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The Effects of Repeated Resurgence Conditions on the Magnitude of Resurgence

Ryan Nathaniel Redner
Western Michigan University, ryannr@hotmail.com

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THE EFFECTS OF REPEATED RESURGENCE CONDITIONS
ON THE MAGNITUDE OF RESURGENCE

by

Ryan Nathaniel Redner

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Advisor: Alan Poling, Ph.D.

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WE HEREBY APPROVE THE DISSERTATION SUBMITTED BY

_____ Ryan Nathaniel Redner _____

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Resurgence
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_____
Alan Poling, Ph.D.
Dissertation Review Committee Chair

_____
Cynthia Pietras, Ph.D.
Dissertation Review Committee Member

_____
Ron Van Houten, Ph.D.
Dissertation Review Committee Member

_____
Marc Weeden, Ph.D.
Dissertation Review Committee Member

APPROVED

_____
Dean of The Graduate College

Date _____ August 2012 _____

THE EFFECTS OF REPEATED RESURGENCE CONDITIONS
ON THE MAGNITUDE OF RESURGENCE

Ryan Nathaniel Redner, Ph.D.

Western Michigan University, 2012

Resurgence is defined as the recurrence of a previously reinforced behavior, under the condition that reinforcer delivery ceases for a more recently reinforced behavior. The current study investigated the effect of repeating the resurgence procedure six times with pigeons and two times with rats to determine the effect of repetitions on the magnitude of resurgence. Three phases were repeated: (a) Response 1 was reinforced while there were no programmed consequences for Response 2, (b) Response 2 was reinforced and Response 1 was extinguished, and finally (c) there were no programmed consequences for either response. The results indicated that the magnitude of resurgence increased for pigeons and decreased for rats as subjects were exposed to repeated resurgence procedures. Additionally, the level of Response 2 decreased in the final condition indicating that the level of extinction responding decreases following repeated training and extinction conditions. Results were discussed in terms of their similarities to other resurgence investigations and potential implications for clinical relapse.

ACKNOWLEDGMENTS

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INTRODUCTION

Extinction, from an operant paradigm, is the withholding of reinforcement from a previously reinforced response (Skinner, 1938). Extinction as a process refers to the subsequent decline in the rate of response caused by the unavailability of reinforcement (Pierce & Cheney, 2008). Extinction produces several adaptive behavioral effects, in addition to the decline in rate, including an increase in response variability. Extinction, and related behavioral effects, has produced a considerable amount of research in Behavior Analytic literature. To illustrate, a search of the *Scopus* database revealed that the term "extinction" yielded 699 results from the *Journal of the Experimental Analysis of Behavior* and the *Journal of Applied Behavior Analysis.* This search reveals that there has been a considerable amount of interest in extinction and related phenomena in both basic and applied work.

Resurgence, defined as the recurrence of a previously reinforced behavior when reinforcer delivery ceases for a more recently reinforced behavior (Catania, 1998), is closely related to extinction. Resurgence has received far less empirical attention than extinction. To illustrate, a search of the *Scopus* database revealed that the term "resurgence" yielded only 27 results from the *Journal of the Experimental Analysis of Behavior* and the *Journal of Applied Behavior Analysis.* The current research examined the effects of repeating the resurgence procedure on the magnitude of resurgence. To provide a conceptual background for the current research, both respondent and operant extinction and related phenomenon are reviewed. A brief review of the resurgence

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literature is provided, followed by an overview of the resurgence literature focusing on

applications to human behavior. The review section ends with a focus on experiments

that have manipulated the number of repetitions of the resurgence procedure.

EXTINCTION AND ITS VARIANTS

Respondent Extinction

There are two forms of extinction, operant and respondent, each entailing different

operations. Respondent extinction will be covered briefly because it is not closely related

to resurgence. Classical conditioning was first discovered and studied by the Russian

physiologist, Ivan Pavlov. Pavlov (1927) began his research by studying the digestive

processes and the action of salivary glands of dogs. Initially dogs would salivate when

food was presented. After repeated presentations of food Pavlov observed that the dogs

would salivate prior to the contact with food (e.g., to the food dish or the experimenter's

footsteps). Following this observation Pavlov conducted a series of experiments to test

these observations. Pavlov found that if the sound of the bell, metronome, or any other

stimulus, was introduced prior to the introduction of meat powder that the dogs would

eventually salivate to that stimulus. Pavlov called this the conditioned reflex. Currently,

the stimuli that did not elicit salivation are called neutral stimuli (NS). The NS onset

precedes the delivery of the meat power, which is an unconditional stimulus (US), which

is followed by salivation, an unconditional response (UR). After repeated NS, US

pairings the NS, subsequently labeled a conditional stimulus (CS), elicits the UR,

subsequently labeled the conditional response (CR).Respondent extinction occurs when the CS is repeatedly presented without the US and no longer elicits the CR.

A NS will become a weaker CS if either (a) the NS is presented frequently without the US, or (b) the US is presented frequently without the NS. To create the most conditioning, the NS onset must precede the US onset and terminate following the onset of the US (i.e., short-delay conditioning). Conditioning will be weaker if the NS and US onset and offset are identical (i.e., simultaneous conditioning) or the NS follows the CS (i.e., backwards conditioning). Respondent extinction can be arranged by presenting the CS without the US. Initially, the CS will elicit the CR. Following repeated presentations of the CS alone the CS will no longer elicit the CR. The US can be presented repeatedly resulting in habituation. Following repeated exposed of the US the UR will no longer be elicited.

An extinguished CS (a CS that no longer elicits a CR) may recover following a period of time and the presentation of the CS (Pavlov, 1927). This effect, spontaneous recovery, is often observed following the first few CS presentations. Extinction of a CR can take up to 40 trials, whereas the CR can be reacquired within two or three trials (Konorski & Szwejkowska, 1950). This effect is called "rapid reacquisition." Lastly, respondent reinstatement occurs when a single presentation of the US is sufficient to fully reinstate an extinguished CR.

Operant Extinction

Operant extinction refers to both a process and a procedure. Extinction as a process refers to a decline in rate of response caused by the non-delivery of

reinforcement. Extinction as a procedure refers to the withholding of reinforcement for a previously reinforced response (Pierce & Cheney, 2008). Consider the child who raises her or his hand and garners attention from the teacher. The student's rate of hand-raising will decrease if the teacher no longer provides attention dependent upon hand-raising. There are a range of effects, including a decreased rate of responding, that result from the extinction procedure. Initially when reinforcement is withdrawn an increase in rate of responding is observed (Pierce & Cheney, 2008). This is called an extinction burst. The child, no longer receiving attention for hand-raising, will increase the rate of hand-raising, shortly after contacting extinction conditions.

Following the introduction of extinction, in addition to the extinction burst, operant behavior becomes more variable (Pierce & Cheney, 2008). Various aspects of the behavior may change, including the topography, magnitude, or force. For example, the hand of the child attempting to get the teacher's attention may be raised higher into the air, sway rapidly to and fro, or both hands may be raised. The classic study on extinction-induced operant variability was conducted by Antonitis (1951) using rats as subjects. Nose pokes through a 50-cm-long slot were reinforced with food, exposed to extinction conditions, and then both conditions were repeated. Pictures of the rats' body position and position of nose entry were taken and recorded at each nose poke. Reinforcement conditions produced stereotyped body positions and nose poke locations, while extinction produced variability of body position and nose poke location. Following extinction an organism may engage in emotional responding. For example, pigeons have been shown to engage in aggressive attacks toward another pigeon following a transition to extinction (Azrin, Huchinson, & Hake, 1966).

The recovery of extinguished operant responses has been demonstrated in induction (e.g., Reynolds, 1964), operant reinstatement (e.g., Franks & Lattal, 1976), and resurgence (e.g., Epstein, 1983). In each of these procedures some response is reinforced in the first condition, is extinguished in the second condition, then recurs in the final condition. The conditions used to induce the recurrence differ between each of the aforementioned procedures. Induction is observed following response-dependent reinforcement. Operant reinstatement is observed following response-independent delivery of the stimuli that served as reinforcers in the first condition. Lastly, resurgence is induced when a second, more recently reinforced response undergoes extinction, and the initial response recurs (Lieving & Lattal, 2003).

RESURGENCE

Resurgence is defined as the recurrence of a previously, but no longer, reinforced behavior when a more recently reinforced behavior is extinguished (Catania, 1998). The first and second response will be referred to as Response 1 and Response 2, respectively, throughout this document. The basic experimental arrangement for resurgence is composed of three conditions. In the first condition a target response (Response 1) is reinforced for a designated period of time. In the second condition, following the acquisition of Response 1, an alternative behavior (Response 2) is reinforced, while Response 1 is programmed for extinction. In the final condition, there are no consequences programmed for either response. If resurgence is evident, Response 1, which usually falls to near-zero levels during the second condition, temporarily recurs in the final condition despite a lack of reinforcement for this response.

In an early demonstration of resurgence, Epstein (1983) exposed six pigeons to three conditions. In the first condition a key peck was reinforced on a variable-interval (VI) 60-s schedule of food delivery. This condition was in effect for 15 sessions. In the second condition key pecking no longer produced food delivery. The second condition was in effect for a variable number of sessions. In the final condition, a response that was incompatible with key pecking (e.g., wing raising) was trained and reinforced 20 times and then subsequently extinguished. During the extinction condition Response 1 was occurring at a near-zero rate. During the final condition, following the decrease and subsequent extinction of Response 2, Response 1 recurred. Of particular importance, Epstein (1985) included a second key so that extinction-induced variability could be differentiated from resurgence effects. That is, in the final condition, if an equal number of responses occurred on Response 1 and the control response the behaviors could be attributed to extinction-induced variability.

In a more recent demonstration of resurgence, Lieving and Lattal (2003, Experiment 1) examined whether the length of time between Response 1 training and the final extinction condition affected the magnitude of resurgence. In the first condition a key peck was reinforced on a VI 30-s schedule of food delivery for 15 sessions. In the second condition a treadle press was reinforced on a VI 30-s schedule of food delivery. Half of the subjects were exposed to the second condition for 5 sessions and the other half of subjects were exposed to the second condition for 30 sessions. In the final condition extinction was programmed for all responses. Resurgence was evident in all subjects. Lieving and Lattal (2003) found that the magnitude of resurgence was not affected by the number of sessions between the first and final conditions.

Since Epstein and Skinner (1980) coined the term "resurgence" three decades ago, there has been enough research to merit at least two reviews (Doughty & Oken, 2008; Lattal & St. Peter Pipkin, 2009). Such interest is merited insofar as resurgence plays an important role in a wide range of human behaviors, including creative and problem-solving repertoires (Epstein, 1987; Epstein & Medalie, 1983; Lattal & Lieving, 2003), undesirable behaviors such as aggression (Lieving, Hagopian, Long, & O'Connor, 2004), and drug taking and drug seeking (Podlesnik, Jimenez-Gomez, & Shahan, 2006). Insofar as non-human research provides information relevant to such important human repertoires it is worthwhile.

