Resurgence of Phonetic Responding

Dissertation

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By

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Abstract

Resurgence has not been researched with respect to persistent, inaccurate, academic behavior. Reading is an essential component for school success and is ubiquitous across content areas (e.g., math, language arts, history, and science). Contact with insufficient instruction and correction procedures may facilitate a reading repertoire that contains many different kinds of reading errors, such as reading words incorrectly.

The purpose of this study was to investigate if resurgence could be evoked for academic-based responding and whether the magnitude of resurgence was related to the rate of differential reinforcement of alternative behavior. Three participants identified Greek letters as an arbitrary consonant-vowel blend. Two sets of four-Greek letters were used to arrange a two-component multiple schedule of reinforcement. Baseline responding was reinforced on a multiple variable interval (VI) 11-s, VI 11-s schedule of reinforcement. Then alternative letter-sounds were taught and reinforced on a multiple VI 5-s, VI 20-s schedule of reinforcement. Then both the original and alternative letter-sounds were placed on extinction. The three conditions (i.e., baseline reinforcement of the original letter-sounds, differential reinforcement of alternative letter-sounds, and extinction of both letter-sounds) were repeated. Based on the results, resurgence was reliably demonstrated; with the exception of the first resurgence test for Participant 1. In addition, the data suggested that the magnitude of resurgence was related to the prior rate of
differential reinforcement of alternative behavior. The results, limitations, implications, and suggestions for future research are discussed.
Dedication

This dissertation is dedicated to my family: Carrie, Annabelle, and Elijah. I have spent countless hours trying to further my education in order to provide a better future for us. Every day that I spent on campus I spent with you on my heart. Alas! This journey is over and a new one begins. I hope that the universe continues to bless us as we walk together into the next phase of our journey.
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Fields of Study

Major Field: Physical Activity and Education Services
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Chapter 1: Introduction

The Ohio Department of Natural Resources, Division of Wildlife, lists 170 species of fish that can be found within the lakes and rivers of Ohio. Of the species listed, 54 species are labeled either as extinct, extinct from Ohio waters, or a species of concern (www.ohiodnr.gov). Building dams along rivers is a primary contributor to the decline of the fish population (www.ohiodnr.gov). There are several negative consequences associated with dams, unfortunately. A dam creates large, stagnant, pools of water and prevents seasonal pools from developing that species use for reproduction and food sources (www.ohiodnr.gov). The stagnant water behind a dam, mixed with high temperatures, creates low-oxygen levels. Under these conditions a sanitation hazard develops for all inhabitants (www.columbus.gov). As part of the Olentangy River Restoration Project in Columbus, Ohio the 5th Avenue Dam was removed from the Olentangy River. The removal of the 5th Avenue Dam allowed the water to flow; thus, eliminating large, stagnant pools that turn into sanitation hazards from runoff and sewage back-up. In addition, the river was narrowed in several locations to foster seasonal flooding and natural pools to develop for spawning and feeding.

The negative consequences of dams can be conceptualized as unintended or unanticipated consequences. Unintended and unanticipated consequences are not uncommon. A review of history can highlight an abundance of examples across several human endeavors, including the sciences.
Unintended Consequences in Applied Behavior Analysis

As will be described later, basic research regarding behavioral momentum theory (BMT) and resurgence provide a framework for understanding an unintended consequence of interventions based on differential reinforcement of alternative behavior (DRA) (Mace et al., 2010; Nevin, Tota, Torquato, & Shell, 1990; Podlesnik & Shahan, 2009; Pritchard, Hoerger, & Mace, 2014). BMT is a metaphor of Newton’s first law of physics in which an object in motion stays in motion until disrupted by some force (Nevin, Mandell, & Atak, 1983; Pritchard, Hoerger, & Mace, 2014). The speed and the mass of an object in motion play an important role in determining the resistance of the object to a disrupting force. For example, given the same disrupting force, an object that has greater speed and mass will show greater resistance to change compared to an object with less speed or mass. Similarly, research regarding BMT has demonstrated that higher density schedules of reinforcement show greater resistance to change following disruption compared to lower density schedules of reinforcement (Nevin, 1974, 2012; Nevin, Mandell, & Atak, 1983; Nevin, Tota, Torquato, & Shull, 1990). With respect the BMT metaphor, the response frequency is analogous to speed and reinforcement density is analogous to mass.

Further experimentation by Nevin, Tota, Torquato, and Shull (1990) found that resistance to change is a function of the total reinforcement available in a given context. Nevin et al. (1990) conducted two experiments to evaluate the effects of non-contingent reinforcement (NCR) and DRA on the frequency of responding and resistance to change following disruption. In the first experiment, additional food (i.e., NCR) was delivered in
one component of a two-component multiple VI 60-s VI 60-s schedule of reinforcement. The NCR was arranged on a variable-time (VT) schedule of reinforcement. Following disruption, the component with the added reinforcers demonstrated greater resistance to change.

The second experiment evaluated resistance using a three-component multiple concurrent schedule of reinforcement. Two response keys were available in each component and were differentiated by key colors, which is analogous to interventions that use DRA—one key was the target behavior and the second key was the alternative behavior. The rate of reinforcement correlated with the key color in each component. Although the DRA produced a typical deceleration of the target response, the components associated with higher rates of reinforcement (i.e., Components 1 and 3 of the second experiment) demonstrated greater resistance to change.

The results from Nevin et al. (1990), and replications of those findings by Podlesnik and Shahan (2009), suggest that added reinforcers in the context of the target behavior can (a) decelerate a target behavior, and (b) increase the resistance of the target behavior during extinction. Another important discovery by Nevin et al. (1990) was demonstrating that the frequency of responding is a function of the behavior-reinforcer relation and resistance to change is a function of the context-reinforcer relation. Building upon this finding, Podlesnik and Shahan (2009) demonstrated that BMT and resurgence both share context-reinforcer relations. Therefore, the results of Podlesnik and Shahan (2009) suggest that BMT can account for the unintended relapse of a target behavior.
during extinction that follows DRA (Podlesnik & Shahan, 2009; Pritchard, Hoerger, & Mace, 2014).

Mace et al. (2010) extended the findings of Nevin et al. (1990) and Podlesnik and Shahan (2009) by evaluating the effects of extinction following DRA with children with intellectual and developmental disabilities. The results of this study demonstrated resurgence of the target behavior during the extinction phase following a DRA phase. In addition, the target behavior demonstrated greater resistance to change during extinction following DRA compared to extinction following baseline. Resurgence and resistance of the target behavior during extinction were unwanted side effects of DRA. The side effects of DRA may occur in situations analogous to lapses in treatment integrity or premature termination of the intervention (Mace et al., 2010; Pritchard, Hoerger, & Mace, 2014). Furthermore, the side effects (i.e., resurgence and resistance to change) may be overshadowed by the saliency of the socially meaningful effects of DRA—a deceleration of the target behavior. Based on the results of Mulick, Leitenburg, and Rawson (1976), DRA consistently and more rapidly decelerated the target behavior compared to differential reinforcement of other behavior and extinction alone. Given the desired social effects of DRA, resurgence and resistance to change can occur unnoticed by an observer.

