurgence should be comparably low at a given time $t$ in extinction in a condition with the first removal of alternative reinforcement to occur at time $t$ and a condition that receives alternative reinforcement lapses prior to time $t$. Experiment 2 tested these predictions.
Experiment 1

In Experiment 1, we assessed the effects of repeated implementations of extinction plus alternative reinforcement on subsequent resurgence under conditions designed to test the predictions of Equation 3. The experimental parameters used in Experiment 1 provided the basis for the simulation in Figure 2.1.

Method

Subjects

Twelve unsexed homing pigeons (Double T Farm, Glenwood, IA) with varied previous experimental histories served as the subjects. The pigeons were maintained at approximately 80% of their free-feeding weight (±15 g) via postsession feedings in the home cage and adjustments of the hopper duration across subjects ranging from 1.3 to 2 s. The colony room was on a 12-h light cycle with lights on at 7:00 a.m. Experimental sessions occurred in three squads of four pigeons each, with each squad running at approximately the same time each day.

Apparatus

The experimental sessions took place in four Lehigh Valley Electronics pigeon operant chambers that measure 350 mm long, 350 mm high, and 300 mm wide. Three response keys, 83 mm apart, each 25 mm in diameter, were centered on the front panel of the chamber. The keys were transilluminated via back-mounted in-line projectors and could display yellow, blue, and red homogeneous hues, as well as three separate white
shapes (circle, horizontal line, and vertical line) on a black background. About 0.1 N of force was required to operate the keys. A house light located 76 mm above the center key provided general illumination directed toward the chamber ceiling. When the hopper was elevated, a miniature bulb illuminated the available Purina Pigeon Chow in a 50-mm wide × 55-mm tall aperture located 130 mm below the center key. A fan mounted to the outside of each chamber provided ventilation. The fan and white noise helped to mask extraneous sounds. Med Associates (St. Albans, VT) programming and interfacing were used to control the execution and recording of experimental events.

**Procedure**

Experiment 1 involved three phases: baseline, extinction, and test. Because the subjects had previous experimental histories, no shaping or pretraining was necessary before the baseline phase. Baseline consisted of ten sessions, during which only the center key was illuminated and displayed a white vertical line on a black background. Pecks to the center key (the target response) produced food on a variable-interval (VI) 60-s schedule of reinforcement. When a food delivery was arranged, the next target response turned off the house light and response key and produced access to the illuminated hopper aperture. Following the hopper presentation, the key and the house light were relit, and the VI timer restarted. Sessions were 45 min, excluding hopper time.

During extinction (EXT), pecks to the center key (vertical line) no longer produced food, but pecks to the right key (blue hue) produced food on a VI 30-s schedule. As during baseline, hopper time was excluded from the session time, and the
only stimulus illuminated during hopper delivery was the food aperture light. EXT lasted for three days.

Next, in the test phase, both the center key and the right key remained illuminated with their respective stimuli, but neither produced food. The test phase lasted for three days. Next, EXT and test were repeated (EXT 2, Test 2) for three days each, without returning to baseline.

Results

The means and standard deviations of the target key response rate, alternative key response rate, inactive key response rate, and obtained food delivery rate during each phase of Experiment 1 are presented in Table 2.1. Acquisition of the target response (i.e., pecks to the vertical line) proceeded normally during baseline. Pecks to the inactive (unlit) response keys were negligible for all pigeons. The target response rate decreased during the three days of EXT. Acquisition of the alternative response was rapid; pigeons earned close to the maximum food delivery rate on the first day of EXT ($M = 1.88$ foods/min, $SD = 0.08$). Responding on the inactive key continued to be negligible in all subjects. The average target response rate on the last day of EXT was 0.08 pecks/min, $SD = 0.16$.

Figure 2.2 displays target response rates during the final session of each exposure to the repeated EXT and the first session of each test phase. During the first session of the test phase, target response rates increased relative to the last session of EXT. The increase from the last session of EXT 2 to the first session of Test 2 was smaller than the
Table 2.1

*Experiment 1 Response Rates and Food Rates*

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>EXT</th>
<th>Test</th>
<th>EXT 2</th>
<th>Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>66.43</td>
<td>1.95</td>
<td>8.17</td>
<td>0.13</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td>(28.28)</td>
<td>(1.92)</td>
<td>(7.17)</td>
<td>(0.18)</td>
<td>(3.47)</td>
</tr>
<tr>
<td>Alternative</td>
<td>-</td>
<td>81.32</td>
<td>19.20</td>
<td>75.56</td>
<td>12.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(37.50)</td>
<td>(9.73)</td>
<td>(31.22)</td>
<td>(4.68)</td>
</tr>
<tr>
<td>Inactive</td>
<td>0.04</td>
<td>0.003</td>
<td>0.49</td>
<td>0.001</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.01)</td>
<td>(1.38)</td>
<td>(0.002)</td>
<td>(0.62)</td>
</tr>
<tr>
<td>Foods</td>
<td>0.97</td>
<td>1.91</td>
<td>-</td>
<td>1.93</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.05)</td>
<td></td>
<td>(0.03)</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Table 2.1 displays the means and SDs (in parentheses) for target key response rate, alternative key response rate, and inactive response rates (in pecks/min) as well as obtained food delivery rate (in foods/min) for each phase of Experiment 1. For Baseline, each pigeon’s individual mean for the last five days was first calculated, and then included in the above analysis. For each extinction phase, each pigeon’s individual mean was calculated for the entire phase and then included in the above calculation. In each cell of the table above, $n = 12$.

increase from the last session of EXT to the first session of Test. We conducted a $2 \times 2$ within-subjects repeated measures analysis of variance (ANOVA) with the factors Transition and $R_a$. Target response rates for the sessions making up the first transition (i.e., EXT to Test) were coded as part of the first level of transition, whereas target response rates for sessions EXT 2 to Test 2 were coded as part of the second transition. The level of the factor $R_a$ was determined by whether alternative reinforcement was present during the session (EXT and EXT 2) or absent (Test and Test 2). We found significant main effects of transition, $F(1, 11) = 11.98, p < .01$, and of $R_a$, $F(1, 11) = 15.15, p < .01$, as well as a Transition × $R_a$ interaction, $F(1, 11) = 11.85, p < .01$,
capturing that the effect of removing alternative reinforcement on target response rates was different from the first to the second resurgence test. In simple-effects analyses, we found a statistically significant increase in target response rate on the first day of Test relative to the last day of EXT, $F(1, 11) = 16.24, p < .01$, and also a significant decrease in target response rate on the first day of Test 2 relative to the first day of Test, $F(1, 11) = 11.92, p < .01$. No significant difference emerged between target response rates on the last day of EXT and the last day of EXT2, $F(1, 11) = 2.55, p = .14$, nor a significant difference between the last day of EXT 2 and the first day of Test 2, $F(1, 11) = 2.85, p = .12$.

Given the visual increase from the last day of EXT 2 to the first day of Test 2, the data were examined for consistent patterns at the individual-subject level. Figure 2.3 displays the transitions for Test and Test 2. It is clear that for the first test, all but one subject showed an increased target response rate when alternative reinforcement was

![Figure 2.2. A comparison of mean ($n = 12$) target response rates (with SE) on the last day of EXT the first day of Test, the last day of EXT 2 and the first day of Test 2 during Experiment 1. ** indicates significance at $p < .01$ for simple effects.](image)
Figure 2.3. Individual subject data comparing the increases from the first and second resurgence tests.

Figure 2.4. Least squares regression fit (solid line) of Equation 3 to data obtained (filled circles) in Experiment 1.
Table 2.2

Equation 3 Individual Subject Parameter Values for Experiment 1 Fits

<table>
<thead>
<tr>
<th>Subject</th>
<th>936</th>
<th>966</th>
<th>956</th>
<th>957</th>
<th>8405</th>
<th>7095</th>
<th>262</th>
<th>257</th>
<th>175</th>
<th>52</th>
<th>239</th>
<th>887</th>
</tr>
</thead>
<tbody>
<tr>
<td>(k)</td>
<td>.04</td>
<td>.10</td>
<td>.14</td>
<td>.08</td>
<td>.14</td>
<td>.06</td>
<td>.11</td>
<td>.16</td>
<td>.17</td>
<td>.10</td>
<td>.06</td>
<td>.10</td>
</tr>
<tr>
<td>(c)</td>
<td>1.23</td>
<td>3.82</td>
<td>1.72</td>
<td>3.06</td>
<td>3.94</td>
<td>4.53</td>
<td>1.95</td>
<td>2.41</td>
<td>2.66</td>
<td>3.52</td>
<td>3.46</td>
<td>2.53</td>
</tr>
</tbody>
</table>

Note. Table 2.2 displays the values of parameters \(k\) and \(c\) and the variance accounted for \((R^2)\) for the fits of Equation 3 to individual subject data in Experiment 1. The value of \(d\) was fixed to .001 and \(b\) to .5 for all fits reported.

removed. For Test 2, only two subjects showed notable increases in target response rate and were driving the visual difference between mean target response rate on the last day of EXT 2 and the first day of Test 2.

Equation 3 was fitted to the mean subject data across all sessions, which is displayed in Figure 2.4. As in Shahan and Sweeney (2011), the \(d\) parameter was fixed to a value of 0.001, \(b\) was fixed to 0.5, and the values of the variables \(t\), \(R_a\), and \(r\) were determined from the experimental parameters of time in extinction, alternative reinforcement rate, and baseline reinforcement rate, respectively. Because the design included no return to baseline conditions, \(t\) increased daily by a value of 1. During EXT and EXT 2, the value of \(R_a\) in the numerator was set to 120 (i.e., foods per hour), and during Test and Test 2, \(R_a\) in the numerator was set to 0 because alternative reinforcement as a disruptor was not present. Consistent with the usual treatment of the previously experienced response-strengthening effects of reinforcement in the denominator of the
augmented model during extinction (i.e., \( r \) in Equation 1; see Nevin et al., 2001), the value of \( R_a \) in the denominator was 120 throughout all EXT and test phases. Only the parameters \( k \) and \( c \) were free to vary. The least squares regression fit of Equation 3 to the mean subject data accounted for 99% of the variance, with \( c = 2.56 \) and \( k = 0.09 \). Table 2.2 shows the parameter estimates obtained in the fits of Equation 3 to the individual pigeon data. The median of the individual \( R^2 \) values was .99 (\( M = .98, SD = .02 \)). The median value of parameter \( c \) was 2.86 (\( M = 2.90, SD = 0.99 \)), and the median value of \( k \) was 0.10 (\( M = 0.11, SD = 0.04 \)).

**Discussion**

As in previous experiments in more complex situations (Quick et al., 2011; Wacker et al., 2011), the present experiment showed that resurgence appears to decrease across repeated tests. One could argue that for all but two subjects, resurgence did not occur upon the second removal of alternative reinforcement. Furthermore, the quality of the least squares regression fit to the data from Experiment 1 suggests that, on average, Equation 3 adequately describes the repeated-resurgence phenomenon, although considerable variability occurred in the individual parameter estimates. It is important to note that decreased resurgence across tests is not contradictory to previous findings that repeated examinations of resurgence within subjects result in similar relapses (da Silva, Maxwell, & Lattal, 2008; Lieving & Lattal, 2003), because in these previous experiments baseline responding was reestablished before the second examination of extinction and resurgence. In these cases, Equation 3 requires that the value of \( t \) be reset to zero.
following each baseline, and as such, the model would predict similar resurgence across repeated tests rather than reduced resurgence.

The results of Experiment 1 are also consistent with data from Leitenberg et al. (1975, Experiment 4) in which groups that experienced lengthier extinction plus alternative reinforcement showed less resurgence than did a group that experienced only three sessions of extinction plus alternative reinforcement. On the other hand, a recent failure to replicate the findings of Leitenberg et al. was reported by Winterbauer et al. (2013). This discrepancy will be addressed in the General Discussion.

**Experiment 2**

The data from Experiment 1 supported the model prediction that resurgence should decrease with repeated resurgence tests. Equation 3 also predicted that resurgence should be similar at time $t$ in extinction in a condition with no previous lapses in alternative reinforcement and at $t$ in a condition with previous removals of alternative reinforcement. Because no data exist that speak to this prediction, Experiment 2 was designed to assess it. As such, in Experiment 2 we compared target responding on the sixth session of extinction across two conditions. In one condition, alternative reinforcement was removed at Sessions two, four, and six of extinction. In the second condition, the alternative reinforcement was removed only during Session 6 of extinction. A model simulation of Experiment 2, using the values of $c$ and $k$ obtained in the fit to the data from Experiment 1, is displayed in Figure 2.5.
Method

Subjects

The 12 pigeons from Experiment 1, under the same feeding and living conditions, also served as subjects in Experiment 2.

Apparatus

Experiment 2 took place in the same operant chambers as Experiment 1. The session start times were approximately equal to those in Experiment 1, with each pigeon running in the same group of four and in the same chamber as in Experiment 1.