Resurgence of Problem Behaviors

A common and effective treatment for problem behaviors, used frequently by behavioral practitioners, is differential reinforcement of alternative behaviors (DRA; Petscher, Rey, & Bailey, 2009). In the DRA procedure an aberrant behavior (e.g., hitting others) that is reinforced by some consequence (e.g., attention from a teacher) is extinguished and an alternative appropriate behavior (e.g., raising a hand) that serves the same function as the aberrant behavior is trained and reinforced. The DRA procedure can be construed as at least the first two conditions of a resurgence procedure. Initially an aberrant behavior (Response 1) is reinforced in some manner. Following the acquisition of an aberrant behavior a practitioner extinguishes Response 1 and trains an alternative response (Response 2) with the same function as Response 1. If the appropriate alternative response (Response 2) is subsequently extinguished, which often occurs in everyday applications, than conditions similar to Condition 3 have been arranged. At this

point the problem behavior (Response 1) is likely to recur. Because of the similarity of

procedure, research on resurgence has the potential to inform DRA interventions.

Lieving, Hagopian, Long, and O'Connor (2004) examined response-class

hierarchies and the systematic introduction of extinction on the recurrence of behaviors in

the hierarchy. A response-class hierarchy can be identified by patterns of responding in

which participants engage in increasingly severe patterns of behavior, all reinforced by

the same consequence. In a response-class hierarchy when one pattern of behavior is not

reinforced the participant engages in another form of the behavior from the same

response-class that had been previously reinforced. Two children diagnosed with mental

retardation who engaged in various forms of aggression served as participants. A

functional analysis (Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994) revealed that

the participants' behaviors were maintained by access to tangibles. For the first

participant all forms of aberrant behavior (i.e., disruption, aggression, and self-injury)

were reinforced in the first condition. Under these conditions disruptions occurred while

self-injury and aggression did not. In the second condition disruptive behavior was

exposed to extinction while aggression and self-injury were reinforced. Under these

conditions the number of disruptions decreased and the amount of aggression increased.

In the third condition both disruption and aggression were extinguished while self-injury

was programmed for reinforcement. Following the unavailability of reinforcement for

engaging in aggressive behaviors disruptive behaviors resurged. The second participant

emitted a similar pattern of behavior. Initially all patterns of aberrant behavior (i.e.,

disruptions, dangerous acts, cursing, and aggression) were reinforced. Extinction was

sequentially introduced for each problem behavior. Following the introduction of

extinction for cursing, with extinction in place for dangerous acts and disruptions, both dangerous acts and disruptions resurged.

The results of Lieving et al. (2004) suggest that practitioners should consider the effects of resurgence when assessing and treating aberrant behavior. If more recently reinforced forms of behavior in a response-class hierarchy resurge prior to older forms, then the practitioner may want to consider training more than one appropriate form of a response. In the event that one appropriate form of a behavior is extinguished the participant may engage in other appropriate forms of the behavior before engaging in the aberrant behavior.

Volkert, Lerman, Call, and Trosclair-Lasserre (2009) sought to evaluate the potential relevance of resurgence to treatment relapse in a natural environment. Five children diagnosed with autism or other developmental disabilities, who engaged in various problem behaviors, served as subjects. A functional analysis (Iwata et al., 1982/1994) was conducted to identify the function of each participant's problem behavior. The results of the functional analysis revealed that the problem behavior of three participants was maintained by escape from demand, one participant's behavior was maintained by attention and tangibles, and the last participant's problem behavior was maintained by escape from demands and tangible items.

In Experiment 1 participants were exposed to the resurgence procedure twice. The first condition was identical to the functional analysis condition that had resulted in the highest level of problem behavior for each participant. In the second condition, a communication response, that served the same function as the problem behavior, was taught to participants and subsequently reinforced. During the second condition the

problem behavior was exposed to extinction conditions. In the final condition extinction was programmed for both responses. These three conditions were subsequently repeated. Two of three participants' problem behaviors resurged in both resurgence conditions. One participant did not show evidence of resurgence. Volkert et al. (2009) suggested that this higher-functioning participant did not show evidence of resurgence because he could rapidly discriminate extinction conditions and stopped responding rapidly following the onset of extinction conditions.

In Experiment 2 three participants were exposed to the resurgence procedure twice. Instead of standard extinction in the resurgence phase, a fixed-ratio (FR) 12 schedule of reinforcement implemented for Response 2. This experiment was designed to approximate local instances of extinction to determine if resurgence would occur if the reinforcement schedule for Response 2 was thinned or thinned too rapidly. Resurgence was observed in all three participants in all six resurgence conditions. The observed resurgence was not simply due to standard extinction conditions because each participant contacted reinforcement for the functional-communication response in the resurgence conditions.

The results of Volkert et al. (2009) suggest that resurgence may account for some instances of response recovery during treatments that involve DRA procedures. In at least one participant the problem behavior resurged at rates in excess of baseline rates, indicating a robust recovery of problem behavior. Any magnitude of resurgence may present a problem to caregivers because the problem behavior may encounter reinforcement and be restrengthened (Volkert et al., 2009).

Resurgence of Negatively Reinforced Caregiving Responses

Bruzek, Thompson, and Peters (2009) examined the resurgence of infant caregiving responses that were maintained by the termination of simulated infant crying by a baby doll. College students, who had varied histories of caregiving, were instructed to engage in caregiving behaviors toward the doll. Participants were exposed to three conditions. In the first condition of Experiment 1, vertical rocking (Response 1) terminated infant crying. In the second condition, all caregiving responses were programmed for extinction and participants were required to meet extinction criteria. Two of 7 participants were exposed to a shorter duration extinction condition to determine whether the length extinction exposure has an effect on the magnitude of resurgence. In the final condition, feeding the doll (Response 2) was reinforced for a brief period and then exposed to extinction conditions. The recurrence of the initial response was observed in 5 of 7 participants. The length of the extinction condition did not have an effect on the magnitude of resurgence.

In Experiment 2, two topographically similar toy-play behaviors were trained successively over two conditions, to determine the effect of different lengths of training history on the magnitude of resurgence. The first behavior had a longer training history than the second behavior. In the third condition, both toy-play behaviors were exposed to extinction conditions. In the final condition, a third topographically similar toy play behavior was trained briefly then exposed to extinction conditions. When the third toy-play response was exposed to extinction the highest level of Response 1 was observed in 5 of 8 participants relative to Response 2 and the control response. Results indicated that

behaviors that were trained first demonstrated the highest magnitude of resurgence. The behavior with the longer training history was always the first behavior trained, so it is unclear whether a longer training history or primacy of training history resulted in a higher magnitude of resurgence. If behaviors with lengthier reinforcement histories are more likely to recur, further research should determine what factors may override the effects of a longer training history (Bruzek et al., 2009).

A control response was included in Experiment 1 and Experiment 2 (Bruzek et al., 2009). The control response was available, but never reinforced. This allowed researchers to attribute the recurrence of Response 1 to resurgence, instead of extinction-induced variability. These findings replicated Epstein (1985) and Lieving and Lattal (2003, Experiment 1) demonstrating that the degree of exposure to extinction conditions does not affect the magnitude of resurgence. Finally, this experiment was the first demonstration of the resurgence of a negatively reinforced behavior.

Resurgence Experiments that Utilized Rats as Subjects

Leitenberg, Rawson, and Bath (1970, Experiment 2) attempted to evaluate methods for increasing the effectiveness and rapidity of extinction. They utilized 24 hooded rats, maintained at 80% of free feeding weight, as subjects. In the first condition all subjects received reinforcement for pressing lever A (Response 1) on a VI 30-s schedule of food delivery. In the second condition half of the subjects (the experimental group) received reinforcement for pressing lever B (Response 2) on an FR 10 schedule of food delivery. The other half of the subjects (the control group) was exposed to extinction on both levers during the second condition. In the final condition all subjects were

exposed to extinction conditions. The number of sessions that subjects were exposed to Condition 1 was not specified by the authors. Condition 2 and 3 lasted 5 days each. Sessions lasted 24 minutes. Data were analyzed using a between-groups analysis.

Leitenberg et al. (1970) found that the mean Response 1 value for the experimental group during the second condition was significantly lower than the mean for the control group. That is, there was some indication that reinforcing an alternative response (i.e., Response 2) increased the rate of extinction of Response 1. In the final condition the mean number of responses emitted by the experimental group was significantly higher than the control group mean. Leitenberg et al. concluded that extinction was not hastened by including an alternative response during the extinction of Response 1 because responding continued into the third condition (i.e., resurgence occurred). Even though their conclusions were consistent with the resurgence account this research occurred before the term "resurgence" was coined and defined by Epstein and Skinner (1980) and the authors' conclusions reflected this fact.

Winterbauer and Bouton (2010) conducted a series of experiments to determine whether changes in rates of reinforcement, from condition 1 to condition 2, would affect the magnitude of resurgence. In all experiments female Wistar rats served as subjects. A standard resurgence protocol, comprising three conditions, was implemented in all studies. In the first condition lever pressing was reinforced with food delivery. In the second condition the first lever press response was extinguished and another lever press was reinforced. In the final condition there were no programmed consequences for any response.

In the first experiment three groups of rats were used, an experimental group, a rate control group, and an extinction control group (Winterbauer & Bouton, 2010). In the experimental group Response 1 was reinforced on a random-interval (RI) 30-s schedule of food delivery in the first condition. Response 2 was reinforced on a RI 10-s schedule of food delivery in the second condition (i.e., the rate of reinforcement increased from Condition 1 to Condition 2) and Response 1 was exposed to extinction. The rate of reinforcement in the rate control group was RI 30-s for both Condition 1 and Condition 2 for Response 1 and Response 2, respectively. In the extinction control group there were no programmed consequences for any responses in Condition 2 or Condition 3. Results indicated that there was not a significant difference in resurgence in the experimental and rate control groups, but a significant difference was observed in the rapidity of extinction in Condition 2. The experimental group emitted fewer responses on Response 1, when compared to the rate control group, during Condition 2. Presumably this effect occurred because a higher rate of reinforcement was available for Response 2. Results were discussed in terms of their relevance to the response prevention hypothesis. If, during Condition 2, the extinction of Response 1 is prevented, as was the case with the experimental group, more resurgence should be observed according to this hypothesis. The observed magnitude of resurgence was the same, providing evidence contrary to the response prevention hypothesis.

In the second experiment Winterbauer and Bouton (2010) tested the effect of a reinforcement decrement on the magnitude of resurgence. Three groups of rats were used, an experimental group, a rate control group, and a extinction control group. For the experimental group Response 1 was reinforced on a RI 10-s schedule of food delivery in

the first condition. Response 2 was reinforced on a RI 30-s schedule of food delivery in the second condition. The schedule of food delivery was RI 10-s for Condition 1 and 2 for the rate control group. There were no programmed consequences for any response for the extinction control group during Condition 2 or 3. Both the rate control and experimental groups demonstrated resurgence in the final condition. The transition to a leaner schedule of reinforcement did not cause suppression of Response 1 during Condition 2 and resurgence still occurred. These results provide further evidence that challenges the response prevention hypothesis. This is because the leaner schedule of food delivery did not cause the suppression of Response 1 (i.e., Response 1 was exposed to extinction for a standard duration of time)

Finally, in Experiment 3 Winterbauer and Bouton (2010) demonstrated that Response 1 had to be trained initially to recur in the final condition. Experiment 4 tested the effect of training Response 1 with varied schedules of reinforcement, including FR 10, a yoked VT, and a yoked VI. Resurgence was observed in each group.