Response to Intervention and Relapse

Relapse of error-responding may also occur in educational settings without detection due to the effects of DRA during tier-two or tier-three instruction. Response to intervention (RTI) places students in tiers based on the intensity of services needed for successful academic achievement (Fuchs & Fuchs, 2006; Greulich et al., 2014; Johnson
Tier-one instruction involves a general core curriculum and universal interventions (Fuchs & Fuchs, 2006; Johnson & Street, 2013). Tier-two and tier-three instruction is a form of supplemental instruction for a target group of students in which the intensity of instruction is increased (Fuchs & Fuchs, 2006; Johnson & Street, 2013). For example, a student who does not make meaningful reading progress during tier-one instruction will receive tier-two instruction. Hypothetically, during tier-one instruction reading errors can be unintentionally reinforced and contribute to the student’s lower reading performance for both fluency and comprehension (Begeny, Daly, & Valleley, 2006; Neddenriep, Fritz, & Carrier, 2011). However, during tier-two instruction, the student experiences error-correction procedures, which essentially function as DRA. The student’s instructional experience alternates between tier-one instruction—where incorrect responding is reinforced—and tier-two instruction—where correct or alternative behavior is reinforced. Given this scenario, behavior can likely relapse during tier-one instruction if alternative behavior is placed on extinction during tier-one instruction or if the extinction of error-responding occurs in a context different than the tier-one environment even though tier-one discriminative stimuli remain in effect—resurgence and renewal, respectively. Consequently, the relapse of error responding in the tier-one environment can perpetuate the need for tier-two or three services. In addition, based on the results of Leitenberg, Rawson, and Mulick (1975) errors could relapse in the tier-one environment at a magnitude directly related to the rate of differential reinforcement experienced during tier-two instruction.
Purpose of the Paper

The purpose of this dissertation was to extend the findings of Epstein (1983), Leitenberg, Rawson, and Bath (1970), Leitenberg, Rawson, and Mulick (1975), Lieving and Lattal (2003), Mace et al. (2010), Nevin et al. (1990), and Podlesnik and Shahan (2009) regarding the resurgence of operant behavior. This dissertation investigated resurgence within an educational context; specifically targeting see-say phonetic responding.

Included within this document are: (a) a literature review describing the basic and applied research with respect to resurgence, (b) the experimental methodology for a study investigating the resurgence of phonetic responding, (c) the results of the study, and (d) a discussion of the implications of the study.

Research Questions

Will the original letter-sound, analogous to a reading error, resurge during extinction despite previously contacting differential reinforcement of alternative behavior?

Will the original letter-sound resurge at a magnitude directly related to the rate of differential reinforcement of alternative behavior?
Chapter 2: Literature Review

Purpose

The purpose of this chapter is to provide a historical overview of resurgence. Included in this chapter is the methodology of the literature review, the results of the literature review, and the progression of the research with respect to resurgence.

Literature Review Methodology

An electronic search was conducted using EBSCO Host in which the following databases were used: (a) PsycINFO, and (b) Psychology and Behavioral Sciences Collection. The electronic search was modified by selecting only peer-review journals and full-text, PDF, documents. Additional modifiers included removing articles pertaining to drugs and alcohol, and disease (e.g., resurgence of West Nile virus in Africa). A single search term was used—resurgence. The results of the search yielded 508 articles. The title and abstract of the articles were read and selected for the literature review if the article pertained to resurgence of operant behavior. Both basic and applied research articles were included. In addition, experiments and literature reviews were both included. Articles that were exclusively based on reinstatement or renewal were not included in the review. Based on the inclusion and exclusion criteria, 27 articles were selected. The reference section of these articles was examined to locate additional articles. As a result, another 5 articles met the inclusion criteria and were added. Therefore, the total number of articles used for this literature review was 32.
Defining Resurgence

Based on the literature used for this review, resurgence is defined as the reemergence of a target behavior during the extinction of an alternative behavior. Resurgence is the outcome of the following sequence effect: (a) baseline reinforcement of an original behavior, (b) extinction of the original behavior, which can occur prior to or concurrently with, (c) reinforcement of an alternative behavior, and then (d) extinction of both the original and alternative behaviors. During the extinction of both behaviors condition, the original behavior resurges (Epstein 1983; Epstein & Skinner, 1980; Leitenberg, Rawson, & Bath, 1970; Leitenberg, Rawson, & Mulick, 1975; Lieving & Lattal, 2003; Podlesnik & Shahan, 2009; Rawson, Leitenberg, Mulick, & Lefebvre, 1977; Sweeney & Shahan, 2013).

Adaptation and variability. The term resurgence was introduced by Epstein and Skinner (1980) and was used to describe the recovery effect that occurs during extinction of an alternative behavior. Shortly after introducing the term, Epstein (1983) concluded that resurgence was a reliable principle of behavior that involves the recurrence of previously reinforced behavior when recently reinforced behavior is no longer effective for obtaining reinforcement. Resurgence can explain the moment-to-moment changes of behavior during many contexts in which recent behavior is ineffective for producing reinforcement. The principle implies that extinguished behavior is not unlearned, but recurs given the appropriate circumstances (Epstein, 1983), which is consistent with discrimination theory (Baum, 2012).
As a basic principle, resurgence is valuable for understanding operant behavior with respect to the potential mechanisms through which behavioral variability can be expressed (Lieving & Lattal, 2003). Resurgence comprises part of the behavioral repertoire available for reinforcement at any given moment when other behavior fails to produce reinforcement (Epstein, 1983; Lieving & Lattal, 2003). As a mechanism of behavioral variation, resurgence can be viewed as an adaptive element of behavior useful for problem-solving (Lattal & St. Peter Pipkin, 2009; Wilson & Hayes, 1996) through which response classes can synthesize with other response classes. Although, helpful for obtaining reinforcement when other behaviors fail, resurgence is not always socially desired. Examples of situations in which resurgence is not socially desired include: any kind of dangerous or harmful behavior toward oneself or others (e.g., taking drugs, self-injurious behavior, or violence toward others), error-responding within academic contexts, and counterproductive diet- and exercise-related behaviors.