Figure 2.5. A simulation of the predictions of Equation 3 that compares the two conditions in Experiment 2. One condition receives constant alternative reinforcement for the first five extinction sessions (Constant-$R_a$) and the other condition receives alternative reinforcement only on days 1, 3, and 5 of extinction (On/Off-$R_a$). Neither condition received alternative reinforcement during extinction session six. Free parameter values ($k$ and $c$) were fixed to the values obtained in the fit to Experiment 1.
Procedure

In Experiment 2, we compared resurgence across two conditions following equal baselines. In one condition (Constant-$R_a$), the alternative reinforcement was constant for five days of extinction of the target response and was removed for the sixth extinction session. The other condition (On/Off-$R_a$) alternated between one day of reinforcement for the alternative response and one day of extinction of the alternative response. Therefore, on Days two and four of extinction, alternative reinforcement was available for the Constant-$R_a$ condition and unavailable for the On/Off-$R_a$ condition. On Day six of extinction, alternative reinforcement was unavailable in both conditions. Exposure to extinction of the target response was equal (six days) in both conditions. All 12 subjects experienced both series of Constant-$R_a$ and On/Off-$R_a$ conditions in a counterbalanced order. Exposure to the second series of conditions was preceded by a return to baseline. Baseline consisted of nine 35-min sessions during which pecks to the center key produced food on a VI 60-s schedule. During the first series of conditions, in which half of the subjects experienced constant $R_a$ and half experienced On/Off-$R_a$, the center key (target response) was illuminated with a yellow homogeneous hue, and the left key (alternative response) was illuminated with a white circle on a black background. In the second series, when the conditions experienced during extinction were reversed for each subject, the center key (target response) was a white horizontal line on a black background and the right key (alternative response) was a red homogeneous hue. During both the first and second baselines, the alternative response key was dark. During both extinction conditions, the alternative response key remained on, regardless of the
availability of alternative reinforcement.

**Results**

Acquisition of the target response proceeded normally during both series of Experiment 2. During the last five days of baseline, mean target response rates did not differ between Series 1 ($M = 61.85$ pecks/min, $SD = 27.53$) and 2 ($M = 61.99$ pecks/min, $SD = 35.02$) of the study. Performance in the Constant-$R_a$ and the On/Off-$R_a$ conditions did not depend on whether the subjects experienced the condition in the first or the second series of Experiment 2. The means and standard deviations of target-key response rate, alternative-key response rate, inactive-key response rate, and obtained food rate across conditions for each day of extinction are presented in Table 2.3.

Sessions 2, 4, and 6 of extinction (during which alternative reinforcement was removed for at least one condition) will be referred to as Test 1, Test 2, and Test 3, respectively. The data from Test 1, Test 2, and Test 3 across conditions are displayed in Figure 2.6. Resurgence in the On/Off-$R_a$ condition decreased across Tests 1 through 3, and resurgence during Test 3 did not differ for the Constant-$R_a$ and On/Off-$R_a$ conditions. A within-subjects ANOVA using two factors (Condition and Test) was used to compare response rates during Test 1, Test 2, and Test 3 across conditions (Constant-$R_a$ vs. On/Off-$R_a$). In this test, we found main effects of condition, $F(1, 11) = 12.72, p < .01$, and test, $F(2, 22) = 9.72, p < .01$, as well as a Condition × Test interaction, $F(2, 22) = 12.17, p < .01$. Simple-effects comparisons were used to examine the differences between conditions at each test (Constant-$R_a$ vs. On/Off-$R_a$ for Tests 1, 2, and 3), the
Table 2.3

*Extinction Performance During Experiment 2*

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2 (Test 1)</th>
<th>Day 3</th>
<th>Day 4 (Test 2)</th>
<th>Day 5</th>
<th>Day 6 (Test 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant-(R_{o})</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target</td>
<td>10.29</td>
<td>0.82</td>
<td>0.74</td>
<td>0.29</td>
<td>0.26</td>
<td>1.99</td>
</tr>
<tr>
<td></td>
<td>(8.63)</td>
<td>(0.97)</td>
<td>(0.87)</td>
<td>(0.39)</td>
<td>(0.28)</td>
<td>(2.05)</td>
</tr>
<tr>
<td>Alternative</td>
<td>63.78</td>
<td>72.31</td>
<td>72.84</td>
<td>72.34</td>
<td>65.94</td>
<td>29.94</td>
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<tr>
<td></td>
<td>(30.97)</td>
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<td>(34.17)</td>
<td>(34.38)</td>
<td>(34.03)</td>
<td>(20.71)</td>
</tr>
<tr>
<td>Inactive</td>
<td>0.005</td>
<td>0.0009</td>
<td>0.01</td>
<td>0.06</td>
<td>0.96</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.03)</td>
<td>(0.05)</td>
<td>(0.21)</td>
<td>(3.32)</td>
<td>(1.63)</td>
</tr>
<tr>
<td>Foods</td>
<td>0.88</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>0.95</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.16)</td>
<td>(0.05)</td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.06)</td>
<td>-</td>
</tr>
<tr>
<td><strong>On/Off-(R_{o})</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target</td>
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<td>3.11</td>
<td>4.13</td>
<td>0.55</td>
<td>2.01</td>
</tr>
<tr>
<td></td>
<td>(4.73)</td>
<td>(9.50)</td>
<td>(3.13)</td>
<td>(3.97)</td>
<td>(0.64)</td>
<td>(2.22)</td>
</tr>
<tr>
<td>Alternative</td>
<td>77.75</td>
<td>21.03</td>
<td>67.51</td>
<td>28.51</td>
<td>70.14</td>
<td>18.08</td>
</tr>
<tr>
<td></td>
<td>(27.67)</td>
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<td>(23.48)</td>
<td>(16.11)</td>
<td>(26.84)</td>
<td>(12.98)</td>
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<tr>
<td>Inactive</td>
<td>0.0</td>
<td>0.03</td>
<td>0.18</td>
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<td></td>
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<td>(0.07)</td>
<td>(0.57)</td>
<td>(0.35)</td>
<td>(0.01)</td>
<td>(1.12)</td>
</tr>
<tr>
<td>Foods</td>
<td>0.95</td>
<td>-</td>
<td>0.95</td>
<td>-</td>
<td>0.95</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Table 2.3 displays the means and SDs (in parentheses) for target key response rate, alternative key response rate, and inactive response rates (in pecks/min) as well as obtained food delivery rate (in foods/min) for each day of extinction in Experiment 2. Each pigeon’s individual rate was included in the above calculation. In each cell of the table above, \(n = 12\). Days 2, 4, and 6 represent the test days during which no alternative reinforcement was available for at least one condition.
differences across tests within the On/Off-$R_a$ condition (On/Off-$R_a$ Test 1 vs. On/Off-$R_a$ Test 2, and On/Off-$R_a$ Test 2 vs. On/Off-$R_a$ Test 3). A significant effect of condition emerged at Test 1, $F(1, 11) = 13.75, p < .01$, and at Test 2, $F(1, 11) = 10.51, p < .01$. We also observed significant differences in the On/Off-$R_a$ condition between Test 1 and Test 2, $F(1, 11) = 12.15, p < .01$, as well as between Test 2 and Test 3, $F(1, 11) = 5.46, p < .05$. The results of these comparisons can be seen in Figure 2.6. As in Experiment 1, the data were examined on the individual-subject level, and the patterns in general reflected the condition means (see Figure 2.7).

Figure 2.8 shows a least squares regression fit of Equation 3 to the data from Experiment 2. As in Experiment 1, the parameter $d$ was fixed to a value of 0.001, $b$ was fixed to 0.5, and the values of $t$, $R_a$, and $r$ were determined from the experimental
Figure 2.7. Individual subject data for the target response in both conditions of Experiment 2. Each line represents one subject, and each condition was experienced by all 12 subjects in counterbalanced order.
conditions. The value of $t$ increased by 1 each day that extinction of the target response was in effect, and was reset to 0 following the return to baseline. Whenever alternative reinforcement was available, the value of $R_a$ in the numerator was set to 60 (i.e., foods per hour). Whenever alternative reinforcement was unavailable, $R_a$ in the numerator was set to 0. The value of $R_a$ in the denominator, however, was 60 throughout extinction in both conditions. It is important to note that in our fits of Equation 3 to the data from Experiment 2, the value of $R_a$ in the denominator is the programmed reinforcement rate of alternative reinforcement when alternative reinforcement was present, rather than the average alternative-reinforcement rate including (for the On/Off-$R_a$ condition) zero values for test sessions. This is consistent with previous treatments of baseline reinforcement ($r$) in the denominator, because this parameter does not decrease across Experiment 2

![Graph](image)

**Figure 2.8.** Least squares regression fits of Equation 3 to data obtained in Experiment 2. The solid line represents the fit to the Constant $R_a$ condition, whereas the dashed line fits the On/Off $R_a$ condition. Filled circles (Constant $R_a$) and open circles (On/Off $R_a$) illustrate the obtained data.
Table 2.4

*Equation 3 Individual Subject Parameter Values for Experiment 2 Fits*

<table>
<thead>
<tr>
<th>Subject</th>
<th>936</th>
<th>966</th>
<th>956</th>
<th>957</th>
<th>8405</th>
<th>7095</th>
<th>262</th>
<th>257</th>
<th>175</th>
<th>52</th>
<th>239</th>
<th>887</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k$</td>
<td>.05</td>
<td>.14</td>
<td>.19</td>
<td>.06</td>
<td>.25</td>
<td>.07</td>
<td>.07</td>
<td>.05</td>
<td>.09</td>
<td>.16</td>
<td>.12</td>
<td>.08</td>
</tr>
<tr>
<td>$c$</td>
<td>2.05</td>
<td>1.61</td>
<td>4.11</td>
<td>5.35</td>
<td>2.42</td>
<td>4.18</td>
<td>5.07</td>
<td>7.71</td>
<td>5.81</td>
<td>4.86</td>
<td>6.65</td>
<td>2.86</td>
</tr>
</tbody>
</table>

*Note.* Table 2.4 displays the values of parameters $k$ and $c$ and the variance accounted for ($R^2$) for the fits of Equation 3 to individual subject data in Experiment 2. The value of $d$ was fixed to .001 and $b$ to .5 for all fits reported.

extinction sessions, as more and more zero values of no reinforcement would have to be included in the average. Again, only parameters $k$ and $c$ were free to vary. The least squares regression fit of Equation 3 to the data accounted for 99% of the variance ($R^2 = .99$), with $c = 3.50$ and $k = 0.10$. Although the values of $c$ and $k$ changed from Experiment 1 to Experiment 2, these changes were not large enough to merit concern.

When the values of parameters $c$ and $k$ were fixed to the values obtained in the fit to the data from Experiment 1, the variance accounted for by the model decreased only 1% ($R^2 = .98$). Table 2.4 displays the obtained parameter values when Equation 3 was fit to the individual pigeon data. The median $R^2$ value for the individual fits was .99 ($M = .98$, $SD = .02$), the median value of parameter $c$ was 4.52 ($M = 4.39$, $SD = 1.89$), and the median value of $k$ was .08 ($M = .11$, $SD = .06$).
Discussion

Two findings of Experiment 2 are key to our present characterization of resurgence: specifically, the suggested roles of time in extinction and exposure to alternative reinforcement. First, in the On/Off-$R_a$ condition, resurgence decreased across repeated resurgence tests in a manner consistent with the predictions of Equation 3 and with existing data. Second, target response rates at Test 3 were comparably low for the Constant-$R_a$ and On/Off-$R_a$ conditions. One consideration is that target response rates at Test 3 were overall very low, and one possibility is that our failure to reject the null hypothesis was inevitable because of low response rates. However, the presence of comparably little resurgence supports our hypothesis rather than challenges it. If previous lapses in alternative reinforcement were responsible for decreased resurgence rather than increased time in extinction, then target response rates on Test 3 for Constant-$R_a$ would be comparable to Test 1 for On/Off-$R_a$—this was clearly not the case in our data.

Despite the fact that target response rates at Test 3 were comparable across conditions, the rate of the alternative response at Test 3 was not. As is shown in Table 2.3, the alternative response rate was considerably lower in the On/Off-$R_a$ condition than in the Constant-$R_a$ condition. The discrepancy between alternative response rate persistence across conditions is consistent with the general behavioral-momentum-based approach of Equation 3. According to behavioral momentum theory, the decreased rate of alternative reinforcement in the On/Off-$R_a$ condition during extinction (if extinction were characterized as baseline for the alternative response) relative to the Constant-$R_a$
condition ought to make the alternative response in the On/Off-\(R_a\) condition less resistant to extinction. The finding that increased exposure to alternative reinforcement seemed to increase the persistence of the alternative response might carry implications for resurgence in applied settings. In these cases, the target response might be an operant problem behavior, and the alternative a socially appropriate response. Given equal instances of problem behavior in a resurgence test, conditions that foster greater persistence of the alternative response might be preferred over those that do not.

**General Discussion**

The results of both Experiments 1 and 2 suggest that resurgence decreases as time in extinction increases. This finding is consistent with the predictions of Equation 3, as well as with existing data in which resurgence was repeatedly tested without a return to baseline (i.e., Quick et al., 2011; Wacker et al., 2011). These data and the quantitative framework are also consistent with results from Leitenberg et al. (1975, Experiment 4), which compared resurgence across groups that received 3, 9, and 27 sessions of extinction plus alternative reinforcement. The group that received only three sessions of alternative reinforcement showed visually the greatest relapse (although resurgence was not statistically different from the group that received nine days of alternative reinforcement), whereas the group that received 27 sessions of extinction plus alternative reinforcement showed no significant resurgence. Some recent data, however, are challenging for the effect of length of extinction on subsequent resurgence across groups. Winterbauer et al. (2013, Experiment 2) compared groups that received 4, 12, or 36
sessions of extinction plus alternative reinforcement and found no significant differences in subsequent resurgence. The authors suggested that the discrepancy between their results and those of Leitenberg et al. might be the result of a longer baseline in their experiment (12 sessions) relative to the five-session baseline used by Leitenberg et al. However, the equivalent resurgence in their experiment was likely not solely the result of a lengthier baseline, given that decreases in resurgence were seen across repeated tests in Quick et al., in which rats received between 20 and 25 sessions of baseline cocaine self-administration. Furthermore, decreases in resurgence across implementations and removals of FCT in Wacker et al. were seen for target problem behavior with an unknown but presumably extensive history of reinforcement.