Summary and Conclusions Regarding Resurgence

Resurgence has received increased conceptual and empirical attention in recent years. Recent studies have demonstrated that resurgence is a reliable phenomenon and of possible importance in the treatment of problem behavior. Therefore, such work appears to be merited. To date, a systematic study of the effect of repeated resurgence iterations on the magnitude of resurgence has not been conducted. Specifically, there are no known studies that utilized rats as subjects that repeated the resurgence procedure. Both rats and pigeons are used as subjects to increase the reliability of the results and validity of the

methods. Being able to produce resurgence repeatedly would be invaluable for investigating the effects of a wide range of independent variables, such as psychiatric drugs, motivating operations (Michael, 1993), and reinforcement magnitude. Moreover, the within-subject repeatability of resurgence is of interest in its own right. The present study, summarized below, provides a demonstration of the effects of repeated resurgence iterations using rats and pigeons as subjects.

THE EFFECT OF REPETITIONS ON RESURGENCE

Lieving and Lattal (2003, Experiment 2) designed an experiment to determine whether resurgence occurs following repeated exposure to the resurgence procedure. In their experiment four pigeons were exposed to two full iterations of the resurgence procedure. In the first condition subjects were trained to press a key on a VI 30-s schedule of food delivery. This condition was in effect for a minimum of 15 sessions and until key-pressing was stable. In the second condition treadle-pressing was reinforced on a VI 30-s schedule of food delivery and key-pressing was extinguished. This condition was in effect for a minimum of 15 sessions, and until (a) treadle-pressing was stable, and (b) key-pecking was occurring at a sufficiently low rate. In the final condition that lasted 10 sessions, extinction was programmed for both responses. A control response, a second key, was available throughout the experiment but had no programmed consequences. The control response was used to measure extinction-induced variability. That is, if the number of responses on Response 1, in the final condition, were in excess of the number of control responses then that excess can be deemed resurgence. Following the completion of the extinction condition the previous sequence of conditions was repeated.

In the first resurgence condition three of four subjects demonstrated resurgence. The recurrence of key-pressing above levels observed in the second condition and above key-pressing levels observed on the control key was demonstrated. In the second resurgence iteration all four subjects demonstrated resurgence. Comparing the cumulative number of responses in resurgence conditions within subjects indicated that when the second resurgence condition was compared to the first, two subjects responded more frequently, one subject responded less frequently, and the fourth subject responded similarly. The pattern of responding across extinction sessions observed under both resurgence iterations was initially sigmoidal. Initially, subjects primarily emitted Response 2 with few instances of Response 1, and then an increased rate of responding on Response 1 was observed, finally decreasing to zero-levels by the final session. Lieving and Lattal (2003) concluded that repeating the resurgence procedure did not decrease the magnitude of the effect and that resurgence is repeatable within subjects.

Volkert et al. (2009; described above), utilizing children diagnosed with developmental delays, demonstrated that problem behavior would recur following the unavailability or intermittent delivery of reinforcement for an appropriate communication response. Although not a primary objective of their study, Volkert et al. repeated the resurgence procedure within each subject in each experiment. Therefore, the effect of repeated resurgence procedures on the magnitude of resurgence can be observed. In Experiment 1 resurgence was observed in 4 of 6 possible conditions. Two of three participants' problem behaviors resurged in both resurgence conditions. The magnitude (i.e., rate) of resurgence was similar in both resurgence conditions, with one participant engaging in a higher rate of problem behavior during the second exposure to extinction.

In Experiment 2 resurgence was observed in both the initial exposure to extinction and the second exposure to extinction conditions. For one participant the overall number of responses was greater in the second exposure to extinction. Volkert et al. (2009, p. 155) observed that repeated exposure to extinction did not lessen the magnitude of resurgence, and in some cases repeated exposure increased its magnitude.

Cleland, Foster, and Temple (2000) designed an experiment to test the effects of varying the amount of extinction of Response 1 on the degree of resurgence. Six chicken hens served as subjects. Door pushes and head bobs were the responses of interest. Feedback beeps were sounded when a subject responded on either operanda. The order of the responses as Response 1 and Response 2 was counterbalanced across subjects. In the first condition Response 1 was trained and reinforced and the schedule was incrementally increased to a RI 60-s schedule of food delivery. In the second condition, which lasted 7 sessions, Response 1 was reinforced on a RI 60-s schedule of food delivery. In the third condition there were no programmed consequences for any response. The number of sessions of exposure to this condition varied depending on the current iteration of the study. This condition was in effect for 2 sessions for the first 6 iterations, 9 sessions for the 7th, 8th, and 11th iterations, and 0 sessions for the 9th and 10th iterations. In the fourth condition Response 2 was trained on an FR 1 schedule of food delivery. In the fifth condition, which was in effect for 4 sessions, Response 2 was reinforced on an FR 1 schedule of food delivery. In the sixth and final condition, there were no programmed consequences for any response. This condition, the resurgence condition, was in effect for 7 sessions. The aforementioned six conditions were repeated 11 times. The number of

sessions in the third condition was varied to determine whether length of exposure of Response 1 to extinction effected subsequent resurgence.

Cleland et al. (2000) found that the amount of number of responses of Response 1 and Response 2 emitted in respective extinction conditions (i.e., conditions 3 and 6) decreased as subjects were exposed to repeated extinction conditions (i.e., responses emitted in extinction decreased over repeated iterations). Although the number of responses emitted in extinction decreased overall, the pattern of extinction responding changed such that an increasing number of extinction responses occurred later in extinction conditions.

Overall, an increased amount of resurgence responding was observed in the first six resurgence iterations for 4 of 5 subjects. Resurgence data for the remaining iterations were not reported. Data were presented on a logarithmic scale with a regression line fitted with the method of least squares. Positive slopes, reported for 4 of 5 subjects, indicates an increased amount of resurgence over iterations, were 0.07, 0.09, 0.14, and 0.21. The single negative slope, reported for 1 of 5 subjects, indicating a decreasing amount of resurgence over iterations, was –0.02. The percentage of variance accounted for (R^2) by each regression line ranged from 0.02 to 0.87. Cleland et al. argued that the differences observed in extinction and resurgence responding were not due to a change in rate of responding on Response 1 or 2 because the rates observed in the second and fifth conditions (training conditions), respectively, were similar across repeated iterations for each subject.

Although these authors reported an increased amount of resurgence over repeated iterations two factors call these conclusions into question. A single data point was

presented for each resurgence condition, making it difficult to discern patterns of resurgence individually for each subject or within condition patterns of responding. Second, the amount of Response 1 emitted in the condition prior to the resurgence could not be directly compared to the amount of Response 1 in the resurgence condition. A direct comparison of these values is required to conclude that resurgence has occurred; otherwise it is possible that Response 1 had been occurring at a high rate prior to the resurgence condition, and that high rate continued into the resurgence condition.

da Silva, Maxwell, and Lattal (2008, Experiment 1b) exposed three naïve White Carneau pigeons to a concurrent schedule of reinforcement to determine if a higher magnitude of resurgence would occur on a schedule of reinforcement that produced a higher rate of reinforcement. Key presses on a three-key intelligence panel served as the responses of interest. In the first condition one side key provided food reinforcement on a VI 360-s schedule of food delivery. The other side key concurrently provided food on a VI 60-s schedule of food delivery. In the second condition responses to both side keys were extinguished while the center key was scheduled to provide food on a VI 180-s schedule of food delivery. In the final condition extinction was programmed for all responses.

da Silva et al. (2008) observed that resurgence occurred in two of three subjects. A higher magnitude of resurgence occurred on the key that was scheduled to deliver reinforcement more frequently (i.e., VI 60 s). For one subject resurgence occurred at a very low magnitude. Subsequently, this subject was re-exposed to all experimental conditions. Resurgence was observed, consistent with other subjects, following re-

exposure to the resurgence procedure. That is, the magnitude of resurgence increased when the subject was re-exposed to the resurgence procedure.

RATIONALE FOR THE PRESENT STUDY

Resurgence may be relevant to important human behaviors such as problem solving (Epstein, 1987) and the reappearance of inappropriate responding exposed to function-based treatments (Volkert et al., 2009). For example, standard DRA plus extinction procedures are nearly identical to Condition 2 in a standard resurgence preparation, and a client may be repeatedly exposed to such procedures over his or her lifetime. Consider a case in which an inappropriate behavior (Response 1) with an unknown history of reinforcement becomes a problem for a teacher who seeks help from a behavior analyst. The behavior analyst devises a treatment (i.e., DRA) in which the problem behavior is extinguished and a functionally similar alternative response is taught (Response 2). Following the cessation of the problem behavior and acquisition of the alternative behavior the alternative behavior contacts extinction due to a lack of intervention integrity increasing the likelihood of the problem behavior returning. At this point the behavior analyst may return and conduct a similar assessment and treatment, exposing the child to the resurgence procedure again.

An estimate of the potential effects of repeating a function-based treatment can be made by repeating the resurgence procedure. Consider the alternatives. It is possible that the magnitude of resurgence increases over repeated iterations. In this case practitioners should be cautious about repeatedly implementing interventions. Alternatively, the magnitude of resurgence may decrease over repeated iterations. In this case, repeating an

intervention procedure produces beneficial effects for the client in the long run. Lastly, repeating the resurgence procedure may not produce a change in the magnitude of resurgence. In this case repeating standard function-based treatments would be neutral.

The second reason for conducting this study is that there are no well controlled studies examining the effects of repeating the resurgence procedure more than two times with pigeons and no studies (known to this author) that repeated the resurgence procedure with rats. Lieving and Lattal (2003, Experiment 2) repeated the resurgence procedure with pigeons a single time in a methodologically sound study, but the effects of more than one repetition are unknown.

METHODS

Subjects

Four experimentally-naive White Carneau pigeons, purchased from the Palmetto-Pigeon Plant (Sumter, SC), served as subjects. Pigeons were approximately four years old at the beginning of the study. Pigeons were housed individually in a colony room maintained on a 12-h light/12-dark schedule and kept at a constant temperature (20–22 C). Pigeons had unlimited access to grit and water in their home cages. Pigeons were maintained at 80% (+/– 15 g) of their free-feeding weights throughout the study. Post-session feeding occurred as necessary to maintain their weights. This study was approved by the Institutional Animal Care and Use Committee (IACUC) at Western Michigan University (see Appendix A).

Four experimentally-naive Sprague-Dawley rats, purchased from the Charles River (Portage, MI), also served as subjects. Rats were approximately 70 days old at the beginning of the study. Rats were housed individually located in a colony room maintained on a 12-h light/12-dark schedule and kept at a constant temperature (20–22 C). Rats had unlimited access to water in their home cages. Rats were maintained at 80% (+/– 15 g) of their free-feeding weight throughout the study. Post-session feeding occurred, if necessary to maintain their weights. This study was approved by the Institutional Animal Care and Use Committee (IACUC) at Western Michigan University (see Appendix B).

Apparatus

Experimental sessions for pigeons were conducted in three-key pigeon chambers with a work area of 30 cm by 24 cm by 29.5 cm (Med Associates, St. Albans, VT). The chambers were housed in a sound-attenuating enclosure with a ventilation fan to mask extraneous noise. All keys were transilluminated white and were operative throughout the duration of the study. The center of each 2-cm diameter key was located 21.5 cm from the floor panel. The center key was 5.5 cm from each side key. Reinforcers consisted of 3-s access to a solenoid-operated hopper filled with mixed grain that was raised into an aperture centered on the base of the work panel. The food hopper was lit during access to reinforcement only. General illumination was provided, except during reinforcer delivery, by a 28-V light positioned on a panel opposite of the food hopper, 28 cm from the floor panel. A personal computer operating with MedPC® software (Med Associates, St. Albans, VT) recorded data and controlled all experimental events.