**Extinction.** From a broad perspective, resurgence can be conceptualized as one of the many dynamics of behavior evoked by extinction. During extinction, behavior has been shown to spontaneously recover (Lerman, Kelley, Van Camp, & Roane, 1999; Waller & Mays, 2007), evoke response variability (Antonitis, 1951), a component of behavioral contrast (Catania, 1969; McSweeney & Melville, 1993) and is a process necessary to evoke resurgence (Lieving & Lattal, 2003). Extinction is discriminated by the organism, which does not mean unlearning is occurring but that new learning is occurring. However, based on the learning history of the organism new learning during extinction may be expressed differently, for example an organism might use two
discriminated operants to obtain a reinforcer (e.g., resurgence) or in the presence of a stimulus a single discriminated operant recovers (e.g., spontaneous recovery) (Lattal & Lattal, 2012). Clinical applications of extinction can be found in Lerman and Iwata (1996), Lerman, Iwata, and Wallace (1999), and Lerman, Kelley, Van Camp, and Roane (1999). Although widely used, these authors discussed the potential side effects of extinction as a major drawback. For example, extinction can evoke aggression and the recovery of problem behavior, whether during spontaneous recovery or resurgence (Lerman et al., 1999; Mace et al. 2010). Furthermore, the recovery of a problem behavior reduces the probability of the socially desired behavior from generalizing. Although extinction can have negative consequences, it cannot be entirely discarded—as a technology, extinction is a component of a broad array of applied treatments (Lerman & Iwata, 1996). Therefore, more research efforts are needed to discover procedures that minimize the probability and magnitude of the negative consequences associated with extinction.

The progression of research regarding resurgence can be characterized as: (a) initial research with respect to response recovery before the term resurgence was conceived, (b) understanding the conditions necessary for resurgence, (c) recent research linking behavioral momentum theory (BMT) with resurgence, and (d) translational and applied research with human participants. The remainder of this chapter will be dedicated to describing the progression of research regarding resurgence, exploring conflicting results, and providing additional contexts in which resurgence research can be explored.
Early Research: Recovery Following Extinction

A study by Leitenberg, Rawson, and Bath (1970) was one of the first studies that demonstrated resurgence. Using rats as experimental subjects, Leitenberg et al. (1970) found that the original bar press recurred when alternative bar pressing was placed on extinction. Further exploring the recovery phenomenon, Leitenberg, Rawson, and Mullick (1975) investigated recovery of operant behavior by comparing topographically different responses, different rates of reinforcement, and different time allocations of responding. These aspects were evaluated over the course of four experiments. During Experiment One, 30 male hooded rates rats were separated into three groups—a control group, a group in which a topographically similar alternative behavior was reinforced, and a group in which a topographically dissimilar alternative behavior was reinforced. All subjects were maintained at 80% of their ad libitum weight throughout the experiment. The initial response was a bar press. The topographically similar alternative behavior consisted of pressing a different lever in the experimental camber, and the topographically dissimilar alternative behavior was a tube lick. The control group experienced a reinforcement phase followed by two subsequent phases of extinction. The topographically similar group experienced reinforcement for bar pressing, followed by DRA in which an alternative bar press was reinforced, and then extinction of both bar presses. The topographically dissimilar group experienced a reinforcement phase for bar pressing, followed by DRA in which a tube lick was reinforced, and then extinction of both behaviors. The results of the experiment demonstrated resurgence of both alternative behaviors, however, the magnitude of resurgence was greater for the alternative response
that was topographically similar to the original target behavior compared to the topographically dissimilar behavior.

The second experiment also used naïve hooded rats that were maintained at 80% of their normal body weight. The rats were assigned to one of three groups—a control group, a group in which the alternative behavior was reinforced on a fixed ratio (FR)-10 schedule of reinforcement, and a group in which the alternative behavior was reinforced on a yoked variable interval (VI) 12-s schedule of reinforcement. Each group experienced three phases similar to experiment one (i.e., initial baseline reinforcement, DRA, and the extinction of both behaviors). The results of the Experiment Two demonstrated resurgence for both groups that experienced DRA, however, the magnitude of resurgence was greater for the group that experienced the FR-10 schedule of reinforcement compared to the yoked VI 12-s schedule of reinforcement.

The third experiment compared the rates of DRA using adult male Carneaux pigeons maintained at 80% of their normal body weight. Three groups of pigeons experienced three phases similar to experiments one and two. Alternative key pecks were reinforced for one group of pigeons on a variable interval (VI) 30-s schedule of reinforcement, and a VI 4-min schedule of reinforcement for another group of pigeons. The results of the study demonstrated resurgence for both groups that experienced DRA, however, the magnitude of resurgence was greater for the group that experienced the higher density schedule of reinforcement (i.e., the VI 30-s schedule of reinforcement).

Experiment Four was a parametric analysis of time allocation of responding during the DRA condition. The final experiment used naïve male hooded rats maintained

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at 80% of their normal body weight. Four groups of rats experienced the same three phases as in the prior three experiments. The four groups of rats were arranged based on the duration of exposure to the DRA. The durations of exposure to the DRA included: 0, 3, 9, and 27 days. The results of Experiment Four demonstrated resurgence during exposure times: 3, 9, and 27 days. Furthermore, the experiment demonstrated that time allocation, as in exposure to DRA, was inversely related to the magnitude of resurgence—as the duration of exposure to DRA increased, the magnitude of resurgence decreased.

During all four studies, the target behavior recovered (i.e., resurged) during extinction following DRA. In addition, some parameters including, high- and low-density schedules of reinforcement, time allocation, and response topography were discovered with respect to resurgence. Although reliability demonstrating the recovery of a target behavior, Leitenberg, Rawson, and Mulick (1975) did not reach any conclusion with respect to the basic mechanism responsible for the observed changes of behavior. Subsequently, Mulick, Leitenberg, and Rawson (1976) replicated response recovery with squirrel monkeys. However, the authors of that study also did not reach a conclusion regarding the observed changes of behavior.

A study by Rawson, Leitenberg, Mulick, and Lefebvre (1977) was the first to test a hypothesis regarding the controlling mechanisms of recovery. In that study, two hypotheses were proposed to account for response recovery. The first hypothesis was based on the response prevention hypothesis and the second hypothesis was based on the discriminative cue hypothesis. The response prevention hypothesis states that when
punishment and extinction are used concurrently, the aversive properties of the punisher suppress the frequency of the punished response, thus preventing the response from undergoing extinction. When punishment is discontinued, the target behavior once again becomes available (Rawson, Leitenberg, Mulick, & Lefebvre, 1977). The response prevention hypothesis implied that a behavior can be only temporarily weakened. The discriminative cue hypothesis states that response recovery is a function of the discriminative properties of the punisher. When punishment and extinction are introduced concurrently, the punishing stimulus becomes a discriminative cue for extinction. Every subsequent discontinuation of punishment will signal that extinction has been terminated, which results in recovery of the response until extinction takes place under the new stimulus conditions (Rawson, Leitenberg, Mulick, & Lefebvre, 1977). Based on the results of the study, Rawson, Leitenberg, Mulick, and Lefebvre (1977) suggested that the response prevention hypothesis was a more plausible explanation of resurgence compared to the discriminative cue hypothesis.