Winterbauer et al. (2013) also suggested that the predictable, high rate of alternative reinforcement provided on a fixed-ratio (FR) 10 schedule may have contributed to easy discrimination (and consequently similar resurgence) when alternative reinforcement was removed. This interpretation is consistent with their context-change hypothesis. The context-change hypothesis proposes that resurgence occurs when the organism fails to generalize the learning of the extinguished contingency from the treatment context to the new context in which alternative reinforcement is unavailable. From this perspective, it makes sense that one might observe no differences as a function of length of extinction plus alternative reinforcement, because longer treatment alone does not necessarily mean that what is learned during extinction is more easily generalized to a different context. Our findings from Experiment 1, as well as the data from Quick et al. (2011) and Wacker et al. (2011), are quite consistent with the
context-change hypothesis. In these instances, reduced resurgence might be observed because each resurgence test served as generalization training in that extinction was experienced in the context of alternative-reinforcement absence. Our results from Experiment 2, on the other hand, challenge this account of resurgence. If the reduced resurgence observed at Test 3 for the On/Off-\(R_a\) condition were the result of the subjects’ previous exposure to the context without alternative reinforcement, the context-change hypothesis would predict that resurgence for the Constant-\(R_a\) condition at Test 3 should be equal to resurgence at Test 1 for the On/Off-\(R_a\) condition. Because we observed comparably low target response rates for both conditions, time in extinction does appear to play an important part in reduced resurgence. Key variables in the behavioral momentum-based model of resurgence might explain why time in extinction was critical in our data and Leitenberg et al. (1975), but showed little impact in Experiment 2 of Winterbauer and others’ study. A close look at the data reveals a potential source of the discrepancy: The mean alternative-reinforcement rates during extinction in the Winterbauer et al. study varied as a function of group.

Although all subjects in Winterbauer et al. (2013) experienced FR 10 schedules of reinforcement for the alternative response during treatment, treatment ended for the shorter treatment groups at earlier points in alternative response acquisition, meaning that the average alternative response rate across all of treatment was different across groups. The alternative response rate does not enter into the predictions of Equation 3, but the alternative-reinforcement rate plays a crucial role in the degree of predicted resurgence. Because Winterbauer et al. used an FR schedule, the alternative reinforcement rate
directly depended on the rate of the alternative response. In our experimental preparations with VI schedules (in which programmed reinforcement rates are tolerant to fairly wide variations in alternative response rates), we used the programmed rate of alternative reinforcement for sessions in which alternative reinforcement is present as $R_a$ in the denominator to predict degree of relapse. When alternative-reinforcement rate is directly tied to alternative response rate, and alternative reinforcement rate changes considerably as extinction progresses, it may be better to consider the mean alternative reinforcement rate for the entire phase rather than one programmed rate.

Although the mean obtained alternative reinforcement rates across all treatments were not reported in Winterbauer et al. (2013), we estimated alternative response rates (and consequent reinforcement rates because of the ratio schedule) using the GraphClick 3.0 data extraction software. These data suggest that, on average across all sessions of extinction plus alternative reinforcement, the group that received four sessions of extinction received approximately 3.41 alternative food deliveries/min, the 12-session group received 3.92/min, and the 36-session group received 5.30/min during extinction. Therefore, although exposure to extinction was greater in the 12- and 36-session groups, the alternative reinforcement rate was also greater. Higher alternative reinforcement rates should produce greater resurgence, but longer exposures to extinction should reduce it. These two contributing factors may have acted in opposition, ultimately leading to no difference in resurgence, despite dissimilar exposures to extinction. Leitenberg et al. (1975) did not report either on their obtained reinforcement rate during extinction or on the reinforcement schedule type used for the alternative response, but if no differences in
reinforcement rates occurred during extinction across groups, one would only expect differences in observed resurgence across their groups to be a function of time in extinction. Even so, this discrepancy does point out the need for a better understanding of factors that may interact with the effects of extended alternative-reinforcement training on subsequent resurgence.

The variable rates of alternative reinforcement accompanying fixed-ratio schedules also points out the need for a better understanding of how to incorporate reinforcement rates from more dynamic environments into resurgence predictions. In other words, it remains to be seen which is more important in terms of the stimulus–reinforcer relationship, the most recently experienced rate of reinforcement, initially experienced rates, or some average of reinforcement rates experienced in the context. Experiments explicitly designed to test such effects are needed. Furthermore, it remains possible that reduced resurgence following greater exposure to extinction may be limited to within-subject comparisons and may not be consistently seen across groups. Finally, a related potential limitation of the present experiments is the use of experienced rather than naïve subjects. Resurgence is not thought to decrease if baseline training is reimplemented (Lieving & Lattal, 2003), but future studies that are designed to directly examine the effect of prior extinction on subsequent persistence (and consequent behavioral momentum model parameter estimates) is merited.

From the perspective of our model, the effects of time in extinction and exposure to alternative reinforcement on resurgence are linked. The disruptive impact of alternative reinforcement grows larger as time in extinction increases—in Equation 3, this
is captured by the multiplicative effect of $t$ on the numerator. Consequently, the decrease in disruption from removing alternative reinforcement during the resurgence test has less of an impact when the time in extinction is lengthy. Therefore, the effects of increased exposure to alternative reinforcement and increased time in extinction on resurgence are not easily disentangled in model predictions. However, the results of Experiment 2 may suggest a more important role for extinction of the target response than for exposure to alternative reinforcement in reducing resurgence. This is because at Test 3, the times in extinction were equal in both conditions ($t = 6$), but exposures to the alternative reinforcement were different. That is, the pigeons in the Constant-$R_a$ condition had experienced five sessions of alternative reinforcement, and those in the On/Off-$R_a$ condition had only experienced three sessions of alternative reinforcement. Although the model in its present form does not make predictions that pit exposure to alternative reinforcement versus time in extinction, research that assesses the relative impacts of these two factors on reduced resurgence could prove useful.

The relative contributions of alternative reinforcement and time in extinction are important to consider, because without alternative reinforcement during extinction, there is no increased risk of relapse resulting from removal of the alternative reinforcement upon completion of the treatment (not considering risk for relapse from other sources such as contextual renewal and reinstatement). Because alternative reinforcement increases the stimulus-reinforcer relationship of the context, it increases resistance to change despite its disruptive impact (see Nevin & Shahan, 2011, for discussion). In an applied example, Mace et al. (2010, Experiment 1) implemented alternative
reinforcement in the treatment of problem behavior in three participants with developmental disabilities. Although the presence of alternative reinforcement in the same context as baseline reinforcement for the problem behavior generally reduced problem behavior when it was in place, problem behavior was more persistent during subsequent extinction than when extinction followed a baseline condition without alternative reinforcement. These data illustrate that alternative reinforcement, although disruptive, represents an increased risk of later persistence. Again, future work should directly test the importance of increased exposure to alternative reinforcement relative to longer time in extinction, as both factors may contribute to decreased resurgence.

This study was designed to examine the effect of time in extinction on repeated tests. The quantitative model of resurgence predicted that without a return to baseline, relapse following the removal of alternative reinforcement should have decreased with each resurgence test. In Equation 3, this is manifest by larger values of $t$ rendering the impact of removing $R_a$ less influential. The obtained data were consistent with this prediction in Experiment 1, which demonstrated that the resurgence of simple, food-maintained behavior decreased across repeated resurgence tests, in a manner consistent with existing cocaine self-administration and applied behavioral studies. Experiment 2 further challenged the quantitative model of resurgence by comparing resurgence at equal time points in extinction across two conditions, one with previous resurgence tests and one that was tested for the first time. Target response rates were equally low across conditions at the same time point in extinction, despite dissimilar exposure to the alternative reinforcement, consistent with the predictions of Equation 3. The qualitative
prediction of decreased resurgence with increased time in extinction was well met by the data, but we observed considerable variability in the parameter estimates within subjects (across experiments) and between subjects (within experiments). Despite the variability in parameter estimates, currently there is no comparable model against which we might judge our fits of extinction and resurgence. Overall, these data and their consistency with translational work are promising for the general approach of the quantitative model of resurgence. If our results continue to generalize, further work in this vein might be useful for reducing the resurgence of problem behaviors and encouraging the persistence of desirable behaviors in applied settings.
CHAPTER 3

RESURGENCE AND REINFORCEMENT CONTEXT

Introduction

Chapter 2 tested the model prediction that with increased exposure to extinction plus alternative reinforcement, resurgence should decrease. Evidence from the two experiments presented in Chapter 2 support this prediction, and more generally the data suggest that further examining resurgence from the perspective of behavioral momentum theory could be useful in determining important predictors of resurgence magnitude. This chapter presents an experiment that tested the relationship between resurgence and another relapse phenomenon, renewal, from the perspective of behavioral momentum theory. Operant renewal is relapse that occurs when contextual stimuli present during the extinction of an operant response are changed. In animal studies of renewal, contextual stimuli can consist of a flashing versus steady operant chamber illumination (Podlesnik & Shahan, 2009), a distinctive scent (e.g., Bouton, Todd, Vurbic, & Winterbauer, 2011), or stripes on the side of the operant chamber (e.g., Todd, Winterbauer, & Bouton, 2012). For example, a rat might be trained to press a lever to receive a food pellet in one context (context A), but moved to a novel context (B) where no food is available for the target response (i.e., extinction). Even if the target response decreases to low levels, if the rat is returned to context A, or placed a novel context (C), then renewal of the operant response can occur despite continued extinction. Understanding renewal is important because the phenomenon suggests that even when there is successful reduction of operant problem
behavior, such as a period of abstinence from drugs while in a treatment facility, operant behavior may be susceptible to relapse with a change in context, such as returning home from treatment.

Although typically studied separately in animal studies of relapse, it may be useful to consider the renewal and resurgence phenomena together. In analogous treatments of operant problem behavior, predictors of both relapse phenomena are often operating simultaneously. For example, an outpatient child with intellectual or developmental disability may receive DRA treatment that successfully reduces problem behavior in a school or clinic setting (e.g., Volkert et al., 2009). Following treatment, the child may not only be subject to lapses in treatment integrity where alternative reinforcement is removed or reduced (i.e., resurgence), but also to the change in contextual stimuli that are associated with moving from the clinic to the home, which may trigger renewal.

The importance of the context of alternative reinforcement treatment depends on theoretical orientation. According to behavioral momentum theory, alternative reinforcement that is delivered in the same context as baseline reinforcement might decrease the target behavior when alternative reinforcement is in place, but it will strengthen the stimulus-reinforcer relationship of the context and increase subsequent persistence and relapse in that context. In the Shahan and Sweeney (2011) model of resurgence, this is captured by the dual position of alternative reinforcement ($R_a$) in the quantitative model as both a disruptor in the numerator and as an added source of contextual reinforcement rate in the denominator. This is consistent with the inclusion of
all sources of reinforcement in the context as contributors to the stimulus-reinforcer relationship of the context, whether the reinforcer is delivered contingent on the target response, response-independently, or contingent on an alternative response (Nevin et al., 1990). Thus, behavioral momentum theory suggests alternative reinforcement that is delivered in a novel context B ought to contribute only to the persistence of operant responses in context B, not in the baseline stimulus-context A. On the other hand, the change in context from B returning to A might induce renewal. Nevertheless, because alternative reinforcement is delivered in a different context, relapse in a group that experiences alternative reinforcement in a novel context B should be no greater than a group that received ordinary extinction in the novel context B (i.e., typical renewal).

This prediction of behavioral momentum theory can be contrasted with that of the context-change hypothesis of resurgence (e.g., Todd, Vurbic, & Bouton, 2014). The context-change hypothesis considers resurgence to be a special case of contextual renewal rather than resurgence and renewal representing distinct relapse phenomena. It is suggested that presence of alternative reinforcement during extinction of the target response serves as contextual cue, as does the removal of alternative reinforcement following treatment. In other words, this account suggests that resurgence is a type of ABC renewal where baseline reinforcement of the target response is context A, alternative reinforcement plus extinction of the target response is context B, and the removal of alternative reinforcement is a novel context C. In this view, resurgence occurs because the extinguished contingency learned during treatment is not generalized to the novel context of no alternative reinforcement. Therefore, if alternative
reinforcement were delivered in a different context, the context-change hypothesis would predict that one more variable that differentiates the context (in this case, alternative reinforcement) would serve as an additional obstacle to the generalization of decreased responding to the novel context. Thus, the context-change hypothesis would predict that relapse would tend to be greater in a group that experienced alternative reinforcement in context B relative to a group that experienced no alternative reinforcement in context B (i.e., typical renewal).