Experimental sessions for rats were conducted in commercially available operant chambers that measured 30 cm by 24.5 cm by 21.5 cm (Med Associates, St. Albans, VT). The chambers were housed in sound-attenuating enclosures with a ventilation fan and a white noise generator to mask extraneous noise. Each chamber contained one retractable response lever and two nose poke apertures. The response lever was positioned left of the food aperture, 3 cm from the left wall, and 3 cm from the floor panel. The primary nose poke aperture, 2 cm in diameter, was positioned right of the food aperture, 1.8 cm from the right wall, and 2 cm from the floor panel. A second nose poke aperture, of identical dimensions, was placed opposite the response lever on the back panel. All operanda were available and active throughout the duration of the study (except during training sessions). The food aperture was positioned in the middle of the work panel, 3 cm from the floor panel. Reinforcers consisted of the delivery of a single 45 mg dust-free food pellet (Bioserve, Frenchtown, NJ). General illumination was provided, except during reinforcement delivery, by a 28-V light placed above the response lever 21.5 cm from the floor panel. A personal computer operating with MedPC® software (Med Associates, St. Albans, VT) recorded data and controlled experimental events.

Procedure

The procedure was adapted from Lieving and Lattal (2003). Sessions were conducted at approximately the same time each day, seven days a week. Sessions terminated after 60 reinforcers were delivered. Three primary conditions, described below, were repeated, comprising a resurgence iteration. Six iterations were conducted with pigeons and two were conducted with rats.

Pretraining

Subjects were taught to emit Response 1 for food. Initially animals were shaped to do so when an FR 1 schedule was in effect.FR values were increased progressively from 1 to 15 over three sessions. Pigeons were taught to peck on either the left or right key, counterbalanced within birds. Rats were taught to respond on the lever, which was always left of the hopper (i.e., no counterbalancing occurred for Response 1 with rats). This condition only occurred once within the experiment.

Condition 1: Primary Response Acquisition

Responses on the primary operanda were reinforced on a VI 30-s schedule of food delivery. Responses on the inoperative operanda were never reinforced. VI values were selected without replacement from the algorithm described by Fleshler and Hoffman (1962). Reinforcement of Response 1 on a VI 30 was continued for a minimum of 15 days and until performance was deemed stable.

The stability criterion involved first calculating the mean rate of responding for the subject's last six sessions. Two sub-means, based on the first three sessions and the last three sessions of the most recent six sessions, were then calculated. The two sub-means were compared to the overall mean rate. If the two sub-means did not vary more than 10% from the overall mean rate, then performance was deemed stable.

A changeover delay (COD) of 3 s was operative throughout each condition for the inoperative operanda (i.e., Response 2 during the first condition and the control responses). The middle key served as the control response for pigeons. The second nose

poke device, on the wall opposite the hopper, served as the control response for rats. The control response was never programmed for food delivery, throughout the duration of the experiment. Any response to the inoperative operanda or control response resulted in a 3-s delay to the availability of a reinforcer on the operative key. That is, responses on the operative lever that were otherwise eligible for reinforcement during a COD were not reinforced. When the COD elapsed, responses on the operative lever were eligible for reinforcement. Additional responses on any inoperative operanda reset the COD to 3 s.

Pretraining: Response 2

Subjects were taught to emit Response 2 (i.e., a nose poke operanda for rats and the previously non-reinforced key peck for pigeons) for food. Rats were hand shaped to respond to the nose poke aperture. FR values were increased progressively from 1 to 15 over three sessions. This condition only occurred once over the duration of the experiment.

Condition 2: Response 2 Reinforcement

A VI 30-s schedule of food delivery was arranged on Response 2. In this condition, Response 1 was no longer followed by food delivery. Pigeons that were trained to respond to the left key in the first condition, were trained to respond to the right key in this condition, and visa versa. The nose poke aperture positioned right of the food delivery device served as Response 2 for the rats. This condition was in effect for a minumum of 15 sessions, and until (a) Response 2 was deemed stable according to the stability criterion described in the first condition, and (b) the rate on Response 1 was less

than three responses per minute. For rats, following the stabilization of Response 2, if Response 1 occurred more than three times per minute the COD was increased to 10 s. For pigeons, following the stabilization of Response 2, if Response 1 occurred more than one time per minute the COD was increased to 10 s. A 10-s COD was in effect until Response 2 decreased to fewer then three responses per minute.

Condition 3: Extinction

During this condition there were no programmed consuequences for any response. Ten sessions were conducted in this condition and each session lasted 30 minutes.

Repetition of Conditions

Following the completion of 10 sessions in extiction (Condition 3) therats were exposed to the entire resurgence procedure (i.e., Condition 1, 2, and 3) again. Pigeons were exposed to the entire resurgence procedure six times. All subjects were required to finish an iteration of the procedure before the next iteration began and each subject in each group (pigeon or rat) began the resurgence procedure on the same date (i.e., some subjects did not complete sessions inbetween iterations). The sequence of conditions and number of sessions allocated to each condition for each pigeon are shown in Tables 1, 2, 3 and 4. The sequence of conditions and number of sessions allocated to each condition for each rat is shown in Table 5. Rats were exposed to fewer repetitions than pigeons because the rats failed to exhibit robust resurgence during either iteration of the procedure.

Table 1

Sequence of Conditions and Number of Sessions Conducted for Pigeon 1

| Pigeon | Condition | | Number of Sessions |
	Initial Response	Alternative Response	
1	Train left key response		
	VI 30 s	EXT	15
	Train right key response		
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10

Table 2

Sequence of Conditions and Number of Sessions Conducted for Pigeon 2

Pigeon	Condition		Number of Session
	Initial Response	Alternative Response	
2	Train left key response		
	VI 30 s	EXT	15
	Train right key response		
	EXT	VI 30 s	16
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	17
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	18
	EXT	VI 30 s	19
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	16
	EXT	EXT	10

Table 3

Sequence of Conditions and Number of Sessions Conducted for Pigeon 3

Pigeon	Condition		Number of Session
	Initial Response	Alternative Response	
3	Train right key response		
	VI 30 s	EXT	15
	Train left key response		
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	19
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	19
	EXT	VI 30 s	15
	EXT	EXT	10

Table 4

Sequence of Conditions and Number of Sessions Conducted for Pigeon 4

Pigeon	Condition		Number of Session
	Initial Response	Alternative Response	
4	Train right key response		
	VI 30 s	EXT	16
	Train left key response		
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	18
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10

Table 5

Sequence of Conditions and Number of Sessions Conducted for Each Rat

Rat	Condition		Number of Session
	Initial Response	Alternative Response	
35	Train left lever response		
	VI 30 s	EXT	18
	Train right nose poke response		
	EXT	VI 30 s	17
	EXT	EXT	10
	VI 30 s	EXT	16
	EXT	VI 30 s	15
	EXT	EXT	10
36	Train left lever response		
	VI 30 s	EXT	17
	Train right nose poke response		
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	15
	EXT	VI 30 s	15
	EXT	EXT	10
37	Train left lever response		
	VI 30 s	EXT	15
	Train right nose poke response		
	EXT	VI 30 s	20
	EXT	EXT	10
	VI 30 s	EXT	16
	EXT	VI 30 s	15
	EXT	EXT	10
38	Train left lever response		
	VI 30 s	EXT	15
	Train right nose poke response		
	EXT	VI 30 s	15
	EXT	EXT	10
	VI 30 s	EXT	16
	EXT	VI 30 s	15
	EXT	EXT	10

DATA ANALYSIS

The number of responses emitted on each operandum was recorded each session. Data were analyzed on a within-subject basis. The recurrence of Response 1 during the final condition was deemed resurgence if it was in excess of (a) the number of responses on Response 1 emitted in the second condition, and (b) the number of control responses emitted in Condition 3 (see Bruzek et al., 2009, for a similar operational definition of resurgence).

Multiple measures were used to quantify resurgence. One was the absolute number of responses emitted on Response 1 in the final condition. A second measure of the magnitude of resurgence was the proportion of responses emitted on Response 1 in the final condition, particularly compared to the proprotion of responses emitted on Response 2 in the final condition. Finally, the frequency of Response 2 emission during Condition 3 over repeated iterations was evaluated to determine the effect of repeated extinction conditions on the level of extinction.

RESULTS

As noted previously, resurgence was identified by comparing the frequency of Response 1 in Condition 2 to Condition 3. The total number of Response 1s and control responses are reported for the last 6 sessions from Condition 2 and all 10 sessions from Condition 3 for six resurgence iterations for each pigeon (see Figures 1, 2, 3, and 4). Performance was typical of VI schedules with moderate to high rates of responding. The average rate of occurrence of Response 1 expressed as responses per minute (r/min) over

the last 6 sessions of Condition 1 for Bird 1 was 46.20, 51.35, 43.39, 53.12, 58.20, and 45.45 (M = 49.64) for each respective iteration. The average rate of responding over the last 6 sessions of Condition 1 for Bird 2 was 30.76, 34.15, 40.03, 27.04, 32.16, and 33.90 r/min (M = 33.01) for each respective iteration. The average rate of responding over the last 6 sessions of Condition 1 for Bird 3 was 34.83, 37.17, 31.4, 22.44, 17.22, and 20.26 r/min (M = 27.55) for each respective iteration. Bird 3 did not meet stability criteria prior to entering the second condition in the fifth and sixth iteration (due to a number of sessions of non-responding), but was moved on following visual inspection of stability for the final two sessions of Condition 1. This was done to minimize the differences across resurgence iterations for Bird 3 and to reduce the amount of differences between Bird 3 and other subjects. The average rate of responding over the last 6 sessions of Condition 1 for Bird 4 was 36.79, 90.49, 79.19, 89.47, 86.38, and 88.99 r/min (M = 78.57) for each respective iteration. All subjects met the stability criterion for moving to Condition 2, for all iterations (except the aforementioned exceptions with Bird 3) in fewer than 20 sessions.