Although thought provoking and carefully executed, Rawson, Leitenberg, Mulick, and Lefebvre’s (1977) conclusion may not have been the most parsimonious explanation of resurgence. Extinction, combined with the reinforcement history of the organism, is a more parsimonious explanation of recovery. Extinction has been shown to evoke variability of response topography (Antonitis, 1951; Herrnstein, 1961a). In addition to inducing variability, given the behavior history of the organism, extinction can also evoke the recurrence of previously reinforced behavior (Epstein 1983; Epstein & Skinner, 1980; Leitenberg, Rawson, & Bath, 1970; Leitenberg, Rawson, & Mulick, 1975; Lieving &
Lattal, 2003; Podlesnik & Shahan, 2009; Rawson, Leitenberg, Mulick, & Lefebvre, 1977). Therefore, extinction serves as a cue for the organism to try new topographies or revert back to old behavior.

**The Necessary Conditions for Evoking Resurgence**

Lieving and Lattal (2003) evaluated the conditions that were necessary and sufficient to produce resurgence. Lieving and Lattal addressed these parameters of resurgence across four experiments. The purpose of Experiment One was to examine the effects of time allocation of responding during DRA on the magnitude of resurgence, similar to Leitenberg, Rawson, and Mulick (1975). Four naïve Carneau pigeons, maintained at 80% of their ad libitum weight, were used as experimental subjects. Each subject experienced reinforcement for key pecking maintained by a VI 30-s schedule of reinforcement. Then key pecking was placed on extinction for ten, 30-min sessions. Following extinction, a topographically dissimilar alternative behavior, treadle presses, was reinforced. Treadle pressing was maintained by a VI 30-s schedule of reinforcement. Two subjects experienced DRA conditions for 5 sessions and the other two subjects experienced DRA conditions for 30 sessions. After DRA conditions, both key pecking and treadle presses were placed on extinction. In order to better interpret the results, Lieving and Lattal expressed resurgence as a proportion of baseline frequency. Transforming response frequencies as proportions of baseline permitted the comparison of data from different conditions by removing the differences between the levels of baseline responding. The results indicated no differences between the duration of
exposure to DRA conditions and the magnitude of resurgence, which conflicted with the results of Leitenberg, Rawson, and Mulick (1975).

Studies of resurgence prior to Lieving and Lattal (2003) had only examined the initial exposure to extinction; within-subject replications of resurgence had not been demonstrated. Therefore, during Experiment Two, Lieving and Lattal (2003) examined whether resurgence was repeatable with a second exposure to the resurgence procedure. During Experiment Two, four naïve pigeons were maintained at 80% of their ad libitum weight. The baseline reinforcement of key pecks and the DRA condition for treadle pressing were arranged similar to Experiment One. Following extinction of both behaviors and the demonstration of resurgence, the procedures were repeated for each subject (i.e., VI 30-s schedule of reinforcement for key pecks, extinction of key pecks, DRA for treadle pressing, and then extinction of both behaviors). Based on the results, Lieving and Lattal (2003) demonstrated that resurgence was reliable and repeatable across subsequent tests of resurgence. In addition, the results indicated that the effects of resurgence did not diminish during a second exposure to extinction following DRA conditions.

The purpose of Experiment Three was to determine if the removal of the response-reinforcer relation was sufficient for resurgence—that is, will resurgence occur during non-contingent reinforcement? Three naïve pigeons were maintained at 80% of their ad libitum weight. The baseline and DRA conditions were similar to Experiments One and Two. However, instead of experiencing the conventional extinction condition following DRA, the extinction was replaced with a variable time (VT) 30-s schedule of
response-independent food delivery. Based on the outcome of the experiment, non-contingent reinforcement was not sufficient for evoking resurgence.

The result of Experiment Three led to the next experimental question—is local exposure to extinction, as in transitioning from a rich to lean schedule of reinforcement, sufficient for resurgence? During Experiment Four, three naïve pigeons were maintained at 80% of their ad libitum weight. The subjects were exposed to baseline and DRA conditions similar to Experiments One, Two, and Three. However, instead of experiencing the conventional extinction conditions following DRA, the experimenters replaced the VI 30-s schedule of reinforcement for treadle pressing with a VI 360-s schedule of reinforcement. Then after experiencing the abrupt change in reinforcement density, all subjects experienced the conventional extinction condition. The result of experiment four demonstrated resurgence for two out of three subjects during the change of reinforcement density. Additionally, the magnitude of resurgence during the change of reinforcement density was less than the magnitude of resurgence during extinction. During the final extinction condition, key pecking for all three subjects resurged. These results indicated permanent periods of extinction are not necessary for resurgence to occur.

The results of Lieving and Lattal (2003) provided evidence for the role of extinction, whether during local or prolonged exposure, as a necessary condition following DRA for resurgence. Furthermore, Lieving and Lattal (2003) shed light on discrimination theory, in which an interesting question can be posited—what attributes of pigeons’ 964 and 955 (Experiment Four) ontogenetic past enabled them to discriminate
the local shift of reinforcement density as extinction but not pigeon 916? This question falls into the broader category of molar and molecular analyses, which is an ongoing debate (see, Baum, 2013; Shimp, 2013).

Additional research investigating the necessary conditions to evoke resurgence were conducted by da Silva, Maxwell, and Lattal (2008), Bacha-Mendez, Reid, and Mendoza-Soylovna (2007), and Cancado and Lattal (2011). Da Silva, Maxwell, and Lattal (2008) demonstrated resurgence using differential reinforcement of other behavior (DRO), thus providing evidence to suggest that, as a procedure, DRA is not necessary for evoking resurgence. However, the necessary component is differential reinforcement such that at least one additional discriminated operant is shaped in the organism’s learning history. Furthermore, da Silva, Maxwell, and Lattal (2008) found mixed results with respect to the aspects that influence the magnitude of resurgence. Experiment One demonstrated that a VI 1-min schedule of reinforcement evoked resurgence at a greater magnitude compared to a VI 6-min schedule of reinforcement, which is consistent with a behavioral momentum framework (see analysis in the following section). However, given that the response frequency during the VI 1-min schedule of reinforcement was higher than the response frequency during the VI 6-min schedule of reinforcement, da Silva, Maxwell, and Lattal (2008) did not conclusively attribute the behavior change to reinforcement density alone. In the following two experiments, da Silva, Maxwell, and Lattal (2008) demonstrated that when reinforcement rates were similar resurgence was greater during high-frequency responding compared to low-frequency responding and when response frequencies were similar resurgence was not related to baseline

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reinforcement densities; Experiments One and Two, respectively. Overall, the authors concluded that prior response frequency is a better predictor of resurgence than prior reinforcement rates.