The first purpose of this experiment was to test the competing predictions of behavioral momentum theory and the context-change hypothesis. Is relapse greater when both context change and alternative reinforcement removal are at work, or is relapse following alternative reinforcement delivery in a different context no greater than if alternative reinforcement was not delivered, as in typical renewal? The second purpose was to test the persistence of the alternative response when alternative reinforcement is delivered in the same context as it is removed (as in typical resurgence) relative to the persistence of the alternative response when alternative reinforcement was delivered in a different context. Both the context-change hypothesis and behavioral momentum theory would predict less alternative response persistence when alternative reinforcement was delivered in a different context. Behavioral momentum theory suggests that it is only reinforcement delivered in the context of the alternative response that should contribute to its persistence, thus the alternative response ought to be less persistent when reinforcement was delivered in a separate context. The context-change hypothesis would predict that the alternative response would be less persistent because of a failure to
generalize the new learning (of the alternative response) when the context is changed. Even though this result would not tease apart the two theoretical interpretations, it is practically important because the persistence of a socially appropriate behavior is an important factor to consider alongside any differences in relapse that may occur when choosing how to deliver alternative reinforcement. The third purpose was to put forward a novel method for studying resurgence and renewal in the same experimental preparation—a richer analysis of the potential contributors to relapse of operant responding that may occur in clinical settings.

Method

Subjects

This experiment utilized eight rats for each of four experimental groups, for a total of 32 experimentally naïve male Long-Evans rats (Charles River, Portage, MI, USA). This sample size is comparable to a similar between-groups resurgence study that detected a difference between groups using eight subjects per group (Sweeney & Shahan, 2013). The animals were 71-80 days old when they arrived at the research facility. Rats were individually housed in a climate controlled colony room with a 12-h light cycle that began at 7:00 a.m. Rats were allowed ad libitum water access in their home cages and were maintained at approximately 80% of free feeding weight by food received in the session (Bio-Serv 45 mg dustless precision pellets) and daily post-session supplemental feedings (Harlan Teklad Rodent Diet 8604). Because the rats were naïve, prior to the
experiment proper, rats learned to eat from the food magazine in the operant chamber in two, 30-min training sessions where food was delivered on a variable-time (VT) 60-s schedule.

**Apparatus**

Experimental sessions occurred in one of four Colbourn modular operant chambers, the details of which have been described previously (Podlesnik et al., 2006). Two, non-retractable response levers were located on the left and on the right of the food magazine where pellets were delivered. A small hole in the center of the ceiling allowed for a metal response chain to be dropped into the operant chamber.

**Procedure**

This experiment compared performance between groups across three phases, baseline acquisition of the target response (Phase I), extinction treatment in which reinforcement was no longer available for the target response (Phase II), and continued extinction of the target response with a manipulation expected to induce relapse in some groups (Phase III). Phase I was implemented identically for all rats, where a food pellet was delivered for pressing the target lever on a VI 45-s schedule of reinforcement for 10 daily, 25-min sessions. After Phase I, groups were randomly assigned, with the caveat that the groups should not differ in terms of mean target response rates for the last five sessions of Phase I.

During Phase II, reinforcement for pressing the target lever was discontinued in all groups for 15 sessions. Other experimental manipulations implemented during Phase
II differentiated the four experimental groups: Resurgence, Renewal, Compound, and Control. For the Resurgence group, extinction of the target response was accompanied by alternative reinforcement for pulling the chain. Alternative reinforcement, when delivered, was the same 45-mg pellet delivered during Phase I but on a VI 10-s schedule. For the Renewal group, extinction of the target response occurred in a different operant chamber that had striped stimuli on the wall and a pine-scented towel beneath a guard on the chamber floor. The chain was introduced but pulling never produced food. In the Compound group, extinction occurred in a novel chamber with stimuli as in the Renewal group, but chain pulling also produced alternative reinforcement. In the Control group, the chain was introduced but never produced food, and the rat remained in the same chamber as Phase I.

During Phase III, any rat that was in a different chamber for Phase II was returned to the original chamber and no striped stimuli or pine-scent were used, but all chambers had the alternative response chain. No food was available for any response during Phase III, which lasted four sessions.

**Results**

Table 3.1 displays the average target, alternative, and inactive response rates as well as obtained food rates across all phases of the experiment for the four groups. Group assignment following Phase I ensured roughly equal mean baseline target response
Table 3.1

Mean Target, Alternative, and Inactive Response Rates and Obtained Food Rates During Phases I, II, and III Across Groups

<table>
<thead>
<tr>
<th></th>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Responses Per Minute</td>
<td>Foods Per minute</td>
<td>Responses Per Minute</td>
</tr>
<tr>
<td></td>
<td>Target Alt Inactive</td>
<td>Target Alt Inactive</td>
<td>Target Alt Inactive</td>
</tr>
<tr>
<td>Resurgence (n = 8)</td>
<td>Mean 20.67</td>
<td>0.90</td>
<td>1.18</td>
</tr>
<tr>
<td>(SD) (8.86)</td>
<td>(8.86)</td>
<td>(1.22)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Renewal (n = 8)</td>
<td>Mean 21.06</td>
<td>1.34</td>
<td>1.17</td>
</tr>
<tr>
<td>(SD) (13.01)</td>
<td>(13.01)</td>
<td>(1.42)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Compound (n = 8)</td>
<td>Mean 20.88</td>
<td>1.44</td>
<td>1.16</td>
</tr>
<tr>
<td>(SD) (8.03)</td>
<td>(8.03)</td>
<td>(2.10)</td>
<td>(0.13)</td>
</tr>
<tr>
<td>Control (n = 8)</td>
<td>Mean 21.30</td>
<td>1.45</td>
<td>1.17</td>
</tr>
<tr>
<td>(SD) (9.84)</td>
<td>(9.84)</td>
<td>(1.61)</td>
<td>(0.08)</td>
</tr>
</tbody>
</table>

Note. Table 3.1 displays the means and SDs (in parentheses) for target response rate, alternative response rate, and inactive response rates (in presses/min) as well as obtained food delivery rate (in foods/min) for each Phase in the experiment presented in Chapter II. Each rat’s individual rate was included in the above calculation. The last five sessions are included in the Phase I average, and all sessions in the phase are included the average for Phases II and III.
rates across groups. Figure 3.1 displays target and alternative response rates across Phases II and III for all groups. Target response rate reliably decreased across Phase II in all groups, and alternative response rates increased in the two groups that received alternative reinforcement (Compound and Resurgence). Because relapse was not visually different for any group beyond the first session of Phase III, only that session was considered in further analyses of relapse.

Repeated-measures ANOVA was used to assess the effect of the within-subjects factor of Session and the between-subjects factor of Group on target response rate during Phase II and the first session of Phase III. The analysis identified a Session by Group interaction, $F(45,420) = 2.26, p < .001$, which captures that the pattern of target response rates across session differed as a function of group. There was a significant main effect of session, $F(15,420) = 30.92, p < .001$, which captured that target response rates changed across session, but no overall main effect of group, $F(3,28) = 1.76, p = .178$.

Simple effects contrasts using the first session of Phase III as the reference class indicated an overall effect of the change to Phase III, $F(1,28) = 27.70, p < .001$, as well a Session by Group interaction for the transition to Phase III, $F(3,28) = 4.72, p < .01$, which suggests that performance in the transition to Phase III differed across groups. Figure 3.2 shows mean target response rates for the transition to Phase III.

These analyses do not specify for which groups the transition to Phase III differed. For closer analysis, paired $t$-test comparisons for each group assessed whether the mean target response rates on the last session of Phase II significantly differed from
Figure 3.1. Mean target and alternative response rates for all groups during Phases II and III. Note the different height of the y-axes and that error bars are displayed above the data only.
target response rates on the first session of Phase III, which would indicate relapse. Significant relapse of the target response was identified for groups Renewal, \( t(7) = 2.93, p < .05 \), Resurgence, \( t(7) = 3.69, p < .01 \), and Compound, \( t(7) = 5.05, p < .01 \), but not for Control, \( t(7) = 0.48, p = .65 \). Results of a one-way ANOVA comparing target response rates on the first session of Phase III for those groups that did relapse (Renewal, Resurgence, and Compound) showed no significant differences between groups, \( F(2,21) = 1.00, p = .89 \). Data from the last session of Phase II and the first session of Phase III were also scrutinized on an individual subject level (Figure 3.3), and it was confirmed that performance between the Compound, Renewal, and Resurgence groups in the transition to Phase III not consistently differ by visual inspection. Similar results for all analyses were obtained if target response rates were considered in terms of proportion of

![Figure 3.2. Mean target response rates on the last session of Phase II and the first session of Phase III for each group.](image-url)
baseline.

The persistence of the alternative response across Phase III was also examined as a function of group for the Resurgence and Compound groups. Individual alternative response persistence on the first day of Phase III was considered as a proportion of the average alternative response rate for the last five sessions of Phase II and then mean persistence was compared as a function of group. The results of this analysis are displayed in Figure 3.4. A $t$ test comparing alternative response persistence as a function of group revealed a significant difference between Resurgence and Compound, $t(14) = 2.20, p < .05$, where alternative response persistence tended to be less in the group that

![Figure 3.3](image_url)

*Figure 3.3.* Individual subject target response rates from the last session of Phase II and the first session of Phase III. Each rat’s data are plotted as two points and a connecting line.
received alternative reinforcement delivered in a different context.

Discussion

The present experiment represents the first study of renewal and resurgence phenomena in the same procedure. To that end, we have shown that it is feasible to study resurgence and renewal using typical experimental preparations as well as delivering alternative reinforcement in a novel context. This methodology allows direct comparison of the relapse effects because of similar experimental histories. Future investigators may choose to adopt the general methodology we have put forward and systematically replicate and extend our work and the understanding of how context change and alternative reinforcement removal affect relapse alone and together.

We found that relapse following alternative reinforcement delivered in another context was no greater than ordinary renewal. The context-change hypothesis would

![Figure 3.4. Mean and standard error of alternative response persistence on the first session of Phase III as a proportion of the average of the last five sessions of Phase II for both experimental groups that received reinforcement for the alternative response.](image)
suggest relapse following alternative reinforcement in a different context would be
greater than relapse following context change alone, because alternative reinforcement
should serve as an additional discriminative cue that is different from Phase II to Phase
III, making generalization of learning during treatment more difficult. Behavioral
momentum theory predicts that only reinforcement delivered in the same stimulus
reinforcement context contributes to the strength of the stimulus-reinforcer relationship of
the context, but still would predict renewal because of a release from disruption caused
by a change in the stimulus-context. What renewal is observed would be the function of
the strength of the stimulus-reinforcer relationship defined during baseline, which would
be no different in a group that experienced alternative reinforcement in the extinction
context as a group that experienced no alternative reinforcement in the extinction context.
Therefore, these data support behavioral momentum theory’s prediction that relapse
following alternative reinforcement delivered in another context is no greater than
ordinary renewal.

On the other hand, a failure to reject the null hypothesis is not the best way to make assertions about the impact of variables. It remains possible that with more
subjects a significant difference would emerge, but given that no consistent differences
were observed at the individual subject level, increased power by sample size alone
would likely not detect a meaningful difference between groups. A more interesting
future direction would be to test the robustness of this effect by systematically varying
the length of Phase II, which should affect resurgence magnitude (see Chapter 2 and
Leitenberg et al., 1975), but ought not affect the size of renewal. This research would
help to determine whether relapse following alternative reinforcement delivered in a different context might produce a larger effect than ordinary renewal or resurgence at shorter durations of Phase II (where the effect of alternative reinforcement removal ought to be more robust), rather than at longer durations as in the present study. If relapse in the typical resurgence preparation is less following longer exposure to Phase II, but relapse in compound and renewal preparations is consistently similar and does not depend on length of Phase II, then that would suggest relapse in the compound preparation is a result of the change in contextual stimuli and is not impacted by alternative reinforcement delivered in another context. This finding would be consistent with the present results and provide additional support for the predictions of behavioral momentum theory.

The context-change hypothesis is parsimonious in that it suggests all relapse, including resurgence, is a form of renewal. Our data suggest, however, that alternative reinforcement is not simply one additional variable that defines a context and makes generalization of the extinguished contingency more difficult. Other recent experimental evidence suggests that context-change alone is not sufficient to understand the variables that impact resurgence. Winterbauer and Bouton (2012) predicted that gradually thinning alternative reinforcement would serve as generalization training and make resurgence when alternative reinforcement was removed less pronounced. Their data did show less of an increase when alternative reinforcement was completely removed following thinning, but elevated target response rates during Phase II led them to suggest each change in alternative reinforcement rate during treatment served as a context-change and
induced renewal on a small scale. On the other hand, Sweeney and Shahan (2013) found similarly elevated target response rates in later Phase II in a group with thinning alternative reinforcement as a group with constant, low-rate alternative reinforcement. This similarity suggests that the source of elevated target response rates during later Phase II (and less subsequent resurgence) was overall lower rates of alternative reinforcement during treatment, rather than small scale context-change. This is because context-change due to changing alternative reinforcement rates was absent from the group with constant, low alternative reinforcement rates. Future work that directly compares resurgence and renewal may find additional evidence to suggest that these phenomena are sufficiently distinct to merit an understanding of the mechanisms of both kinds of relapse, which may be different.