In general, Response 1 occurred at a very low rate prior to entering the final condition. The average rate of responding over the last six sessions of Condition 2 for Bird 1 was 0.03, 0.15, 0.07, 0.10, 0.03, and 0.09 r/min (M = 0.08), for each respective iteration. The average rate of responding over the last six sessions of Condition 2 for Bird 2 was 0.01, 0.04, 0.01, 0.00, 0.53, and 0.00 r/min (M = 0.10), for each respective iteration. The average rate of responding over the last six sessions of Condition 2 for Bird 3 was 0.09, 0.00, 0.01, 0.12, 0.18, and 0.07 r/min (M = 0.08), for each respective
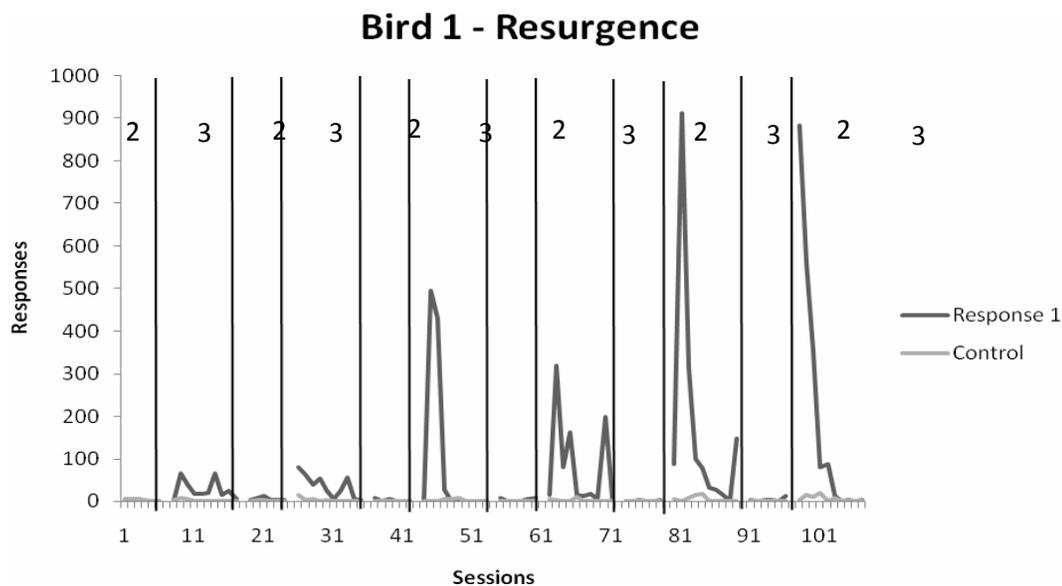
Figure 1. Total number of Response 1s and the control responses for Bird 1 during the final six sessions of Condition 2 and during the 10 sessions of Condition 3 for six resurgence iterations. Higher numbers on Response 1 indicate a higher magnitude of resurgence. Sessions are not consecutive.
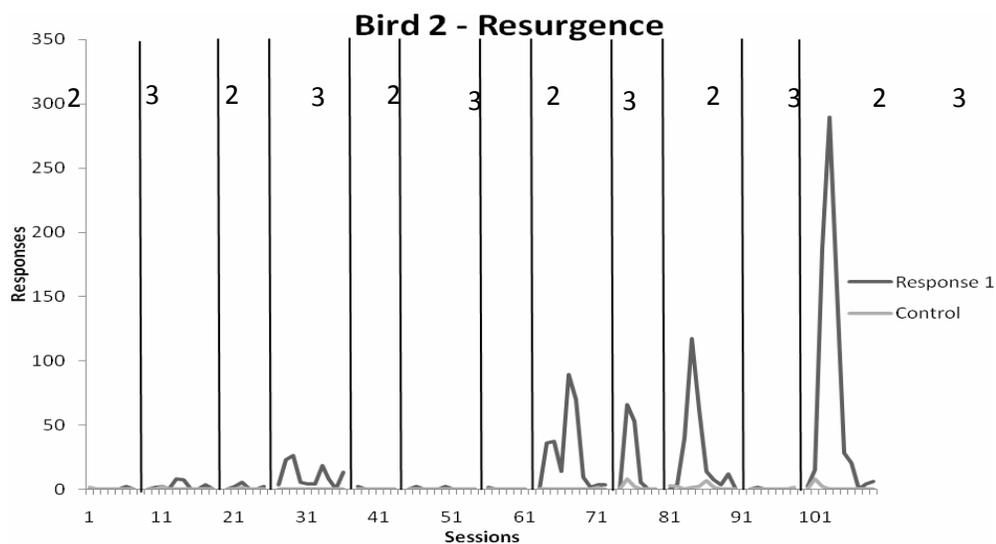

Figure 2. Total number of Response 1s and the control responses for Bird 2 during the final six sessions of Condition 2 and during the 10 sessions of Condition 3 for six resurgence iterations. Higher numbers on Response 1 indicate a higher magnitude of resurgence. Sessions are not consecutive.
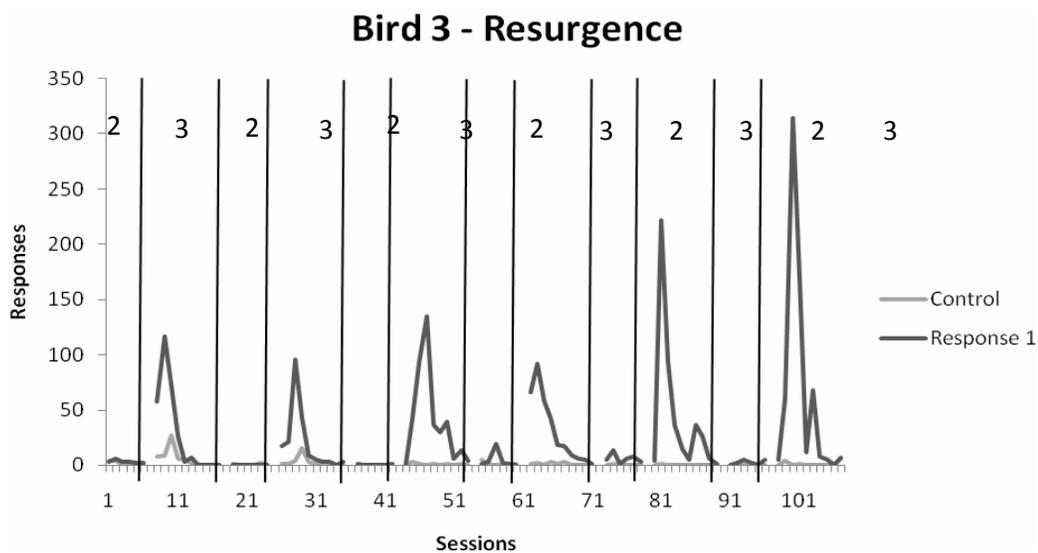
Figure 3. Total number of Response 1s and the control responses for Bird 3 during the final six sessions of Condition 2 and during the 10 sessions of Condition 3 for six resurgence iterations. Higher numbers on Response 1 indicate a higher magnitude of resurgence. Sessions are not consecutive.
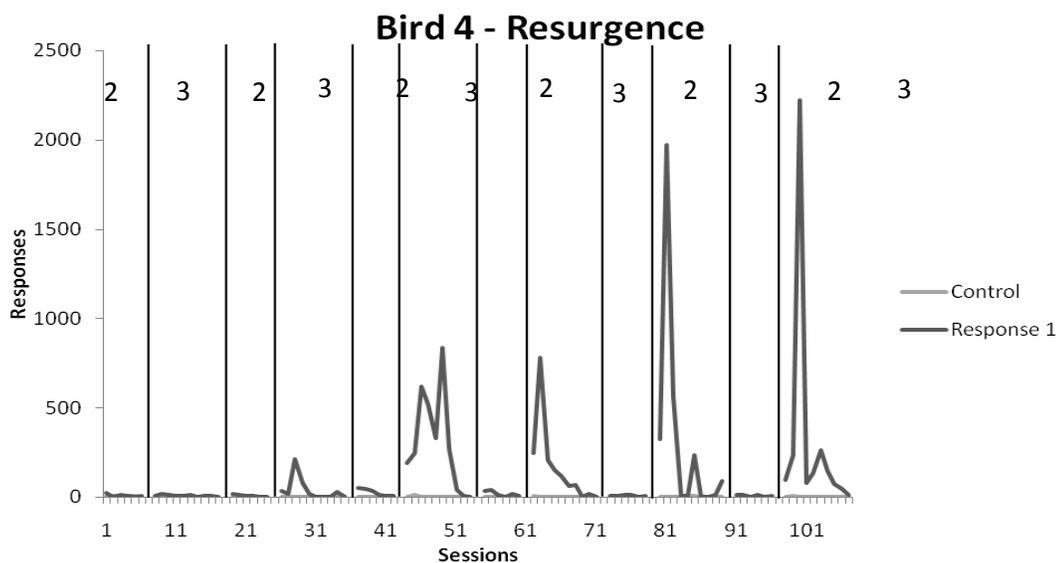

Figure 4. Total number of Response 1s and the control responses for Bird 4 during the final six sessions of Condition 2 and during the 10 sessions of Condition 3 for six resurgence iterations. Higher numbers on Response 1 indicate a higher magnitude of resurgence. Sessions are not consecutive.

iteration. The average rate of responding over the last six sessions of Condition 2 for Bird 4 was 0.15, 0.05, 0.70, 0.53, 0.00, and 0.00 r/min ($M = 0.24$), for each respective iteration. A 10-s COD was introduced during the third and fourth iteration to reduce Bird 4's rate of responding below 1 response per minute prior to entering the final condition.

Resurgence occurred in 6, 4, 6, and 5 out of 6 possible resurgence conditions for Bird 1, 2, 3, and 4, respectively. The total number of responses emitted on Response 1 and the control key for the last six sessions of Condition 2 and 10 sessions from Condition 3 for all iterations for each subject are shown in Figures 1, 2, 3, and 4. Resurgence was evident for 2 of 4 subjects (i.e., Bird 1 and Bird 3) during the first iteration. The middle key was utilized as the control response and was available throughout the duration of the study. If an equal number of responses occurred on the control response and Response 1 in Condition 3, then the recurrence of Response 1 cannot be labeled resurgence because it could be due to extinction-induced variability. Few control responses occurred during each resurgence condition, especially compared to the number of Response 1s.

As subjects were exposed to repeated resurgence conditions within condition patterns of responding changed such that Response 1s were emitted later in Condition 3. During the initial exposures to Condition 3, few responses occurred late (i.e., session 8 to 10) in Condition 3. Following repeated exposures to the resurgence procedure, some responding became evident in sessions 8 to 10 of Condition 3.