Bacha-Mendez, Reid, and Mendoza-Soylovna (2007) demonstrated resurgence of response sequences or as the authors labeled them, integrated behavioral units. During two experiments, rats were engaged in a two-response sequence of lever presses until responding was stable. Then, a new response sequence was reinforced. When the second response sequence stabilized extinction was introduced for both response sequences. During extinction the initial sequence resurged. This study demonstrated integrative behavioral units can resurge during extinction and that resurgence is not limited to single discriminated operants.

Further exploring resurgence, Cancado and Lattal (2011) demonstrated resurgence of algorithm-defined temporal patterns during discrete trials. This study provided evidence suggesting that resurgence is not limited to free-operant procedures. In addition, this study demonstrated that previous delay patterns or temporally organized patterns of responding can resurge during extinction.

Together, the articles in this section provided evidence of the conditions and procedures necessary and sufficient to evoke resurgence. The most common characteristics found across each study are the sequence effect and the learning history. The sequence effect is the process in which an original behavior, whether free-operant, trial-based with embedded temporal parameters, or a response-sequence is reinforced and then is extinguished, followed by differential reinforcement of a new behavior of some
type, which may or may not be topographically similar to the original behavior. Given
this sequence effect, the organism acquired two behaviors in their repertoire using both
behaviors during extinction. Presumably, the recurrence of old behavior maximizes the
chances of obtaining a reinforcer and thus serves as an adaptive function for organisms
when other behavior fails to produce reinforcement.

**Resurgence and behavioral momentum theory.** Based primarily on Nevin, Tota, Torquato, and Shull (1990), Podlesnik and Shahan (2009) investigated the function
of response-independent food delivery in one component of a two component multiple
schedule of reinforcement in order to examine the role of the context-reinforcer relation
during relapse. The context-reinforcer relation was investigated across three experiments,
each experiment involved a different relapse paradigm—reinstatement, resurgence, and
renewal, respectively. During Experiment Two, 10 unsexed Homing pigeons were used
as subjects. During baseline, key pecks on a center key were reinforced on a multiple VI
120-s VI 120-s schedule of reinforcement. Response-independent reinforcers were
delivered on a VT 20-s schedule of food delivery in one of the two schedule components.
Following the baseline reinforcement condition, pecks on the center key were
extinguished and pecks on a right key were reinforced and maintained by a multiple VI
30-s VI 30-s schedule of reinforcement. The resurgence condition (i.e., extinction of both
initial and alternative behaviors) began once response frequencies on the center key
decreased below 10% of baseline response frequencies in both components for a single
session. An analysis of the frequency of the initial key peck during the baseline condition
indicated that key pecking during the component with the added reinforcers was lower in
frequency compared to the other component. However, the magnitude of resurgence was greater for the component that had the added reinforcers during baseline. Based on their finding, Podlesnik and Shahan (2009) concluded that both behavioral momentum theory (BMT) and resurgence share context-reinforcer relations.

The outcome of Podlesnik and Shahan (2009) conflicted with Reed and Morgan (2007) and Da Silva, Maxwell, and Lattal (2008) who discovered that resurgence was a function of response frequency during baseline not reinforcement density during baseline. Reed and Morgan did not compare the data using log proportions of baseline responding. Therefore, Reed and Morgan’s conclusion was based on an artifact of the way the data were displayed. The results of three experiments from Da Silva, Maxwell, and Lattal compared the data using log proportions of baseline and found some evidence to suggest that response frequency was a better predictor of resurgence compared to the rate of reinforcement. However, this finding was not reliable across the three experiments. Although replicating Nevin et al. (1990), Podlesnik and Shahan suppressed response frequency using response-independent reinforcement, therefore compromising the potential role response frequency plays with respect to the magnitude of resurgence. In sum, there is no conclusive evidence to suggest which is a better predictor of resurgence—reinforcement rate or response frequency.

Using BMT as a framework, Shahan and Sweeney (2011) developed quantitative models of resurgence using existing data. In addition, they used the quantitative model to make predictions with respect to an inverse relation between the magnitude of resurgence
and the time exposure to DRA. Their prediction stated that as time exposure to DRA increases, the magnitude of resurgence decreases.

Previous studies have demonstrated conflicting results with respect to Shahan and Sweeney’s (2011) prediction. Leitenberg, Rawson and Mulick (1975) demonstrated that longer exposure to DRA diminished the magnitude of resurgence. However, evaluating the proportion of baseline frequency, Lieving and Lattal (2003) found no significant difference between exposure to DRA and the magnitude of resurgence. The conflicting outcome of the previous two studies was evaluated further by Sweeney and Shahan (2013) using the following equation:

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

where \( B_t \) is the response frequency during time \( t \) in extinction and \( B_o \) is the baseline response frequency before extinction, \( c \) is the suppressive effect of breaking the response–reinforcer contingency, \( d \) scales the suppression associated with the elimination of reinforcers from the situation (i.e., generalization decrement), \( r \) is the rate of reinforcement within the context at baseline, \( b \) is sensitivity to the reinforcement rate, \( R_a \) is the rate of alternative reinforcement during extinction, and the parameter \( k \) scales the disruptive impact of the alternative reinforcement during extinction (Sweeney & Shahan, 2013). This equation was a modified version of the quantitative models used in BMT research (Nevin & Grace, 2000).

During Experiment One, Sweeney and Shahan (2013) evaluated the effects of repeated exposure to extinction and alternative reinforcement on subsequent resurgence. The results indicated that resurgence diminishes across repeated exposure to DRA and
then extinction. Regression line analysis indicated that the equation was an adequate predictor of the finding. Therefore, the data from Experiment One provided support for the prediction that resurgence decreases during repeated exposure to extinction following DRA. During Experiment Two, Sweeney and Shahan reproduced results obtained by Leitenberg, Rawson and Mulick (1975). Regression line analysis accounted for 99% of the variance ($R^2 = .99$), which indicated that the quantitative model adequately accounted for the observed changes of behavior. The results of both experiments suggested that repeated cycles of DRA and then extinction and prolonged exposure to DRA will decrease the magnitude of resurgence (Sweeney & Shahan, 2013). These findings have implications for clinical practice with respect to strategies that minimize the magnitude of resurgence. Overall, Podlesnik and Shahan (2009), Shahan and Sweeney (2011), and Sweeney and Shahan (2013) provided support for the shared relations of BMT and resurgence.