We also found that the alternative response was more persistent during Phase III when alternative reinforcement was delivered in the same context relative to a different context. This is consistent with both behavioral momentum theory and recent experimental evidence that suggests operant responses are more persistent in the context in which they were originally trained (Bouton, Todd, & León, 2013). Even if future studies detect differences in relapse of the target response as a function of alternative reinforcement context, the persistence of the alternative response (which is usually a desirable alternative to the target response) must be taken into account when deciding whether to deliver alternative reinforcement in a novel or familiar context. Overall, this study is useful because it puts forward a richer animal model of relapse that allows direct comparison of renewal and resurgence. Future research may modify our manipulation to
compare renewal, resurgence, and compound manipulations to test the effects of relapse predictors such as length of time in extinction and reinforcement history.
CHAPTER 4
RESURGENCE IN HUMAN PARTICIPANTS

Introduction

Resurgence is usually studied in one of two settings: in a laboratory using animal models (e.g., Winterbauer et al., 2013), or in a clinical setting treating problem behavior in individuals with intellectual or developmental disabilities (e.g., Volkert et al., 2009). Research with laboratory animals has illustrated important variables that dictate the persistence and resurgence of behavior in the face of treatment; for example, it has been shown that high rates of alternative reward are more effective during treatment than low rates, but that relapse is greater following high rates of reward relative to low rates of reward (Leitenberg et al., 1975; Sweeney & Shahan, 2013). In addition, the experiments presented in Chapter 2 of this dissertation, in conjunction with existing data (Leitenberg et al., Experiment 4; but see Winterbauer et al., 2013) suggest increased time in extinction plus alternative reinforcement may decrease subsequent resurgence. The generality of these findings to human populations is unknown.

What research has been done to examine resurgence in typically functioning adult participants has involved complex or unusual discriminations, such as resurgence of derived stimulus relations, infant caregiving responses, schedule-driven behavior or revealed operant behavior, and often consists of lengthy or repeated sessions (i.e., Bruzek, Thompson, & Peters, 2009; Dixon & Hayes, 1998; Doughty, Cash, Finch, Holloway, & Wallington, 2010; Doughty, Kastner, & Bismark, 2011; Mechner, Hyten,
Field, & Madden, 1997; Wilson & Hayes, 1996). Although the complexity of these procedures supports the broad implications of basic resurgence work, the time consuming nature of the sessions and complex response patterns makes it difficult to isolate and manipulate variables that may be of general importance in persistence and resurgence. The small sample sizes necessitated by the complex procedures also make it difficult to parse out psychological or demographic characteristics that may predict different responses to alternative reinforcement treatments. A simple procedure that parallels behavior in the animal laboratory would serve to test the generality of basic animal research findings while avoiding any adverse consequences (e.g., explicitly rewarding problem behavior as in Volkert et al., 2009) of manipulating variables that may affect the relapse of clinically significant behaviors.

Another shortcoming common to existing resurgence data is the availability of only two behaviors (e.g., Dixon & Hayes, 1998; McHugh, Procter, Herzog, Schock, & Reed, 2012). This makes it difficult to establish that resurgence that occurs in these human operant preparations is a result of the history of reinforcement for the target behavior above and beyond extinction-induced variability. In animal models of resurgence, resurgence is distinguished from a simple increase in response variability by the inclusion of an inactive response. For example, in order to be considered resurgence, target response rates when alternative reinforcement is removed ought to exceed rates on a lever (or a key, for pigeons) that has never been associated with food. This is the case in the animal models of resurgence presented in Chapters 2 and 3 of this dissertation, as well as other published tests of resurgence as it relates to behavioral momentum theory.
(Podlesnik & Shahan, 2009; Podlesnik et al., 2006; Sweeney & Shahan, 2013). Therefore, if tests of the generality of the findings of behavioral momentum theory are to be tested in a human operant resurgence, the task must include at least one response that has no history of reinforcement to control for random increases in responding not associated with reinforcement history.

A novel resurgence procedure should also attempt to constrain variability that has made between-subject comparisons difficult in prior human operant resurgence research. One way to do this would be to have a trial-based procedure that forces a choice between three arbitrary stimuli. Rather than free-operant response rate across session, relative preference for a given stimulus during a particular trial block could be measured, which cannot exceed 100% or drop below 0%. Trial-based procedures are simpler to program, and therefore increase the likelihood of adoption by other laboratories for replication and extension. The use of arbitrary rather than disorder relevant behaviors reduces the risk of increased persistence and relapse of clinically relevant behavior and also increases the generality of the behavioral implications. In addition, arbitrary behaviors allow researchers greater control of reinforcement history for the experimental behavior rather than attempt to manipulate reinforcement for an existing behavior with an unknown history of reinforcement. Thus, the present experiment examined resurgence during a behavioral task in which each trial required the choice of one of three arbitrary stimuli in order to maximize points.
Method

Participants

Participants were 36 adult college students recruited through the Introduction to Psychology participant pool and through announcements in psychology courses.

Procedure

Instructions. Following informed consent, participants were directed to the chair in front of the experimental computer. General instructions (based in part on instructions found in Kangas et al., 2009 and Doughty et al., 2011) were read aloud to the participant. The full instructions script can be found in Appendix II. After the task instructions were read and any questions had been answered, the participant was left alone until the task was completed.

Demographic information. The computer program asked the participants to provide the following basic demographic information: age, gender, ethnicity, and years of education following high school. Gender and ethnicity had an option that read, “I prefer not to answer.”

Behavioral task. The behavioral task consisted of three phases. In Phase I, selecting the target stimulus earned the participant 10 points with a probability that varied according to which version, or condition, of the task they experienced. Choosing the alternative stimulus or the inactive stimulus never resulted in points. Which stimuli served as the target and alternative were selected in a pseudorandom order. The length of Phase I also varied according to condition. In Phase II, selection of the alternative
stimulus produced points with a given probability according to condition, whereas selection of the target stimulus or control stimulus never produced points. In the third phase, no points could be produced no matter which stimulus was selected.

These phases are analogous to the typical three-phase resurgence procedures used in animal research: Phase I in which the target response is trained, Phase II in which the alternative response is trained and the target response is no longer productive, and Phase III in which no response is productive. The key difference is that rather than response rate in terms of responses per minute to the target or the alternative serving as the primary measure of responding, it is relative preference for the target, alternative, or control stimulus during any given block of 12 trials. Choices distributed equally between stimuli (around four per stimulus) illustrate no preference, whereas unequal choices illustrate a relative preference for stimuli chosen more often within that trial block. The control stimulus served as our indication of an effect of reward history over extinction-induced variability.

**Stimuli.** Target, alternative, and control stimuli were a yellow square, an orange circle, and a blue triangle. All colored shapes were in the foreground of a black square to ensure equal total surface area of the stimulus.

**Choice screen.** In each trial, participants were presented with a stimulus “choice” screen with a white background and the three shapes in a triangular configuration. Each choice screen allowed the participants to choose between three options (circle, square, or triangle) and the participant indicated the selection by clicking anywhere on the shape, including the black background. There was no minimum or maximum time limit on the
choice screen. The only way to advance was by clicking on the shape with the mouse. The arrangement of the shapes was randomized across the trials. The mouse changed position randomly at the start of each choice trial, but it was always equidistant between two shapes or at the center of the screen. This was to increase participants’ engagement with the screen by compelling them to look at the screen before selecting the shape, and at the same time ensured the mouse position was never biased toward only one shape.

**Feedback screen.** Immediately following the participants’ selection, the three shapes and mouse disappeared and the “feedback” screen displayed the message “Win!” in green letters if the selection earned points or “Nothing.” in black if the selection did not earn points. A running total of points earned always displayed on the bottom of the feedback screen. There was no minimum or maximum time limit on the feedback screen. The only way to advance was by pressing SPACE, which immediately brought up the next choice screen.

**Reflection questions.** Following the behavioral task, the participants were asked a series of questions (via Qualtrics®) that were designed to help us understand how participants’ subjective experience mapped on to their performance during the behavioral task. The questions are available in Appendix III.

**Feasibility**

Feasibility of the program was assessed after every five participants. An acceptable procedure would be one for which four of five participants showed resurgence and the data were generally consistent at the individual subject level. Resurgence was defined as an increase in the selection of the target stimulus during the first block of
Phase III (when no points are available for any selection) relative to the last block of Phase II, and also that the selection of the target stimulus during the first block of Phase III is greater than for the inactive control stimulus (which never produced points). The inactive control stimulus serves as our indication of an effect of reward history beyond extinction-induced variability. Thus, if there is an increase in preference for the target stimulus during Phase III relative to the end of Phase II, and also a preference for the target stimulus over the inactive control stimulus, then we can say that resurgence has occurred. The extent of this increase in preference and the difference between preference for the target and control stimulus indicate the magnitude of the resurgence effect. If resurgence did not occur in four of five participants, then the procedure was modified. The order and nature of the modifications (conditions) are discussed below.

Results

Participants

Participants had a mean age of 21.0 years ($SD = 2.4$) and a mean of 2.2 years of education following high school ($SD = 1.3$). Of the 36 total participants, 19 identified as female and 17 as male. One participant identified as American Indian or Alaska Native, 34 identified as White, and one participant preferred not to answer this question. There were no systematic differences in performance as a function of participant gender, age, or education. Participant 18 experienced a program malfunction and his data were excluded from the rest of the analysis.
Conditions

When resurgence was not observed in four of five participants, the procedure was changed. There were seven variations of the task outlined above that are described in Table 4.1. The first strategy of change was to increase the length of Phase I relative to Phase II (Conditions 1, 2, & 3), as longer Phase I (Bruzek et al., 2009; Doughty et al., 2011; Winterbauer et al., 2013) and shorter Phase II (see Chapter 2 and Leitenberg et al., 1975, Experiment 4) may increase the magnitude of resurgence. The second strategy was to modify the probability of reward. We began with a high probability of .8, and because acquisition of preference for the target stimulus was rapid, we decreased the probability of reward in order to make extinction less discriminable from reinforcement for the target, which can increase persistence in certain circumstances (Nevin et al., 2001). We first decreased the probability to .5 in both Phases I and II (Condition 4). Then, we decreased the probability of reward to .1 during Phase I, but kept the probability of reward at .5 in Phase II (Condition 5). We kept the probability of reward higher during Phase II because the data suggested that any lower probability would likely have required an increase in the length of Phase II, which would counter our efforts to see a resurgence effect. When we decreased to .1 during Phase I, acquisition of preference for the target stimulus never emerged, so we increased the probability of reward in Phase I to .2 (Condition 6). When acquisition of preference for the target stimulus remained inconsistent at a probability of .2, we increased the probability of reward during Phase I to .3 (Condition 7). In Condition 7, acquisition of preference for the target stimulus
Table 4.1

*Experimental Conditions: Variations of the Three-Phase Procedure*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Number of Trials</th>
<th>Probability of Reward</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase I</td>
<td>Phase II</td>
<td>Phase III</td>
<td>Phase I</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
<td>60</td>
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</tr>
<tr>
<td>2</td>
<td>120</td>
<td>60</td>
<td>60</td>
<td>.8</td>
</tr>
<tr>
<td>3</td>
<td>180</td>
<td>60</td>
<td>60</td>
<td>.8</td>
</tr>
<tr>
<td>4</td>
<td>180</td>
<td>60</td>
<td>60</td>
<td>.5</td>
</tr>
<tr>
<td>5</td>
<td>180</td>
<td>60</td>
<td>60</td>
<td>.1</td>
</tr>
<tr>
<td>6</td>
<td>180</td>
<td>60</td>
<td>60</td>
<td>.2</td>
</tr>
<tr>
<td>7</td>
<td>180</td>
<td>60</td>
<td>60</td>
<td>.3</td>
</tr>
</tbody>
</table>

*Note.* Above are the seven conditions of the experiment. Aside from the number of trials and the probability of reward, the methodology remained the same across all conditions. Five participants experienced each condition.

emerged, but no resurgence was observed. Because the manipulation of phase length made no difference and the range of reward probabilities was exhausted, we stopped data collection using this procedure.