In general, the magnitude of resurgence increased as subjects were exposed to additional resurgence iterations. The total number of Response 1s emitted in each resurgence condition is reported for each subject in Figure 5. The total number of

Response 1s emitted in Condition 3 increased for each subject as subjects were exposed to repeated iterations of the resurgence procedure. As the magnitude of resurgence responding increased the amount of extinction responding decreased. The total number of Response 2s emitted in each resurgence condition is reported for each subject in Figure 6. A decreasing number of Response 2s was evident for Bird 1, 2, and 4. The total frequency of Response 1s divided by the frequency of Response 1 plus Response 2 in Condition 3 for each iteration and each subject is reported in Figure 7. In general, the proportion of responses that were Response 1s increased as subjects were exposed to repeated iterations of the resurgence procedure. Three values were noteworthy. Bird 1 emitted a larger proportion of Response 1s than Response 2 in the sixth iteration (50.82%) and Bird 4 did so in the fifth and sixth iterations (79.88 and 74.47%, respectively).
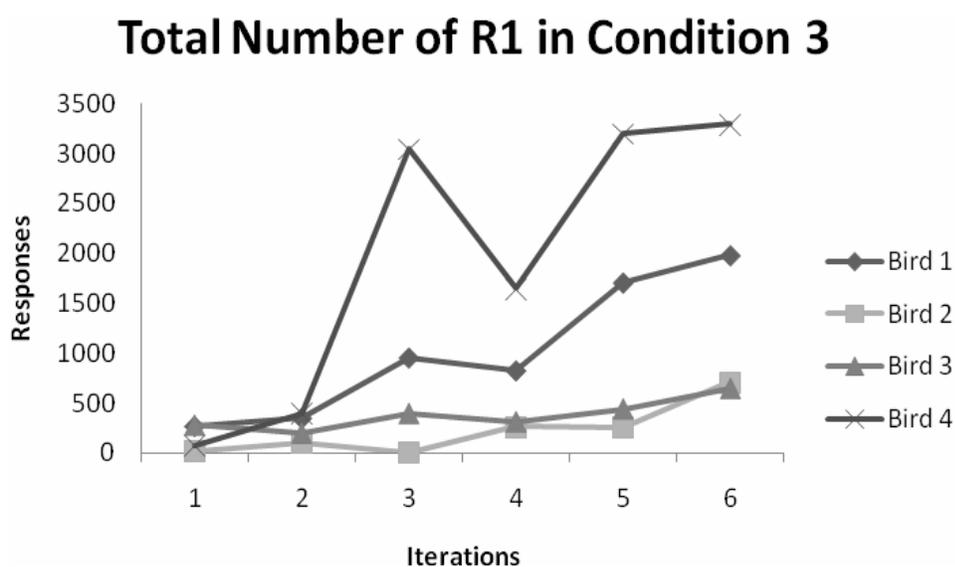

Figure 5. Total number of Response 1s per resurgence condition for each iteration of the resurgence procedure by pigeon. Higher values indicate a higher magnitude of resurgence.
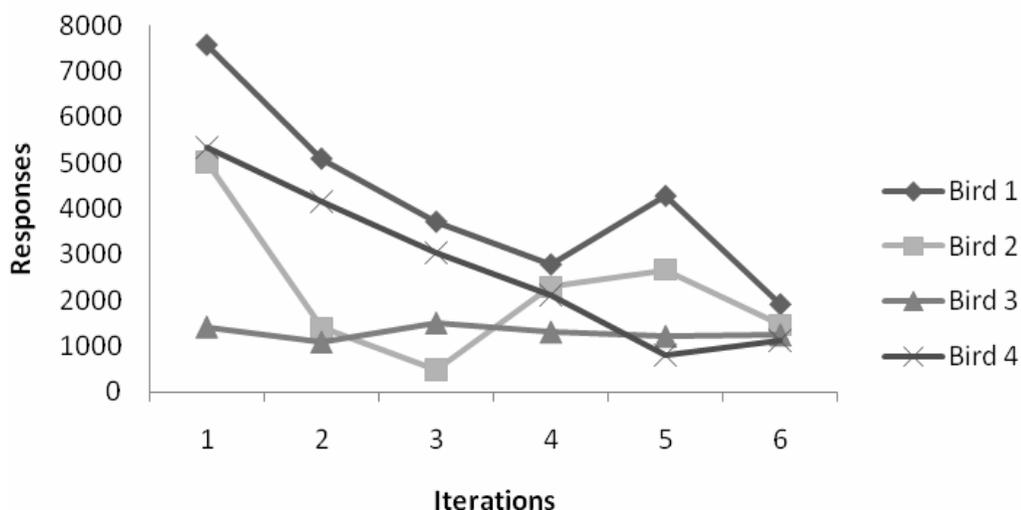
Figure 6. Total number of Response 2s per resurgence condition for each iteration of the resurgence procedure by pigeon. Higher values indicate a higher number of responses in extinction.
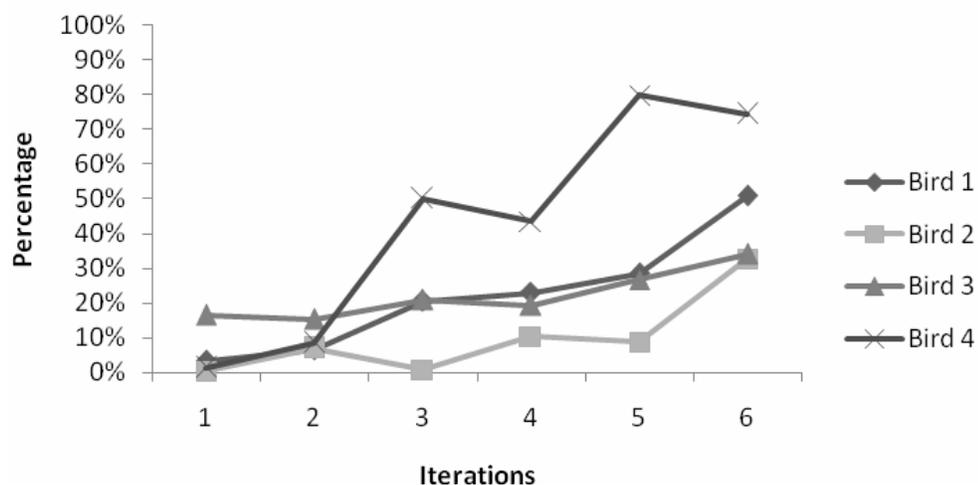

Figure 7. Total amount of Response 1s divided by Response 1s plus Response 2s in Condition 3 for each iteration and each subject. Higher numbers indicate a larger proportion of responding was allocated to Response 1.

An analysis of extinction patterns for Response 1 during Condition 2 was conducted. The total number of Response 1s emitted during the first 10 sessions of Condition 2 for each subject is shown in Figure 8. The number of sessions used to calculate extinction responding was selected for two reasons: (a) it matches the number of sessions in the final condition so direct comparisons regarding the number of responses in extinction can be conducted, and (b) the duration of Condition 2 varies, so utilizing values from the entire condition would result in meaningless comparisons. For all four subjects an increasing level of responding was observed from the first to the second iteration. For three of four subjects a decreasing trend of extinction responding was evident following the second exposure to Condition 2. In general, the total frequency of extinction responding decreased for Response 1 in Condition 2 and Response 2 in
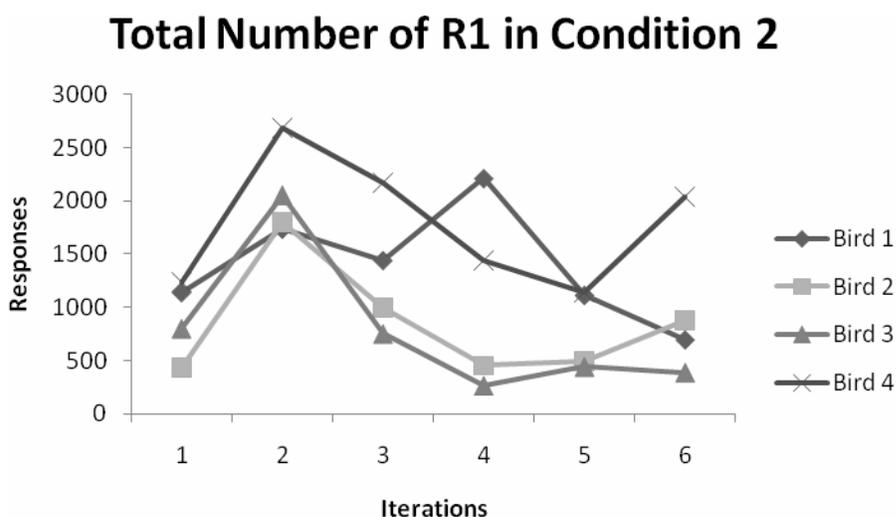

Figure 8. Total number of Response 1s in the first 10 sessions of each iteration of Condition 2 for each pigeon. Higher values indicate a higher amount of responding in extinction conditions.

Condition 3 as subjects were repeatedly exposed to resurgence iterations. Note that a much higher frequency of extinction responding was observed in Condition 3, when compared to the extinction of Response 1 in Condition 2. This was due to the availability of reinforcement for Response 2 in Condition 2.

The total number of Response 1s and of control responses are reported for the last 6 sessions from Condition 2 and all 10 sessions from Condition 3 for two resurgence iterations for each rat (see Figures 9, 10, 11, and 12). Performance was typical of VI schedules with moderate to high rates of responding. The average rate of responding over the last 6 sessions of Condition 1 for Rat 35 was 9.11 and 4.31 r/min, for each respective iteration. The average rate of responding over the last 6 sessions of Condition 1 for Rat 36 was 20.35 and 13.27 r/min, for each respective iteration. The average rate of responding over the last 6 sessions of Condition 1 for Rat 37 was 23.19 and 19.34 r/m for each respective iteration. The average rate of responding over the last 6 sessions of Condition 1 for Rat 38 was 36.48 and 37.36 r/min, for each respective iteration. All subjects met the stability criterion for moving to Condition 2 in under 19 sessions during both iterations.

In general, Response 1 occurred at a very low rate prior to entering the final condition. The average rate of responding over the last six sessions of Condition 2 for Rat 35 was 0.13 and 0.09 r/min, for each respective iteration. The average rate of responding over the last six sessions of Condition 2 for Rat 36 was 0.26 and 0.43 r/min, for each respective iteration. The average rate of responding over the last six sessions of Condition 2 for Rat 37 was 2.18 and 2.39 r/min, for each respective iteration. The average rate of
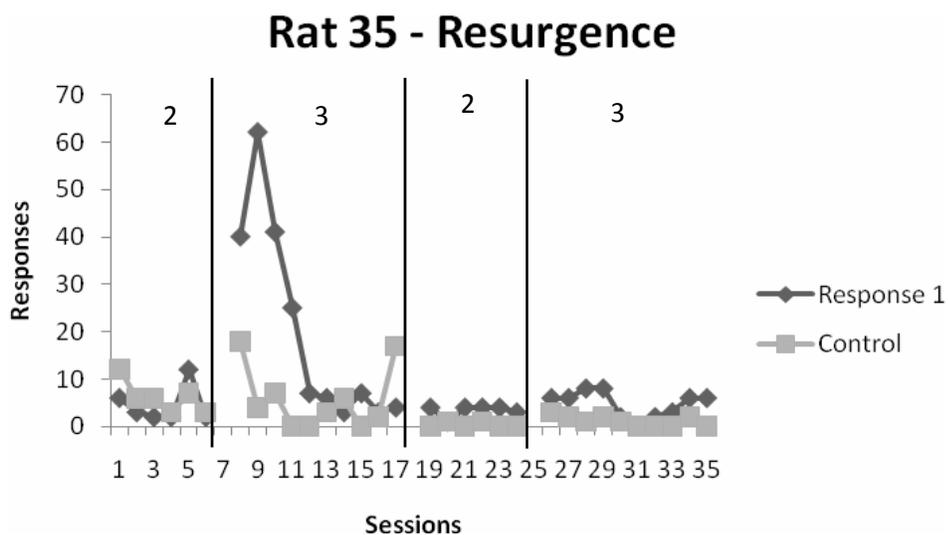
Figure 9. Total number Response 1s (left nose pokes) and control responses (right nose pokes) Rat 35 during the final six sessions of Condition 2 and during the 10 sessions of Condition 3 from two resurgence iterations. Higher numbers on Response 1 indicate a higher magnitude of resurgence. Sessions are not consecutive.