With respect to the conflicting results of Leitenberg, Rawson and Mulick (1975), Lieving and Lattal (2003), and Sweeney and Shahan (2013), it is difficult to directly compare these studies primarily due to the lack of a consistent time unit. DRA was measured across days in Leitenberg, Rawson and Mulick (1975), across sessions in Lieving and Lattal (2003), and across days with an alternating exposure to DRA and extinction in Sweeney and Shahan (2013). However, for each study, the total duration of exposure to DRA expressed in a common time unit is unknown. Therefore, it is impossible to know if an inverse relation between the exposure to DRA and the magnitude of resurgence exists. For example, in Lieving and Lattal (2003) the total
number of minutes of DRA may not have been long enough to produce the effects observed by Leitenberg, Rawson and Mulick (1975) in which subjects were exposed to a nearly a month of DRA. In the absence of a common time dimension, mathematical models (Sweeney & Shahan, 2013) might be placing the cart before the horse—the equation does not include a representation of $tRa$, or time exposure of DRA. As a remedial effort, future studies should conduct parametric analyses of exposure to DRA and the magnitude of resurgence similar to Leitenberg, Rawson and Mulick (1975), but expressed as proportions of baseline similar to Lieving and Lattal (2003). With a common time unit (e.g., total minutes of exposure to DRA) we can begin to establish reliable parameters and then based on reliability construct a mathematical equation.

Human Studies of Resurgence: Translational and Applied Research

The research regarding resurgence using human participants is sparse. The majority of these studies involved children with intellectual and developmental disabilities (IDD)—Reed and Clark (2011) and Volkert, Lerman, Call, and Trosclair-Lasserre (2009) evaluated resurgence with children with autism; Lieving, Hagopian, Long, and O’Connor (2004) and Wacker et al. (2013) evaluated resurgence with children who were identified as having an intellectual disability; and Mace et al. (2010) evaluated resurgence of problem behavior with children with autism, Down Syndrome, and mental retardation.

Bruzek, Thompson, and Peters (2009) evaluated resurgence using university undergraduates as participants. The authors demonstrated resurgence of simulated infant-caregiver responses across two experiments. The purpose of Experiment One was to
identify whether resurgence would occur during a negative reinforcement arrangement. During baseline, a simulated infant cry was terminated contingent upon rocking. Then rocking behavior was extinguished—the simulated cry did not terminate during rocking. Alternatively, feeding behavior was differentially negatively reinforced. During the final condition, both rocking and feeding were placed on extinction. The results demonstrated that behavior maintained by negative reinforcement can resurge in the context of an analog situation involving infant and care provider behaviors.

The purpose of Experiment Two was to evaluate the effects of duration and recency of reinforcement history on responding during the resurgence condition. Using eight undergraduates as participants, two behaviors were negatively reinforced during baseline. The target behaviors were using a certain toy to play with a doll. The behavior associated with Toy 1 was exposed to negative reinforcement for a longer duration compared to the behavior with Toy 2. Then both behaviors were placed on extinction. The results of Experiment Two demonstrated that a longer history of reinforcement resurged at a greater magnitude compared to responses with a shorter and more recent history of reinforcement. These results appear to have consistency with BMT and provide additional evidence that resurgence and momentum share context-reinforcer relations (Podlesnik & Shahan, 2009). According to BMT, resistance is a function of the total amount of reinforcement in a given context. Based on the results of Experiment Two, the longer duration of the reinforcement history (i.e., the context associated with more reinforcement) was a better predictor of the magnitude of resurgence.
**Resurgence of problem behavior.** The emerging literature has primarily investigated resurgence of problem behavior (Lieving, Hagopian, Long, & O’Connor, 2004; Mace et al., 2010; Volkert, Lerman, Call, & Trosclair-Lasserre, 2009; Wacker et al., 2013). During Experiment One, Mace et al. (2010) evaluated the effects of extinction following DRA with children with intellectual and developmental disabilities. The target behaviors in Mace et al. included hair pulling, food stealing, and aggression. The results of this study demonstrated resurgence of the target behaviors during extinction following DRA. Similar findings were reported by Wacker et al. and Volkert, et al. In both studies, functional communication training (FCT) was used to reduce problem behavior maintained by negative reinforcement (i.e., escape). Based on the results of those studies, when FCT was placed on extinction the problem behaviors resurged; at times the magnitude of resurgence exceeded baseline levels (Volkert et al., 2009). In addition to demonstrating resurgence, both Mace et al. and Wacker et al. demonstrated that DRA increases resistance of problem behavior to extinction.

Volkert et al. (2009), Experiment Two, systematically replicated Lieving and Lattal (2003) Experiment Four. During Lieving and Lattal, pigeons where exposed to a thick schedule of DRA and then a thin schedule of DRA. Resurgence occurred for two of the three pigeons during that experiment. As noted by Volkert et al., during clinical applications of FCT, the schedule of reinforcement for the alternative response is thinned to promote response maintenance and generalization. Therefore, the purpose of Experiment Two was to evaluate if resurgence would occur if the schedule of reinforcement for the alternative behavior was thinned. The participants were exposed to
baseline, FCT, and then a thinner schedule of reinforcement for the alternative behavior. The results of the study demonstrated resurgence for all three participants. In addition, the implications of the results suggest that practitioners should carefully adjust reinforcement schedules and monitor for side effects.

Lieving, Hagopian, Long, and O’Connor (2004) demonstrated resurgence of response-class hierarchies. This study evaluated two participants who exhibited response-class hierarchies consisting of various topographies of severe problem behavior. Baseline levels of problem behavior were maintained by access to tangibles for both participants. Then, an alternative topography of severe problem behavior was differentially reinforced. Following differential reinforcement, both topographies were placed on extinction and the initial topography recovered.

These studies have implications for best practices with respect to interventions using differential reinforcement. Future studies should continue researching methods that reduce the probability and the magnitude of resurgence. This potential body of literature can produce behavioral technology that can be used as a protective measure against lapses of treatment integrity.

**Future Research**

Resurgence may occur in numerous contexts in which an alternative behavior is exposed to extinction. These contexts include, but are not limited to: drugs and alcohol, diet and exercise, and academic-based behavior. Furthermore, future studies investigating procedures that reduce the likelihood and magnitude of resurgence will have implications for treatment of problem behavior.
Drugs and alcohol. Animal models regarding relapse of drug-related behavior have not focused on the type of relapse (e.g., renewal, reinstatement, or resurgence). A study by Quick, Pyszczynski, Colston, and Shahan (2011) demonstrated resurgence of lever pressing maintained by access to cocaine. The implication of this study suggested that relapse can occur with humans as a result of extinction of DRA. Instead of the general framework of relapse, future research can specify the type of relapse (e.g., resurgence). Thus, a better understanding of the controlling variables in which behavior relapses could provide rehabilitation clinicians with more effective treatment technology.

Diet and exercise. Resurgence may be an important element of diet and exercise failures. In this context, old eating habits are placed on extinction while alternative eating behavior is reinforced. Then, for an unknown number of reasons, alternative eating behavior is placed on extinction and old behavior resurges. In addition, based on Nevin (1974) and Nevin et al. (1990), the density and value of reinforcement during baseline (i.e., eating behavior prior to a diet) can increase resistance to change. Therefore, the context in which individuals diet may negatively affect the success an individual experiences. Given these considerations, the resurgence effect experienced during extinction of an alternative behavior may be inappropriately attributed to a diet’s failure, rather than a basic principle of behavior. Research exploring diet and exercise is especially important given the rise in obesity rates across America (Glassman, Glassman, & Diehr, 2013).