**Behavioral Task Performance**

Mean subject preferences for each stimulus across the experimental phases in each condition can be seen in Figures 4.1 and 4.2. General performance for critical phases and point totals are displayed in Table 4.2. Except for Condition 5, where the probability of reward during Phase I was .1, and Condition 6, where the probability of
Figure 4.1. Mean preference for the target, alternative, and inactive stimulus for Condition 1 (top left), Condition 2 (top right), and Condition 3 (bottom).
Figure 4.2. Mean preference for the target, alternative, and inactive stimulus for Condition 4 (top left), Condition 5 (top right), Condition 6 (bottom left), and Condition 7 (bottom right).
Table 4.2

Mean Performance for Critical Trial Blocks, Mean Point Total, and Mean Subjective Distress for Each Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Target</th>
<th>Alt</th>
<th>Inactive</th>
<th>Target</th>
<th>Alt</th>
<th>Inactive</th>
<th>Total Points</th>
<th>Subjective Distress</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td>1.8</td>
<td>2.0</td>
<td>1.2</td>
<td>9.8</td>
<td>1.0</td>
<td>2.8</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>(3.9)</td>
<td>(1.6)</td>
<td>(2.3)</td>
<td>(1.6)</td>
<td>(2.5)</td>
<td>(1.0)</td>
<td>(0.8)</td>
<td>(1.1)</td>
</tr>
<tr>
<td>2</td>
<td>11.4</td>
<td>0.2</td>
<td>0.4</td>
<td>0.0</td>
<td>11.8</td>
<td>0.2</td>
<td>2.6</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>(0.5)</td>
<td>(0.4)</td>
<td>(0.5)</td>
<td>(0.0)</td>
<td>(0.4)</td>
<td>(0.4)</td>
<td>(0.9)</td>
<td>(1.8)</td>
</tr>
<tr>
<td>3</td>
<td>11.8</td>
<td>0.0</td>
<td>0.2</td>
<td>0.0</td>
<td>11.8</td>
<td>0.2</td>
<td>2.8</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>(0.4)</td>
<td>(0.0)</td>
<td>(0.4)</td>
<td>(0.0)</td>
<td>(0.4)</td>
<td>(0.4)</td>
<td>(1.1)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>4</td>
<td>11.8</td>
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<td>0.2</td>
<td>2.2</td>
<td>9.4</td>
<td>0.4</td>
<td>3.6</td>
<td>6.4</td>
</tr>
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<td>(0.0)</td>
<td>(0.4)</td>
<td>(2.8)</td>
<td>(2.7)</td>
<td>(0.5)</td>
<td>(2.2)</td>
<td>(2.3)</td>
</tr>
<tr>
<td>5</td>
<td>5.2</td>
<td>3.4</td>
<td>3.4</td>
<td>4.2</td>
<td>5.2</td>
<td>2.6</td>
<td>5.4</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>(3.8)</td>
<td>(2.2)</td>
<td>(2.4)</td>
<td>(1.6)</td>
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<td>7</td>
<td>8.6</td>
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<td>0.6</td>
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<td>1.4</td>
<td>7.6</td>
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<td></td>
<td>(4.5)</td>
<td>(1.8)</td>
<td>(2.9)</td>
<td>(0.9)</td>
<td>(1.8)</td>
<td>(1.3)</td>
<td>(0.9)</td>
<td>(2.9)</td>
</tr>
<tr>
<td>Total</td>
<td>9.3</td>
<td>1.3</td>
<td>1.4</td>
<td>1.5</td>
<td>9.2</td>
<td>1.3</td>
<td>3.0</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>(3.5)</td>
<td>(1.8)</td>
<td>(2.0)</td>
<td>(2.0)</td>
<td>(3.3)</td>
<td>(2.1)</td>
<td>(1.9)</td>
<td>(2.4)</td>
</tr>
</tbody>
</table>

Note. Performance for critical block of 12 trials as the mean number of times the target, alternative, or inactive stimulus was chosen. Total Points is the mean points obtained in the entire session. Units of Subjective Distress (from 1-10 where 1 is the least distressed you can feel, and 10 is the most distressed you can feel) reports the mean for responses to question 11 of the reflection task, available in Appendix III. Standard deviations are below the means in parentheses. n = 5 for each condition
reward during Phase I was .2, acquisition of preference for the target stimulus and subsequent acquisition of the alternative stimulus during Phase II was good.

There was generally an increase in preference for the target stimulus on the first block of Phase III relative to the last block of Phase II. Consistent with Chapters II and III of this dissertation, these increases were examined on the individual subject level (Figures 4.3 and 4.4). Whether examined on the individual subject level, by condition, or overall, the increase in preference for the target upon removal of alternative reinforcement was indistinguishable from the increase in preference for the inactive control stimulus.

In addition to the mean and individual subject examination of performance when alternative reinforcement was removed, each participant was coded as indicating an increase in preference for the target stimulus, the inactive stimulus, or no preference between target and inactive. An increase in preference for the target or inactive stimulus was indicated if (1) the participant selected the target or inactive stimulus more during the first block of Phase III than it was selected during the last block of Phase II, and (2) the participant chose the target or inactive stimulus more than the other stimulus during the first block of Phase III.

Using these criteria, nine participants showed an increase and preference for the target, 12 for the inactive, and 14 showed no difference. This distribution is within the range of what would be expected if the task engendered indifference: many exactly even and a roughly equal number choosing either one over the other. Participants who showed
Figure 4.3. Individual subject target preference from the last trial block (12 trials) of Phase II and the first trial block of Phase III for Conditions 1, 2, and 3. Each participant is represented by two data points and a connecting line.
Figure 4.4. Individual subject target preference from the last trial block (12 trials) of Phase II and the first trial block of Phase III for Conditions 4-7. Each participant is represented by two data points and a connecting line.
a preference for either the target or inactive did not differ systematically in terms of Phase I or Phase II acquisition or point totals.

**Reflection Task**

When asked what they thought the purpose of the experiment was, most participants provided a response (31) and four responded, “I don’t know.” Common responses were that the task was to examine the tendency to choose a response after being rewarded for choosing that response \( n = 10 \), to see how well people can identify patterns \( n = 11 \), to see how people respond to rewards \( n = 4 \) and to see how people respond to random rewards \( n = 2 \). One participant thought the study may be about gambling and how people make decisions when “winning” versus when “losing”. These responses were roughly evenly distributed across experimental condition.

When participants were asked how they made their decisions, all participants provided a response. The most common theme in these responses was that participants reported finding a response that worked and then switching when it no longer worked (e.g., “I just chose whichever shape had given me points. When that one stopped giving me points I tried different shapes,” \( n = 22 \)). Of those 22, four described their strategy after the second shape “stopped working,” or what was likely Phase III following alternative reinforcement removal. One reported “I would go back to the one that I was rewared(sic) on,” two reported trying the inactive shape, eight indicated that they responded randomly, and one responded consistently choosing one shape hoping that would make it work. Other responses to how they made their decisions were: trying to find a pattern but failing (e.g., “I tried to find a pattern to earn points. I thought maybe
there was a certain order to the shapes, then I tried order of position, and position and shape. If there was a pattern I couldn't figure it out. After a few tries I didn't care what shape I picked,” \( n = 8 \), trying to find a pattern (e.g., “I tried to figure out how the shapes were shifting and match up a pattern(sic) with the ones I was getting correct so that I could find the pattern of which would be the correct answer,” \( n = 3 \)), and responding randomly (e.g., “mine was just some guess,” \( n = 2 \)). The categories of responses were roughly evenly distributed across experimental conditions, with the exception that trying to find a pattern and failing was very common (seven out of ten participants) in Conditions 5 and 6 where acquisition was generally poor. Answers to questions about describing strategy and how strategy changed were redundant with participant descriptions of how they made their decisions.

Because loss of alternative reinforcement could be considered a stressor, we examined subjective units of distress (on a scale of 1 to 10 where 1 is “the least distressed you can feel,” and 10 is “the most distressed you can feel”) as a function of whether the participants were coded as showing an increase and preference during the first block of Phase III for the target (\( M = 3.72, SD = 1.37 \)), the inactive (\( M = 4.02, SD = 2.30 \)), or indifferent (\( M = 4.23, SD = 2.19 \)) and found no clear differences.

**Discussion**

Although consistent increases in preference for the target stimulus were observed, they could not be distinguished from increases in preference for the inactive control stimulus that was never associated with reinforcement. Thus, one of the major design
innovations for this study proved an important control condition that calls into question two past resurgence studies with human participants that used only two response options. Dixon and Hayes (1998) instructed participants that there were two possible responses, repeating a pattern of movements of a circle, or moving the circle in different patterns. Similarly, McHugh et al. (2012, p. 407), participants were told, “You must press either quickly or slowly in order to earn points.” This dichotomy without a control response does not allow for us to understand resurgence as something above extinction-induced variability. If participants were operating under the rule, “This response is not working, it must be some other response that is working,” then the only reason that we did not see resurgence is that past research constrained the participants to only two responses and did not include a response that was not associated with a history of reinforcement. Because of this, the increase in the target topography seen by Dixon and Hayes and McHugh et al. cannot be separated from the collective increase in preference for both the target stimulus and the inactive stimulus seen in this study.

Resurgence could be characterized as a specific form of extinction-induced variability, where behaviors with a history of reinforcement reappear as well as novel responses. In that case, it could be that rather than introducing an essential control by including an inactive stimulus, we are adding unnecessary complexity. However, if resurgence is a function of a history of reinforcement associated with the target response, as behavioral momentum theory suggests, then it is important to distinguish between response recovery and response novelty. In animal research, an increase in the target response does not occur when the target response has no history of reinforcement
(Winterbauer & Bouton, 2010). In addition, animal studies usually include an inactive response that has never been associated with reward, and the resurgence of the target response is readily distinguishable from the small increases of the inactive response during Phase III (Chapter 2, Chapter 3, Sweeney & Shahan, 2013). The variables that have governed resurgence of a previously reinforced response in animal research may not similarly affect increases in novel responding. Therefore, if we hope to generalize knowledge based on animal studies of resurgence and behavioral momentum theory, a response that has never been associated with reinforcement is a necessary control in human research.

There are three additional differences in this procedure relative to past research that may account for the lack of resurgence observed: The brevity of baseline training phase, the use of a discrete-trial choice procedure rather than a VI schedule, and the presence of the alternative response during baseline training. In animal studies, the alternative response is usually not available during the baseline training phase. For example, the alternative response might be a nose poke that is not illuminated during baseline but a light comes on in the nose poke once alternative reinforcement is introduced (Sweeney & Shahan, 2013), or a chain is introduced in the roof of the chamber during Phases II and III as was done in Chapter III. Even though the presence of the alternative stimulus during baseline in this study represents a departure from animal research studies, increased experience with non-reinforcement of the alternative response would, if anything, negatively affect alternative response acquisition (which was not a problem in this study) rather than impair target response relapse. Further, from a
generalization perspective, having only two stimuli during Phase I and three stimuli during Phases II and III would make Phase III less similar to baseline reinforcement of the target response and prevent resurgence rather than encourage it. Finally, human studies of resurgence that have used matching to sample procedures have included the alternative response from the outset, and it did not prevent resurgence (Doughty et al., 2010, 2011; Wilson & Hayes, 1996). Therefore, the presence of the alternative stimulus during baseline is a minor procedural difference and not likely responsible for the lack of resurgence in the present study.

Another difference between our procedure and existing animal studies of resurgence is the use of a discrete-trial choice procedure rather than a procedure in which the trial is unsignaled, such as a VI schedule. The use of a choice procedure here is not unique among human laboratory procedures designed to produce resurgence. Wilson and Hayes (1996), Doughty et al. (2010), and Doughty et al. (2011) used discrete-trial matching to sample procedures and observed resurgence. The key difference may be that in an effort to create a brief, very simple resurgence experiment, the baseline training phase in our procedure was not as extended in time as in other examples. It could be that in an effort to create a more time- and cost-effective human laboratory model of resurgence that we left out a key variable in resurgence: the length of the baseline history of reinforcement for the target response. Experimental research that tests the effect of length of baseline training for the target response on subsequent resurgence is very limited (Bruzek et al., 2009; Doughty et al., 2010; Winterbauer et al., 2013), but does suggest that lengthier baseline training is associated with greater resurgence, even when
acquisition of the target response reaches comparable levels at the end of baseline. Despite the limited knowledge of the parametric effects of length of baseline training on subsequent resurgence, it may be that by having lengthy baseline training sessions or even multiple visits to the laboratory, past research was able to see resurgence, whereas we were not.

This leaves at least two options for future work: dramatically increase the number of trials in Phase I of a trial-based procedure beyond what was implemented here, or move to VI schedules to more closely parallel the animal laboratory. The mean duration of the behavioral task reported here was very brief ($M = 13$ min, $SD = 3$ min), so there is some room for expansion. On the other hand, that the tripling of Phase I length here had no effect on subsequent preference during Phase III is not promising for simply lengthening Phase I. Also, repeated sessions or a very lengthy session is contrary to the goals of a brief procedure that can be implemented easily with many participants to tease out subject characteristics that may be predictive of resurgence. Perhaps the best course of action, therefore, would be to implement a similar procedure of comparable duration with arbitrary stimuli using VI schedules of reinforcement for responses to the target and alternative stimuli. If the brief baseline training period with a VI schedule does not produce consistent resurgence, then the length of baseline training can be increased. Even if the resulting experimental preparation results in equally lengthy experimental sessions as more complex matching to sample discriminations, it would have the added advantage of simplicity of response topography and closer resemblance to animal studies, which would make replication of basic animal research in human subjects more
straightforward. The presence of the inactive control stimulus remains critical to establish that manipulations of reinforcement ought to affect resurgence.
CHAPTER 5
GENERAL DISCUSSION

Introduction

The overarching theme of this dissertation is to identify important predictors of persistence and resurgence when alternative reinforcement is removed. Data presented in Chapters II and III speak to the potential role of time in extinction and alternative reinforcement context, respectively. Although not an explicit test of the effect of baseline history of reinforcement, the lack of resurgence observed in Chapter 3 may be related to the length of reinforcement history with the target response. Other experimental investigations have suggested that alternative reinforcement rate during extinction plus alternative reinforcement and alternative reinforcement contingency may also affect resurgence. These potential predictors will be discussed in turn, often as they relate to the predictions of the quantitative model of resurgence put forward by Shahan and Sweeney (2011),

\[ \log \left( \frac{B_t}{B_o} \right) = \frac{-t(kR_a + c + dr)}{(r + R_a)^b} \]  

which provided the impetus for many experimental investigations of resurgence. Again, Equation 1 predicts proportion of baseline response rates at time \( t \) in extinction where \( k \) is a free parameter that scales the disruptive impact of alternative reinforcement \( (R_a) \), \( c \) is a free parameter that captures the disruptive effect of the response-reinforcer contingency, and \( dr \) is the generalization decrement associated with the removal of baseline
reinforcement. The denominator captures the strength of the stimulus-reinforcer relationship of the context, where the effect of baseline ($r$) and alternative ($R_a$) reinforcement both contribute to the persistence of an operant response, and $b$ is the sensitivity of an organism to reinforcement rate.