Figure 10. Total number of Response 1s (left nose pokes) and control responses (right nose pokes) for Rat 36 during the final six sessions of Condition 2 and during the 10 sessions of Condition 3 from two resurgence iterations. Higher numbers on Response 1 indicate a higher magnitude of resurgence. Sessions are not consecutive.
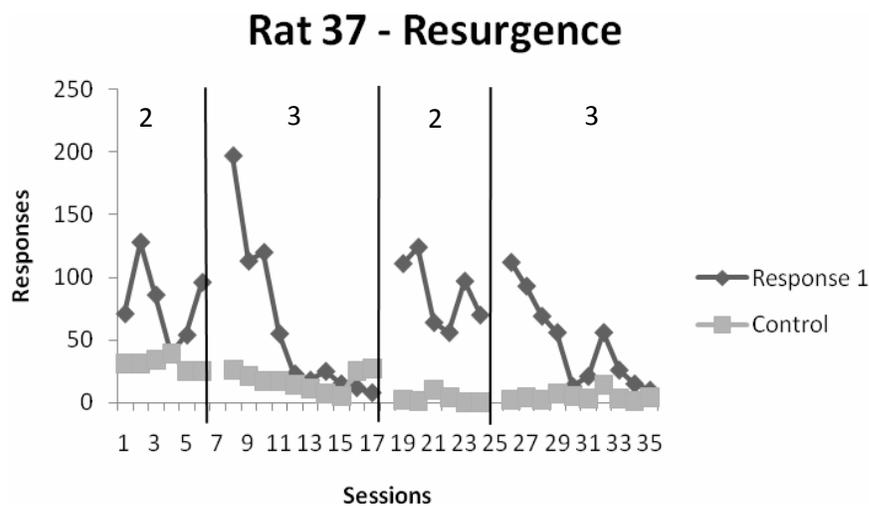
Figure 11. Total number of Response 1s (left nose pokes) and control responses (right nose pokes) for Rat 37 during the final six sessions of Condition 2 and during the 10 sessions of Condition 3 from two resurgence iterations. Higher numbers on Response 1 indicate a higher magnitude of resurgence. Sessions are not consecutive.
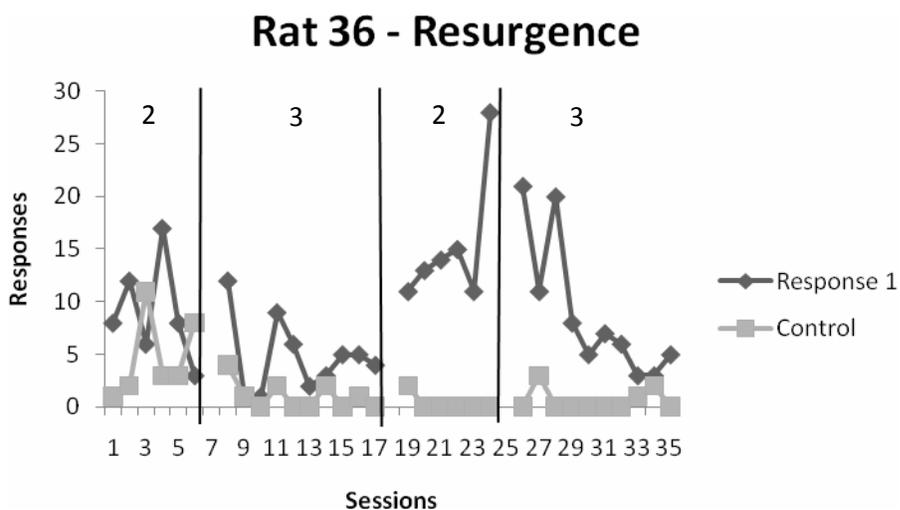

Figure 12. Total number of Response 1s (left nose pokes) and control responses (right nose pokes) for Rat 38 during the final six sessions of Condition 2 and during the 10 sessions of Condition 3 from two resurgence iterations. Higher numbers on Response 1 indicate a higher magnitude of resurgence. Sessions are not consecutive.
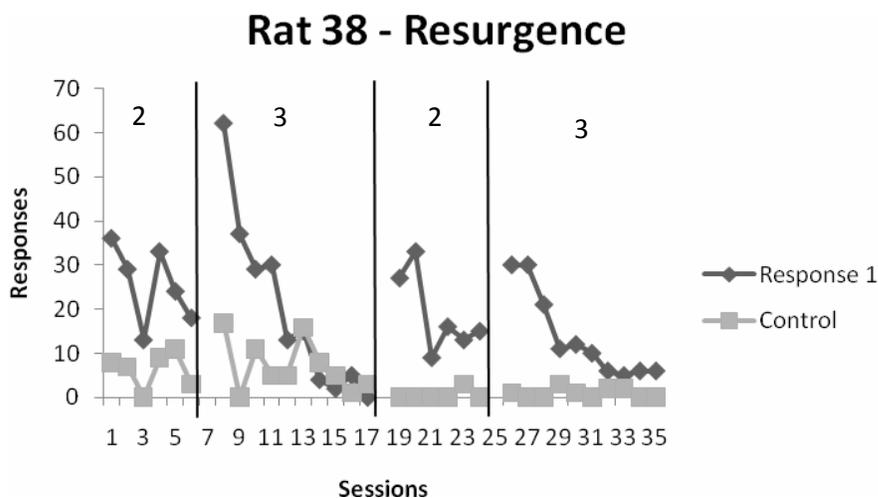
responding over the last six sessions of Condition 2 for Rat 38 was 0.74 and 0.55 r/min, for each respective iteration. A 10-s COD was introduced during the second condition of the first resurgence iteration to reduce Rat 37's rate of responding below 3 responses per minute prior to entering the final condition. All subjects met the stability criterion in 20 or fewer sessions prior to being moved to Condition 3.

Resurgence occurred in 1, 0, 1, and 1 out of 2 possible resurgence conditions for Rats 35, 36, 37, and 38, respectively. The total number of Response 1s and of control responses for the last six sessions of Condition 2 and 10 sessions from Condition 3 for all iterations for each subject are shown in Figures 9, 10, 11, and 12. Resurgence was evident in 3 of 4 subjects during the first iteration and 0 of 4 subjects during the second iteration. Few control responses occurred during either resurgence condition, especially compared to the number of Response 1s.

Each rat that exhibited resurgence in the first iteration no longer displayed resurgence when exposed to an additional resurgence iteration. In the second resurgence iteration there was no evidence of resurgence for any subject. The total number of responses emitted for all 10 sessions of Condition 3 for each resurgence iteration is shown in Figure 13. A decreasing pattern of Response 1 emission is evident over iterations for all subjects except Rat 38, which did not display resurgence in either iteration.
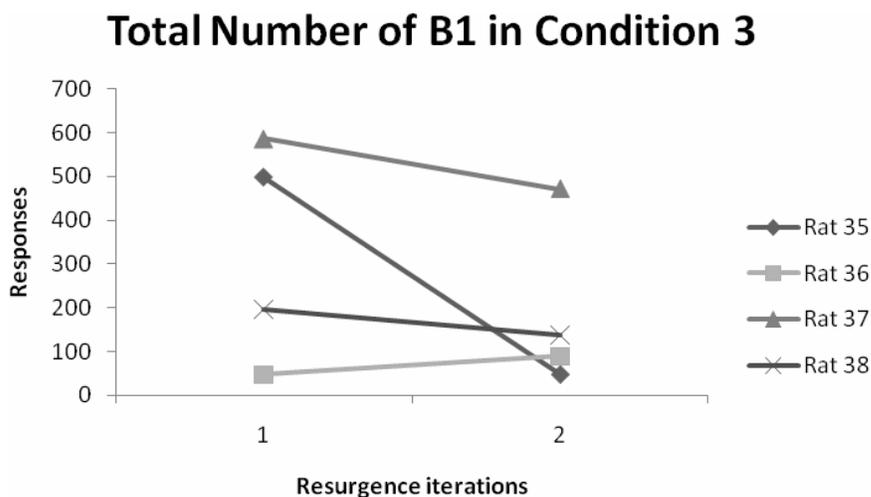
Total Number of B1 in Condition 3

Figure 13. Total number of Response 1s per resurgence condition for each iteration of the resurgence procedure by rat. Higher values indicate a higher magnitude of resurgence.

An analysis of extinction responding following repeated training and extinction conditions was conducted. The total number of Response 2s emitted in Condition 3 per iteration for each rat is reported in Figure 14. A decreasing level of Response 2 is evident for all subjects except Rat 36, which emitted approximately the same number of responses each iteration. The total number of Response 1s emitted during the first 10 sessions of Condition 2 (see above for a rationale for this boundary) per iteration for all subjects is reported in Figure 15. A clear pattern of responding is not evident from iteration to iteration. A decreasing pattern is evident for Rat 35 and 37, whereas Rat 36 and 38 demonstrate a steady or increasing pattern, respectively.
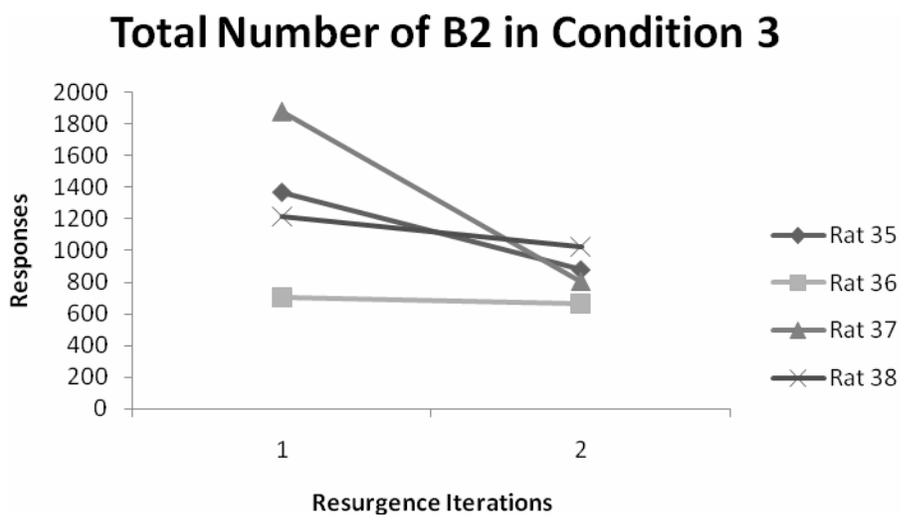
Figure 14. Total number of Response 2s per resurgence condition for each iteration of the resurgence procedure by rat. Higher values indicate a higher number of responses in extinction.
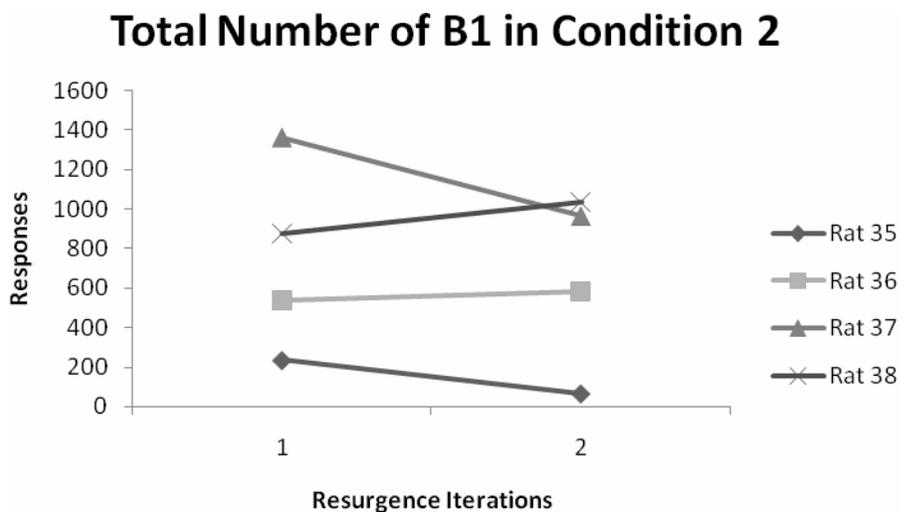

Figure 15. Total number of Response 1s in the first 10 sessions of each iteration of Condition 2 for each rat. Higher values indicate a higher amount of responding in extinction conditions.