Reducing the probability of resurgence. Lieving and Lattal (2003), Experiment Three, used non-contingent reinforcement (NCR) as a replacement for the traditional
DRA procedure to investigate whether NCR was sufficient for resurgence. However, the results indicated that NCR was not sufficient to evoke resurgence. Their failure to demonstrate resurgence may be an important procedure for minimizing the unintended impact of DRA and the magnitude of resurgence. Although demonstrating a non-effect of resurgence, future studies should investigate if this is a reliable phenomenon. If so, then it may have important implications for treating problem behavior, especially given the growing concerns for resurgence during lapses of treatment integrity (Lieving et al., 2004; Mace et al., 2010; Volkert et al., 2009; Wacker et al., 2013). Conceptually, NCR might reduce the probability of resurgence due to the greater selection of behaviors in the organism’s reinforcement history. Traditionally, resurgence research has demonstrated that an organism will select between the two discriminated operants that have been previously reinforced during extinction. However, if for example four behaviors are reinforced following baseline using NCR and then extinction is introduced, then the organism has five operants to select from instead of two. The experimental question based on this rationale would be: does increasing the number of behaviors in the organism’s repertoire decrease the likelihood that the original behavior resurges? This experimental question could have implications for applied treatment of problem behavior in which several behaviors are selected for alternative reinforcement. The benefit would be that access to reinforcement is maximized and the probability of resurgence is reduced even if treatment integrity is an issue (Mace et al. 2010). Eventually, the procedure would narrow the parameters for reinforcement to shape a single alternative behavior.
**Academic-based behavior.** Error-correction procedures are a common educational practice (Jenkins & Larson, 1979; Marvin et al., 2010) and function as DRA. If an error initially develops in a student’s repertoire, and a procedure is used to teach the correct or alternative behavior, then during these circumstances error-responding may resurge if newly learned academic behavior contacts extinction. This is problematic because resurgence can hinder acquisition of correct academic behavior (e.g., reading or solving math facts) and interfere with the generalization of a response across settings (i.e., correct responding from a tier-two instructional setting to a tier-one instructional setting).

As an initial step towards investigating the resurgence of error-responding, the study conducted within this document evaluated resurgence of phonetic responding; specifically, consonant-vowel blends that were arbitrarily assigned to Greek letters. This translational study was conducted to determine if academic-based responding can resurge and if the magnitude of resurgence was related to the prior rate of DRA. The implications of this study can be best understood within the context of response to intervention (RTI) in which the instructional tiers can align, conceptually, with the sequence effect used to evoke resurgence.
Chapter 3: Method

Participants

Three general education students who attended kindergarten at an urban school district participated in this study. Young grade-school students were the desired population for this study to avoid any exposure effects older students may have had with the Greek alphabet. Each participant lived in a high-poverty, urban community. Participants were recruited by sending parent consent forms home with the students. The students who returned the consent form and verbally assented to participate in the study were included. Participant 1 was a 6 year-old male student who attended full-day kindergarten. Participant 2 was a 5 year-old female who attended full-day kindergarten. Participant 3 was a 5 year-old male who attended full-day kindergarten. Each student attended separate classrooms.

Setting

The study was conducted in various resource rooms within the urban elementary school. The experimenter and participant sat side-by-side, with the participant always sitting on the right side of the experimenter. The experimenter and each participant were separated by approximating 45 cm. A container used for a token economy was placed approximately 35 cm in front of each participant. Tokens were placed on the table in front of the experimenter. The Greek-letter matrices were placed on the table in front of the
participant. All additional materials used during the experiment were placed on a chair to the left side of the experimenter; thus, out of reach and view of the participants.

Materials

**Greek-letter matrices.** Two independent sets of four Greek letters were randomly arranged on 8.5 in × 11 in colored printer paper (e.g., green, blue, red, and yellow) in a 10×12 matrix. All letters were styled with times new roman and were 32-font. The matrix was centered on the paper with equal margins on all sides. There were three spaces between each letter in each row of the matrix. Each set of Greek letters corresponded to a component of a two component multiple schedule of reinforcement. The colors—green, blue, red, and yellow—functioned as discriminative stimuli for the components of a multiple schedule of reinforcement throughout each condition of the experiment (i.e., baseline reinforcement, differential reinforcement of alternative behavior, and extinction).

**Reinforcers.** Tokens and edibles were used as reinforcers during each schedule component. The tokens consisted of game pieces from Connect Four and were exchanged for food items. The food items included mini M&M’s, Skittles, pretzels, potato chips, dried mango, and banana chips. Preferred edibles were identified using a multiple stimulus without replacement (MSWO) procedure (DeLeon, & Iwata, 1996), which will be described later. Based on the results of the MSWO, the most preferred food item was evaluated using a multi-element design to determine if the preferred item functioned as a reinforcer.

**Timer.** A timer was used to arrange 2-min intervals during each component of the multiple schedule of reinforcement across all conditions. In addition, the timer was used
to arrange a 2-min change-over delay (COD) between the two schedule components. The timer was a standard application of a Samsung Galaxy-5. The screen had a count-down section which displayed hours, minutes, and seconds. Below the count-down section were the numerals 0–9 which were used to set a desired time interval. After the time interval had elapsed, a two-count, pulsating beep occurred which was terminated by a swipe of the experimenters finger across the screen.

**MotivAider.** The MotivAider is a device that can arrange fixed or variable intervals of time. The MotivAider was a small, grey-colored, device approximately 6.5 cm × 6 cm × 1.5 cm. On the front of the MotivAider is a count-down display screen. Below the display screen are two buttons and a slide switch. The buttons are used to select various options including time length, fixed or variable intervals, and vibration strength. The slide switch was used to activate and deactivate the timer. On the back of the MotivAider is a clip that functions so that the device and be secured to a belt or waist-line. The termination of an interval occurred concurrently with a vibration. The interval automatically reset and then counted down. The vibration served as a cue for the experimenter to deliver a token after the first response immediately following the vibration.

During this study, the MotivAider was set for random intervals of 10 s, 20 s, and 30 s. These intervals are not consistent with variable interval (VI) schedules of reinforcement. For example, during a VI 30-s schedule, 30 s is the average interval duration. The durations 10 s, 20 s, and 30 s functioned as the maximum interval (MI) duration of a set of random durations. Therefore, the average interval duration was
calculated. From this point on, a VI schedule will be separated from the MI schedules arranged by the MotivAider.