**Time in Extinction**

Chapter 2 of this dissertation was a test of the effect of time in extinction plus exposure to alternative reinforcement on subsequent resurgence. The data from those two experiments, and from Quick et al. (2011) and Wacker et al. (2011), suggest that an increase in extinction plus exposure to alternative reinforcement results in a decrease in resurgence. This conclusion is in line with the data from Leitenberg et al. (1975, Experiment 4) but contrary to the more recent study of Winterbauer et al. (2013), both of which compared the effect of length of extinction plus alternative reinforcement across groups of rats that experienced different lengths of Phase II. In the general discussion of Chapter II, the point was made that although the length of extinction plus alternative reinforcement was increased in Winterbauer et al., alternative reinforcement rate was also higher in those groups that experienced longer Phase II. Because higher alternative reinforcement rate ought to increase subsequent resurgence and longer Phase II should decrease it, these two variables may have counteracted one another and resulted in roughly equal resurgence across groups despite differences in length of Phase II.

Although this interpretation is consistent with the data reported, it suggests that increasing the length of exposure to extinction plus alternative reinforcement alone is not
enough. If increased length of Phase II results in an increase in the average rate of alternative reinforcement, then resurgence may be comparable to a shorter Phase II with lower rate of alternative reinforcement. The efficacy of lengthening alternative reinforcement treatments is potentially dependent on the combination of other predictors of resurgence, including alternative reinforcement rate, and alternative reinforcement schedule. Alternative reinforcement schedule (e.g., FR vs. VI) has the potential to affect resurgence via a change in organism-determined alternative reinforcement rate, as the data we extracted from Winterbauer et al. (2013) suggest. Given that the use of FR schedules is common in applied settings (e.g., Wacker et al., 2011, 2013), the extent to which changes in alternative reinforcement rates can counteract increased time in alternative reinforcement is important to understand more thoroughly. Overall, the data from Wacker et al. (2011) examining resurgence following FCT suggest that decreases in resurgence were observed with increased exposure to treatment. On the other hand, recent data from another study examining resurgence following FCT in children with Intellectual and Developmental Disabilities found that only one of two participants who received more than one resurgence test following FCT showed substantially less resurgence on the second resurgence test (Wacker et al., 2013).

Although the fit of the resurgence model to the data from seven children in Wacker et al. (2011) was adequate for naturalistic treatment settings, accounting for 43% of the variance, one variable that may explain some of the unaccounted variance may be differences in rate of alternative reinforcement. Differences in alternative reinforcement rate may have been driven by the participants’ completion of a two-response chain at
different rates, and controlling for alternative reinforcement rate is inherently difficult to control for when therapy is implemented in the home with caregivers as therapists. Future work that explicitly determines the relative importance of length of treatment and alternative reinforcement rate could prove useful when making decisions regarding the most time and cost-effective ways to implement alternative reinforcement treatments.

**Alternative Reinforcement Context**

According to behavioral momentum theory, all reinforcement (target response dependent, alternative response dependent, or response independent) delivered in the context contributes to the persistence of the target response (Nevin et al., 1990). It follows that one strategy to reduce persistence is to deliver alternative reinforcement in a context other than the one in which the target response occurs. For example, Mace and colleagues (2010) implemented reinforcement for the alternative response in a novel environmental context and found less persistence of the target response in the novel context compared to the familiar context. Similarly, recent data from our laboratory examined the effect of delivering alternative reinforcement in a novel context (Ahearn et al., 2014). Following equal baselines in a two-component multiple schedule signaled by key color of the target response, baseline continued in one component and a differential reinforcement of other behavior (DRO) contingency was introduced in the other component. Rather than earning food, satisfying the DRO requirement (abstaining from the target response for 15 s) earned the pigeons access to an alternative reinforcement context in which the pigeons could earn food on a VI schedule for pecking the alternative
stimulus key. When alternative reinforcement was removed in the alternative stimulus context (pigeons could earn access with the same DRO but the alternative response no longer produced food), no resurgence in the baseline context was observed. The lack of resurgence is consistent with the predictions of the model; the delivery of alternative reinforcement would not be contributing to the stimulus-reinforcer relationship of the target response context, and the disruptive impact of alternative reinforcement was not introduced in the target response context, so there would be no resurgence because of a release from disruption.

Although these data are promising methods by which to reduce persistence, the data from Chapter 3 suggest that delivering alternative reinforcement in a novel context does not avoid renewal, or relapse that occurs with a change in context. Although it did not appear that alternative reinforcement delivered in a different context contributed to increased relapse above what was be seen by a change in context alone, rats exhibited comparable relapse to a group that received alternative reinforcement in the same context. In the pigeon experiment in which birds earned access to alternative reinforcement in a novel context described above, renewal was not observed. Presumably, renewal was not observed in those subjects because they had continued exposure to the baseline context with the DRO contingency in place, and thus there was not a change in the target context when alternative reinforcement was removed. Because there was also no release from disruption or removal of alternative reinforcement in the target context, there was no resurgence. Therefore, taken together with the results of Chapter 3, pigeon data suggest that delivering alternative reinforcement in a novel
context and continued exposure to nonreinforcement of the target response in the target context are important for reducing relapse. The extent to which the experimental definitions of context can be generalized to applied scenarios remains to be seen.

**Length of Baseline for the Target**

Few empirical investigations have been designed to assess the potential role of the length of baseline reinforcement on the target response, but there is some evidence to suggest that an increase in the length of baseline history of reinforcement results in more subsequent resurgence. Bruzek et al. (2009, Experiment 2) published the first study to explicitly examine the effect of length of history of reinforcement for the target response on subsequent resurgence. Bruzek et al. examined the resurgence of infant caregiving responses where college undergraduates were negatively reinforced by the cessation of recorded infant cries by engaging in the appropriate (experimenter determined) infant caregiving response with a baby doll. They created a lengthier history of reinforcement, three consecutive sessions of with five continuous minutes of playing with one toy, and introduced reinforcement for only one session of five continuous minutes of playing with the second toy. Both playing with toy one and toy two were placed on extinction and no response could turn off the infant cry. Then, reinforcement for a third toy was introduced and then placed on extinction to test for resurgence of the toy one and toy two. Five of eight participants showed more resurgence of toy one with a lengthier history of reinforcement relative to the more recently reinforced toy two. In this example, however, primacy and length of reinforcement history are confounded such that
it could be the longer history of reinforcement or the first response learned that is more likely to resurge.

Similarly, Doughty et al. (2010) examined resurgence of conditional discrimination training in college undergraduates where a second discrimination was introduced and trained halfway into the training for the first conditional discrimination such that the first discrimination had double the training history. An alternative response was then trained for both conditional discriminations. In the final phase, where no response in those discriminations could earn points, three of three participants showed resurgence of the target response with the lengthier history of reinforcement training for the conditional discrimination, whereas only one participant showed resurgence of the response with the shorter history. In the study presented in Chapter 4, we tripled the length of Phase I training, and still observed no resurgence. Our 60-trial increases actually exceeded the 50-trial difference in training trials for the extended training versus limited training condition in Doughty et al., but other procedural differences make the effect of number of training trials difficult to anticipate across studies. Because both Bruzek et al. (2009) and Doughty et al. observed resurgence of the target response, they are in a better position to determine the effect of length of training on resurgence magnitude. Still, Bruzek et al. and Doughty et al. examined the effect of reinforcement history length within subjects and confounded length of reinforcement training with primacy of the target response.

Winterbauer et al. (2013), compared the effect of length of baseline between groups of subjects and therefore primacy and length of reinforcement history were not
confounded. They compared resurgence across a factorial design with two independent variables, length of training (12 vs. four sessions of baseline) and schedule of reinforcement (ratio schedules vs. yoked VI). The 12-session ratio schedule group and the 4-session VI group had substantially higher and lower target response rates at the end of acquisition (respectively), and therefore their response rate increases during resurgence are difficult to interpret. However, the two other groups, 12-session yoked VI group and 4-session ratio group reached approximately the same target response rate by the end of acquisition and therefore resurgence can be examined without concern for a transformation into proportion of baseline response rates. Of these two groups, the 12-session baseline group showed more resurgence than the 4-session baseline group. There is another potential explanation of these results besides length of acquisition training. In these two groups, where response rates were equal, the schedules in place (VI versus ratio) mean that the group that showed less resurgence also experienced a lower average rate of reinforcement during Phase II, meaning that smaller resurgence could be explained by less acquisition training or a lower rate of alternative reinforcement. Had the target response been allowed to reach equal levels across groups that experienced the same schedule of reinforcement, the different effects of length of baseline reinforcement history, baseline response rates, and alternative reinforcement rates could have been disentangled.

Models of persistence of operant behavior from behavioral momentum theory make no explicit predictions regarding the length of the baseline history of reinforcement. This is because the models are built on the assumption that we are examining behavior in
the steady state where baseline response rates have reached asymptote (e.g., Nevin & Grace, 2005). In addition, problem behaviors that would be the target of alternative reinforcement treatments presumably have an extensive history of reinforcement that exceeds the length of baseline in the three studies with fairly short baseline procedures here and may be at asymptote. Still, the paucity of data that speak to the effect of length of reinforcement history for the target on resurgence calls for new work that explores this issue more parametrically, allowing the comparison of more than two levels of baseline length to assess whether the effect of length of baseline history of reinforcement for the target continues to result in greater resurgence once the target behavior reaches steady state asymptote and also without the confound of any primacy effect.

**Alternative Reinforcement Contingency**

The nature of the contingency in place for alternative reinforcement may also be important in the disruptive impact of alternative reinforcement and resurgence that occurs when it is removed. Traditionally, the disruptive impact of alternative reinforcement is thought to be the result of alternative reinforcement directly, rather than resulting from an indirect effect of an increase in the time spent on the alternative response (Catania, 1963; Rachlin & Baum, 1972). However, we have collected data that suggest the contingency upon which alternative reinforcement is provided is very important in the disruptive impact of alternative reinforcement treatments, even after reinforcement is removed. Two experiments reported by Sweeney et al. (2014) compared the efficacy of DRA and non-contingent alternative reinforcement (NCR) when delivered at equal rates. In
Experiment 1, using pigeons as subjects, we compared persistence and resurgence of key pecking in a multiple schedule where one component introduced extinction plus DRA and another introduced extinction plus NCR following equal baselines. In general, DRA was more effective at the reduction of the target response than was NCR, both when alternative reinforcement was in place and when it was removed for a resurgence test. Experiment 2, a collaboration with the New England Center for Children, replicated the general pattern of results using touch screen responses in children with intellectual and developmental disabilities and also found that DRA was more effective than NCR.

The discrepancy in the disruptive impact of alternative reinforcement when delivered contingently or noncontingently is at odds with the approach of the quantitative model of resurgence. When alternative reinforcement ($kR_a$) is included in the numerator as a source of disruption, the predictions of the model are the same whether reinforcers are delivered contingent on another response or response independently. Therefore, data that suggest an additional disruptive impact of the alternative response rather than through alternative reinforcement directly present important information both in terms of how the disruptive impact of reinforcement should be characterized quantitatively and also relative treatment efficacy. Future characterizations of alternative reinforcement as a disruptor must incorporate the additional effect of the alternative response requirement, and DRA treatments ought to be preferred over NCR treatments when possible.
Rate of Alternative Reinforcement

Another empirically examined prediction of the quantitative model of resurgence is the effect of the rate of alternative reinforcement on persistence and resurgence. Equation 1 predicts that although higher rates of alternative reinforcement are more disruptive than low rates of alternative reinforcement, high rates also contribute more to the stimulus-reinforcer relationship of the context. This means that high rates of alternative reinforcement cause more resurgence than low rates when alternative reinforcement is ultimately removed. The model was built on existing data collected by Leitenberg et al. (1975, Experiment 3) who compared persistence and resurgence using a VI 240-s and a VI 30-s schedule of alternative reinforcement across groups following equal baselines. They consistently observed less persistence when a higher rate (VI 30-s) of alternative reinforcement was introduced during Phase II relative to when a lower rate (VI 240-s) was introduced. On the other hand, little if any resurgence was observed following the removal of a low rate of alternative reinforcement but consistent resurgence was observed when a high rate of alternative reinforcement was removed. More recent data with rats as subjects are consistent with their original findings (Sweeney & Shahan, 2013). Sweeney and Shahan compared two groups that differed with respect to rate of alternative reinforcement during Phase II, one that experienced a high rate of alternative reinforcement (VI 10 s) and another that experienced a low rate of alternative reinforcement (VI 100 s). Less response suppression during Phase II and less of an increase was observed upon the removal of alternative reinforcement compared to the group of rats that experienced a high rate of reinforcement for the alternative response.
We have also collected data that compare the efficacy of high rate reinforcement for the alternative versus low rate alternative reinforcement within-subjects using a multiple schedule preparation with pigeons (Craig et al., 2014). In a series of experiments, we found greater response suppression with higher rates of alternative reinforcement, although we were unable to compare differences in resurgence because of relatively small increases during Phase III—probably because of a lengthy exposure to extinction plus alternative reinforcement.