DISCUSSION

The results of repeated resurgence iterations with pigeons indicate that resurgence is repeatable within subjects, which is consistent with the results of Lieving and Lattal (2003, Experiment 2). Because of the repeatability of the resurgence process it can be used as a baseline to test the effect of psychotropic drugs, motivating operations, the magnitude of reinforcement, and other independent variables of potential conceptual or practical significance. Additionally, the results from pigeon subjects demonstrate that the magnitude of resurgence increases following repeated exposure to the resurgence procedure. These findings are consistent with past findings with non-human animals (Cleland et al., 2000), but not with human participants (Volkert et al., 2009). Cleland et al. (2000), after repeating the resurgence procedure six times with chickens, concluded that resurgence increased with repeated exposures. The resurgence of aberrant behaviors also increased with at least one, but not all, human participants following repeated exposures to the resurgence procedure (Volkert et al., 2009). Similarly, resurgence was not evident for Bird 2 or 4 after the first exposure to the resurgence procedure. Following the second exposure to the resurgence procedure resurgence was apparent for both Bird 2 and 4. The aforementioned pattern was observed by da Silva et al. (2008) when one subject did not demonstrate resurgence, was then subsequently exposed to an additional resurgence iteration, and resurgence occurred. All of these findings in conjunction indicate that the magnitude of resurgence either is steady or increases over repeated iterations. Additional research on the pattern of problem behavior in human participants is required to determine if the magnitude of resurgence of such responding increases

following more than one repeated resurgence iteration. This research would help to determine which intervention strategies should be implemented by practitioners when working with clients who have been treated frequently with DRA plus extinction procedures.

A pattern of increasing resurgence responding is interesting because the amount of responding in extinction decreased for both Response 1 and 2 (with pigeon subjects) over repeated iterations. These data indicate that extinction responding is independent of resurgence responding. Resurgence and extinction processes appear to occur independently but in parallel, with both resulting from extinction.

Results from the resurgence study with rats indicate that the magnitude of resurgence decreased following repeated exposure to the resurgence procedure. Initially, resurgence was evident in 3 of 4 subjects, but subsequently it was evidenced in none of them. This pattern of resurgence has not been observed in studies that repeated resurgence conditions. In some cases the magnitude of resurgence decreased, but not to zero or near-zero levels. For example, one subject in Lieving and Lattal (2003, Experiment 2) emitted fewer responses during the second exposure to resurgence conditions, but the results from the present rat resurgence study are inconsistent with Lieving and Lattal's (Experiment 2) general finding with pigeons. Future research should determine the long-term pattern of resurgence over more than one repetition with rats.

The current findings, with resurgence increasing with pigeons and decreasing with rats, appear unusual because the methods for both studies were nearly identical (see below for an analysis of methodological considerations). The reason(s) for the difference in the performance of rats and pigeons are unknown. Unfortunately, there are no

published studies that utilized rats as subjects and repeated the entire resurgence procedure. Quick, Pyszczynski, Colston, and Shahan (2011), using qualitatively different reinforcers for Behavior 1 and Behavior 2, repeated Condition 2 and Condition 3 (but not Condition 1), and found that Response 1 recurred at a lower magnitude than was observed in the first iteration of the resurgence procedure. Additional replications of this process with rats will be required to determine the relationship between repeated resurgence iterations and the magnitude of resurgence in this species.

One factor that may modulate the likelihood of resurgence occurring is a subject's sensitivity to extinction. Volkert et al. (2009, Experiment 1) described a human participant who did not demonstrate resurgence in the initial resurgence procedure or the repeat conditions. They hypothesized that the subject was particularly sensitive to the conditions in place, rapidly discriminating the extinction conditions. Consider Rat 36, which did not display resurgence in either iteration. This subject emitted the fewest extinction and fewest resurgence responses in Condition 3 for both iterations, when compared to other subjects, suggesting a particular sensitivity to extinction conditions. Although sensitivity to extinction may modulate the likelihood of resurgence occurring, the history required to become especially sensitive to extinction is unknown and therefore does not provide insight into the history required to produce the aforementioned outcomes.

An analysis of the extinction pattern for Response 1 in Condition 2 and Response 2 in Condition 3 was conducted. Previous research indicates that the number of responses in extinction tend to decrease after repeated training and extinction conditions (e.g., Bullock, 1960). This effect is called the repeated-extinction effect (e.g., Zarcone, Branch,

Hughes, & Pennypacker, 1997). Anger and Anger (1976) reported that the repeated-extinction effect did not occur when eight extinction sessions were arranged; other studies that found the effect arranged extinction for five or fewer sessions. The pattern of Response 2 in Condition 3 is the best measure of extinction because reinforcement was not available for an alternative response as occurred in Condition 2. For both rats and pigeons, the amount of extinction responding decreased as Response 2 was trained and extinguished repeatedly, which is consistent with past research, except Anger and Anger (1976). The results of the current study provide supportive evidence for the repeated-extinction effect, even though extinction conditions in the current study were longer than those reported by Anger and Anger (1976).

A pure analysis of extinction cannot be conducted with Response 1 during Condition 2 because Response 2 was concurrently being reinforced. Regardless, there was a decreasing pattern of Response 1 in Condition 2 for pigeons, but not for rats. An interesting pattern emerged with pigeons in which the total number of responses was initially low during the first iterations, increased during the second iteration, and decreased in subsequent iterations (see Figure 8). The anomalous data points for the first iteration are likely due to the training that occurred during the first resurgence iteration. During the pretraining of Response 2, during the first iteration, Response 1 was available and did not deliver reinforcement (i.e., Response 1 was extinguished during pretraining). Responding in extinction during pretraining could account for the low amount of extinction observed early in Condition 2 for the first iteration.

Based on the results of the current study it is tempting to conclude that the differences observed in the magnitude of resurgence are due to species differences. There

are, however, a few subtle differences between the rat and pigeon resurgence protocols

that merit mention that may temper that conclusion. Differences observed in the

magnitude and pattern of resurgence may be due to any of these factors instead of species

differences. The most obvious difference is the topography of the response. In the rat

protocol Behavior 1 and Behavior 2 had different topographies, whereas both responses

were key pecks for pigeons. In the case of the pigeons' resurgence some portion of

responding may be due to response generalization, artificially increasing the amount of

resurgence observed. Previous research has utilized behaviors with the same topography

(e.g., da Silva et al., 2008; Bruzek et al., 2009, Experiment 1) and behaviors with

different topographies (e.g., Lieving & Lattal, 2003; Bruzek et al., 2009, Experiment 2) as

the behaviors of interest. Future research should examine the impact of the similarity or

difference of the topographies of Response 1 and Response 2 on the magnitude on

resurgence. Specifically, this procedure should be repeated with rats utilizing the same

response topography for Response 1 and Response 2.

Another difference between the rat and pigeon resurgence-repeat protocol is the

feeding arrangements. Pigeons generally acquired all their food during the session, not

requiring postsession feeding, whereas rats generally required approximately three-

quarters of their daily rations postsession to maintain their weights. Immediate

postsession feeding has been shown to reduce the rate of responding in rats on VI

schedules of food delivery (Smethells, Fox, Andrews, & Reilly, 2012). Smethells et al.

exposed rats to VI 60-s schedules of food delivery in both 60-min and 15-min sessions

over three conditions: (a) immediate postsession feeding, (b) delayed (5-hr) postsession

feeding, and (c) immediate postsession feeding. Three of four subjects exhibited a higher

rate of responding when postsession feeding was delayed and emitted a lower rate of responding in the immediate postsessions feeding conditions in both 60-min and 15-min sessions. Data were collected after at least 15 sessions in each condition. In any case, some unknown length of exposure to immediate postsession feeding was required to have a decreasing effect on rate of responding. Rats in the current study received immediate postsession feeding prior to entering the resurgence condition for at least 15 sessions and this history may have decreased the rats' rate of responding during the resurgence condition. In contrast, the pigeons in the current study did not have a long history of postsession feeding prior to entering each resurgence condition and a rate reduction would not have occurred.

A simple difference exists between the first resurgence iteration and subsequent resurgence iterations. Response training only occurs during the first resurgence iteration and may function as an important difference between the first and subsequent iterations. The number of reinforcers for Response 1 and 2 during the first iteration is increased compared to other iterations and the length of time between Condition 1 and 3 is also increased. In this respect the first iteration differs from subsequent iterations. The impact this may exert on resurgence is unclear, but it is a potentially important difference.

Relative to other extinction phenomenon, resurgence has not received much empirical attention. However, the amount of research on resurgence has increased in recent years. Such research is merited insofar as it allegedly provides information relevant to important human behaviors such as the relapse of problem behavior (Volkert et al., 2009) and creativity (Epstein, 1987). Be that as it may, it is unclear whether the magnitude of resurgence would increase if humans were exposed to repeated resurgence

iterations, although such an effect was not observed following one repetition of the resurgence procedure (Volkert et al., 2009). Additional research is needed to determine how well the current study generalizes to human populations and important human problems, particularly as it pertains to repeated resurgence iterations. Lastly, resurgence typically is not reliably demonstrated in all subjects, even when exposed to identical conditions (e.g., Lieving & Lattal, 2003). Future research should determine the factors that decrease or increase the likelihood of resurgence. For example, a modulating factor in basic research might be the proportion of food acquired outside of the experimental session. Resurgence is an interesting behavioral phenomenon, but it is not a simply one. Further research is needed to understand its conceptual and practical implications, as well as the variables that modulate its occurrence. In pigeons, at least, these variables can potentially be studied using within-subjects experimental designs, which are highly advantageous from a behavior-analytic perspective. Demonstrating that this is the case, and showing that rats and pigeons behave differently in respect to the appearance of resurgence under similar conditions, are the main contributions of the present study.

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Appendix A

**Western Michigan University Institutional Animal Care and Use Committee
Approval for Pigeons**

WESTERN MICHIGAN UNIVERSITY

Institutional Animal Care and Use Committee

Centennial
1903-2003 Celebration

Date: November 12, 2009

To: Alan Poling, Principal Investigator

From: Robert Eversole, Chair

Re: IACUC Protocol No. 09-08-02

Your protocol titled "Drug Effects on Resurgence" has received approval from the Institutional Animal Care and Use Committee. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

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

Approval Termination: November 12, 2010

Appendix B

Western Michigan University Institutional Animal Care and Use Committee Approval for Rats

WESTERN MICHIGAN UNIVERSITY

Centennial
1903-2003 Celebration

Date: January 11, 2012

To: Alan Poling, Principal Investigator

From: Robert Eversole, Chair

Re: IACUC Protocol Number 12-01-01

Your protocol entitled "An Examination of the Non-Arbitrary Nature of Resurgence Responses" has received approval from the Institutional Animal Care and Use Committee. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

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

Approval Termination: January 11, 2013