Although the data collected that compare the effects of high rates of alternative reinforcement to low rates of alternative reinforcement are consistent with model predictions, there is another comparison made by Sweeney and Shahan (2013) that suggests the role of alternative reinforcement as a disruptor may depend on its rate. In addition to the group of rats that experienced a high rate of alternative reinforcement and the group that experienced a low rate, there was also a group in which the nose poke apparatus for the alternative response was illuminated but never produced food. The target response was less persistent when there was no alternative reinforcement than it was when a low rate of alternative reinforcement was delivered. In its current form, the quantitative model of resurgence predicts that any alternative reinforcement delivered is an additional source of disruption and ought to decrease persistence compared to an extinction only control condition without alternative reinforcement. These data suggest that low rates may result in increased arousal or reinforcer misallocation and greater persistence, and therefore more data designed to directly compare the arousing, discriminative, and disruptive effects of alternative reinforcement is merited.
**Future Directions**

One avenue for future research that was not examined in this dissertation is to the neurobiological mechanisms that may mediate the resurgence effect. Only two research studies have examined potential neurobiological mechanisms of resurgence using pharmacological manipulations (Pyszczynski, 2013; Quick et al., 2011). Quick et al. found that systemic 10 μg/kg injections of dopamine (DA) D₁ receptor antagonist SCH23390 prior to Phase III sessions blocked resurgence relative to a group that received no injections, consistent with past research that suggests a critical role for DA D₁ receptors in reinstatement and renewal (Alleweireldt et al., 2002; Bossert, Poles, Wihbey, Koya, & Shaham, 2007; Capriles, Rodaros, Sorge, & Stewart, 2003; Crombag, Grimm, & Shaham, 2002; Hamlin, Blatchford, & McNally, 2007; Norman, Norman, Hall, & Tsibulsky, 1999; Sciascia, Mendoza, & Chaudhri, 2013). Pyszczynski compared resurgence of food-seeking across groups of rats that received DA D₂ receptor antagonist raclopride (vehicle, 50, or 100 μg/kg) or α₂ agonist clonidine (vehicle, 20, or 40 μg/kg) prior to Phase III sessions. Both doses of raclopride and the 40 μg/kg dose of clonidine blocked resurgence, but only the 40 μg/kg dose of clonidine blocked resurgence without evidence of general motor response suppression. The next experimental investigations regarding the neurobiological mechanisms of resurgence should use site-specific injections to reduce the risk of generalized motor impairment. The comparison of whether central noradrenergic (NA) activation (which should be blocked with site-specific NA antagonists) is more critical to resurgence than DA D₂ receptors is particularly important, because it would provide evidence that relapse following
alternative reinforcement loss is more closely related to stress-induced rather than cue-induced relapse (e.g., Leri, Flores, Rodaros, & Stewart, 2002).

In addition to the lack of understanding of the underlying neurobiology of resurgence, one common criticism of the typical resurgence procedure is that extinction of the target response is not always possible in real treatment settings. Although extinction of the target response is commonly a component of FCT (Carr & Durand, 1985) and of DRA more generally (Petscher et al., 2009), these alternative reinforcement treatments are most often implemented in individuals with intellectual or developmental disabilities who have problem behavior maintained by environmental contingencies that can be changed, such as caregiver attention, escape from demand, or tangible items. On the other hand, some problem behavior is presumably maintained by the sensory consequences of the behavior itself, often deduced when an external event cannot explain the frequency of the response. In this case, the sensory consequences of the response cannot be separated from the response and extinction cannot be implemented (e.g., Vollmer, 1994). Similarly, decreasing the reinforcing effects of drug taking is not possible without the voluntary administration of another substance such as antabuse or immunotherapy medication (Ellis & Dronsfield, 2013; Martell et al., 2009). Therefore, alternative reinforcement is often introduced in the absence of extinction of the target response. New animal models of relapse following alternative reinforcement loss ought to avoid implementing extinction for the target response and develop other means of target response suppression, such as increased aversive consequences of drug taking (Cooper, Barnea-Ygael, Levy, Shaham, & Zangen, 2007).
Conclusion

The extension of the behavioral momentum theory to include resurgence by Shahan and Sweeney (2011) has provided many predictions that have been tested empirically. Chapter 2 presented data that stress the importance of time in extinction and exposure to alternative reinforcement on resurgence. Chapter 3 introduced a novel methodology for studying resurgence and renewal phenomena together, allowing us to determine that although resurgence was no greater when alternative reinforcement was delivered in a different context, renewal still occurred when the extinction context was changed. Chapter 4 presented the beginnings of task development to test the generality of the results of animal models of resurgence in typically functioning adult human participants. The generality of animal research findings to this population is critical before the true applied implications of this work can be known, because alternative reinforcement treatments such as contingency management treatments of substance abuse and behavioral activation treatments of depression are implemented most frequently in adults without intellectual or developmental disability. Still, the consistency of data where collaborations have extended in settings and populations of interest (Wacker et al., 2011; Sweeney et al., 2014) is encouraging for inspiring future research questions, even if the data are not always in line with what behavioral momentum theory would predict. These collaborations have the potential to contribute to both the way resurgence is characterized in conditioning and learning theory as well as to our knowledge of how resurgence may be reduced in practice.
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APPENDICES
Appendix I

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Appendix II

Instructions:

Welcome to our study of reward learning! Your task today will be completed on a computer using the keyboard and mouse to respond. First, you will be asked some basic demographic information. Next, you will proceed to the reward-learning task. The computer will present you with many trials. On each trial, you will be presented with the choice between three options indicated by a TRIANGLE, a SQUARE, and a CIRCLE. You will indicate your choice by clicking on your choice with the mouse. Sometimes, your choice will earn you points. How you respond is completely up to you. Psychology 1010 research credit is not dependent on how well you play. However, the participant who scores the most total points will receive a $75 gift card to the Utah State University Bookstore, so try to earn as many points as you can! Following the reward-learning task, you will be asked to answer a few questions that will help us understand your experience during the task. Watches and cellular phones are not allowed in the experimental room. They can be safely stored during the session with me. Please leave the room only when the task is completed, in the event of an emergency, or if you wish to withdraw from the study. Do you have any questions?
Appendix III

Reflection Questions:

1) What do you think was the purpose of the task you just completed? If you do not know, please feel free to respond, “I don’t know.” Leave this question blank if you prefer not to answer.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

2) How did you make your decisions during the reward-learning task? If you aren’t sure how you made your decisions, please say so.

   a. Describe how you made your decisions during the reward-learning task:

   ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

   b. I prefer not to answer.

3) Did you have an overall strategy that you used throughout the reward-learning task?

   a. Yes
   b. No
   c. I prefer not to answer.

4) Please describe your overall strategy that you used throughout the reward-learning task.
a. I did not have a strategy.

b. Describe your overall strategy that you used throughout the reward-learning task: ________________________________________________
   ________________________________________________
   ________________________________________________

c. I prefer not to answer.

5) Did your strategy change as you moved forward in the reward-learning task?

   a. I did not have a strategy.

   b. My strategy did not change.

   c. My strategy did change.

   d. I prefer not to answer.

6) Please describe how your strategy changed as you moved forward in the reward-learning task.

   a. I did not have a strategy.

   b. My strategy did not change.

   c. Describe how your strategy changed as you moved forward in the reward-learning task: ________________________________________________
   ________________________________________________
   ________________________________________________

   d. I prefer not to answer.
7) Which shape (TRIANGLE, SQUARE, or CIRCLE) seemed to earn you the most points overall?
   a. TRIANGLE
   b. SQUARE
   c. CIRCLE
   d. All shapes seemed to produce the same amount of points.
   e. Two shapes seemed to produce the same amount of points.
   f. It was impossible to earn points.
   g. I prefer not to answer.

8) Which shape (TRIANGLE, SQUARE, or CIRCLE) seemed to earn you the most points during the first third of the task?
   a. TRIANGLE
   b. SQUARE
   c. CIRCLE
   d. All shapes seemed to produce the same amount of points.
   e. Two shapes seemed to produce the same amount of points.
   f. It was impossible to earn points.
   g. I prefer not to answer.

9) Which shape (TRIANGLE, SQUARE, or CIRCLE) seemed to earn you the most points during the middle third of the task?
   a. TRIANGLE
   b. SQUARE
c. *CIRCLE*

d. All shapes seemed to produce the same amount of points.

e. Two shapes seemed to produce the same amount of points.

f. It was impossible to earn points.

g. I prefer not to answer.

10) Which *shape* (TRIANGLE, SQUARE, or CIRCLE) seemed to earn you the most points *during the last third of the task*?

a. TRIANGLE

b. SQUARE

c. CIRCLE

 d. All shapes seemed to produce the same amount of points.

e. Two shapes seemed to produce the same amount of points.

f. It was impossible to earn points.

g. I prefer not to answer.

11) On a scale of 1 to 10, where 1 is *the least distressed you can feel*, and 10 is *the most distressed you can feel*, how did you feel during the reward learning task?

__________

12) If there is any other information you wish to explain about your experience during the reward-learning task, please describe here: ____________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________
CURRICULUM VITAE

Mary Margaret Sweeney
February 2014

PERSONAL INFORMATION

Address:
Office
Department of Psychology
Utah State University
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Logan, UT 84322

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1560 Talon Dr.
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EDUCATIONAL HISTORY

Utah State University (August 2009-present)

Advisor: Timothy A. Shahan, Ph.D.

M.S. in Experimental and Applied Psychological Science, 2012

Masters thesis: A quantitative analysis of response elimination and resurgence using rich, lean, and thinning schedules of alternative reinforcement.

Ph.D. in Experimental and Applied Psychological Science, May 2014 (anticipated)

Purdue University (August 2005-May 2009)

B.A. in Honors Psychology, May 2009

Honors thesis: Reflexivity in pigeons using successive matching.

Thesis advisor: Peter J. Urcuioli

Minor: French Language and Literature

RESEARCH EXPERIENCE

Graduate Research Assistant, Behavior Laboratory, Department of Psychology, Utah State University

August 2009-present

Principal Investigator: Timothy A. Shahan, Ph.D.

Research areas: Conditioning and learning, animal models of drug self-administration and relapse, divided attention, animal models of executive functioning.

Collaborative Graduate Affiliate, Multisensory Cognition Laboratory, Department of Psychology, Utah State University

August 2012-present

Principal Investigator: Kerry Jordan, Ph.D.

Research areas: Numerical cognition and development, attention restoration, impulsivity, environmental psychology.

Undergraduate Research Assistant, Department of Psychology, Purdue University

June 2007-May 2009

Principal Investigator: Peter J. Urcuioli, Ph.D.
Research areas: Stimulus equivalence, emergent differential sample behavior, instrumental learning, the Simon Effect.

_Undergraduate Research Assistant_, Department of Psychology, Purdue University

June 2006-August 2006

Principal Investigator: E. John Capaldi, Ph.D.

Research areas: Serial order anticipation learning, Pavlovian conditioning, delay conditioning.

TEACHING EXPERIENCE

_Instructor_, Department of Psychology, Utah State University

Course: Scientific Thinking and Methods in Psychology

August 2013- present

_Teaching Assistant_, Department of Psychology, Utah State University

Course: Scientific Thinking and Methods in Psychology

August 2012 – May 2013

_Guest Lecturer_, Department of Psychology, Utah State University

Course: Advanced Behavior Analysis

Lecture topic: Conditioning and Substance Abuse

Course: Introduction to Psychology

Lecture topic: Motivation

Course: Advanced Development (graduate)

Lecture topic: Impulsivity and Development
HONORS AND AWARDS

Utah State University

Walter R. Borg Scholarship and Research Productivity Award, USU Department of Psychology, April 2013.

Elected student representative to faculty meetings for the Experimental and Applied Psychological Science Program for 2012-13, August 2012.

Experimental Analysis of Behavior Fellowship, The Society for the Advancement of Behavior Analysis, January 2011.

First place poster presentation, USU Graduate Student Research Symposium, March 2010.

Basic Psychological Science Research Grant, American Psychological Association of Graduate Students, Fall 2010.

Purdue University

Distinguished Service Key, 2009, Alpha Phi Omega National Service Fraternity, Alpha Gamma Chapter.

Phi Beta Kappa Honor Society, 2009.


Warren J. Luzadder Friendship Award, 2007, Alpha Phi Omega National Service Fraternity, Alpha Gamma Chapter.

Academic Success Award Scholarship, Purdue University, 2005-2009.
PROFESSIONAL MEMBERSHIP

Association for Behavior Analysis International

American Psychological Association

Society for the Quantitative Analysis of Behavior

EDITORIAL ACTIVITIES AND PROFESSIONAL SERVICE

Ad hoc reviewer for:

Journal of the Experimental Analysis of Behavior

Behavioural Processes

Student reviewer for:

2014 Association for Behavior Analysis International, Society for the Alteration of Behavior Analysis Innovative Student Research Grants

MANUSCRIPTS IN PREPARATION


MANUSCRIPTS UNDER REVIEW


PUBLICATIONS


**PRESENTATIONS AT PROFESSIONAL MEETINGS**