**Reinforcer Assessment**

**MSWO.** A preference assessment was conducted to discover the most preferred food item for each participant. The items used during the MSWO consisted of two salty items (e.g., potato chips and pretzels), two sweet items (e.g., mini M&Ms and Skittles), and two dried fruit options (e.g., mango and banana chips). Food items were presented in a random, six-item, configuration. Before each selection, participants were asked to select their favorite food item. The selected item was not replaced during the next presentation, thus reducing the array by one item during subsequent displays. This procedure repeated until all six food items were selected. The entire procedure was repeated to verify if the food items selected previously maintained preference (DeLeon, & Iwata, 1996). The MSWO was completed in one to two sessions.

**Multi-element design.** The most preferred food item was evaluated using a multi-element design to determine if the food item functioned as a reinforcer. Participants were asked to see-say numbers 1–10. The numbers were randomly arranged on standard 8.5 in × 11 in white and green paper in a 20×20 matrix. The numbers were styled using a size 14, times new roman font. Participants identified numbers until responding discontinued for 30 s. During baseline, participants were exposed to both the white and green colored paper in an alternating order. No contingencies of reinforcement were arranged for identifying numbers during baseline. The experimenter placed the paper on the table in
front of the participant and said, “Tell me these numbers. You can stop whenever you want.”

Then, a multi-element design was conducted in which a fixed-ratio (FR) 5 schedule of reinforcement was associated with green paper and no reinforcement when white paper was presented. The white and green stimuli were presented in an alternating order. During the FR-5 schedule of reinforcement, a single food item was delivered immediately after a participant’s responding met the contingency requirement. Participants were permitted to eat the food item immediately after delivery. The application of the FR-5 schedule of reinforcement continued until the participant stopped responding for 30 s or if the participant continuously responded for 10 min.

Based on the comparison of baseline and reinforcement conditions, if the number of responses during the schedule of reinforcement was higher in level compared to baseline responding and was visually separated from the responding during extinction, then the food item can be determined to function as a reinforcer. Count was selected because baseline and reinforcement conditions shared these common dimensions. Frequency was not used during this evaluation because eating during the FR-5 schedule of reinforcement interfered with the performance frequency by extending inter-response time, thereby compromising the comparison across conditions.

The multi-element analysis was conducted for approximately one week per participant. No more than two sessions occurred on a given day. A session was defined as completing both elements of the multi-element design.
Token Economy

A token economy was used to reduce the effects of satiation as a potential threat to internal validity during the experiment. Furthermore, tokens helped ameliorate the effects of excessive sugar and caloric intake associated with sweet and salty food items.

After the completion of the multi-element design, tokens were paired with the exchange of food items. The researcher prompted the initial exchange. One token was dropped in a container. Then the researcher stated that the token could be exchanged for one food item. After the prompted exchange, the researcher provided the participant with four more tokens, each independently dropped in the container. Then the researcher stated, “If you want more food items then you have to exchange these tokens.” The participants exchanged a single token for a single food item until all four tokens were exchanged. The tokens were then evaluated under the same conditions as the food item using the same materials. During the evaluation, the experimenter dropped a token in a container after the FR 5 contingency requirement was met. The sound of the token landing in the container signaled to the participant that a token was awarded, thereby avoiding interrupting the participant while he or she was responding. If the level of responding was maintained, then the tokens were considered to function as conditioned reinforcers.

Reinforcement Analysis

Mean MotivAider interval duration. The arithmetic mean was calculated per MI (i.e., 10 s, 20 s, and 30 s) given that the MotivAider did not arrange random time intervals that were conceptually systematic with VI schedules of reinforcement. During
an evaluation separate from the experiment, the MotivAider was set for each MI—10 s, 20 s, and 30 s. A timer was set for 2 min. The timer and MotivAider were activated simultaneously. During the 2-min timing, the experimenter wrote down the random time intervals selected by the MotivAider. The process was repeated two additional times for each of the three time intervals. The mean interval duration was calculated across the three trials, providing a schedule duration more closely approximating a traditional VI schedule of reinforcement.

**Reinforcement density per schedule component.** During the experiment, the number of tokens delivered were counted for all participants for each schedule of reinforcement (i.e., VI 5-s, VI 11-s, and VI 20-s). The reinforcers delivered were counted to provide assurance that the density of reinforcement varied indirectly with the change of the MotivAider interval arrangement—as the interval duration increased, the number of tokens delivered decreased. Using the reinforcer counts, the average number of reinforcers delivered per schedule component was calculated.

**Greek Letters as Error Analog**

Participants were trained to identify Greek letters using an English consonant and a long vowel. Identifying Greek letters was selected as an analog of error responding for two reasons. First, the analog avoided reinforcing actual reading errors. The process of seeing a stimulus (i.e., a grapheme) and saying a consonant and a vowel—known as alphabetic principles—is an essential skill of an effective reading program (NRP, 2000) because establishing alphabetic principle is a strong predictor of later reading achievement (Elliott, Lee, & Tollefson, 2001; Good et al., 2004; Muter & Snowling,
The arbitrary nature of the Greek letters avoided the potential harm (i.e., hindering a participant’s reading achievement) that reinforcing actual reading errors might cause. The second reason for selecting the analog was that identifying Greek letters as a consonant-vowel blend is a similar see-say activity used during alphabetic instruction (e.g., commercial reading programs such as Reading Mastery and Corrective Reading by McGraw Hill SRA), assessment (e.g., nonsense word fluency assessment in the Dynamic Indicators of Basic Early Literacy Skills-Next), and research (Daly et al., 2004; Daly, Johnson, & LeClair, 2009). In sum, the only difference between actual alphabetic responding and the response examined in the current study was the physical shape of the stimulus; instead of /b/ /i/, written as bi, the grapheme would be a Greek letter (e.g., α).

**Accuracy Training of the Original and the Alternative Letter-sounds**

Prior to baseline, the participants were instructed on accurately identifying the letter-sounds. Accuracy training of letter-sounds consisted of two phases. During the first phase, the experimenter presented a single Greek letter on a note card and said the letter-sound, “This is bi.” Then, the experimenter asked the participant to repeat the nonsense name. After 5 s the card was presented again. The experimenter asked, “What sound?” If the participant provided the correct response then the card was presented for two more trials. Each trial was separated by a 5-s inter-trial interval. If the participant responded correctly during three consecutive trials, then the second phase of accuracy training was implemented. If the participant did not respond correctly, then experimenter provided the card and prompted the correct sound by saying the consonant and vowel. Praise was provided for all accurate responses, whether the response was prompted or independent.
The second phase of accuracy training consisted of identifying a row of the Greek letters in which each of four letters was presented twice. A row of Greek-letters was placed on 8.5 in × 11 in white computer paper. The style and font were similar to the Greek-letter matrices—letters were styled with times new roman and were 32-font. If the participant identified all eight letters accurately across two consecutive opportunities, then he/she began the baseline condition of the experiment. If the participant did not correctly identify all letters in the row, then phase one of accuracy training was used for the letters that were not correctly identified.

After stable responding was established during baseline, the participants were taught alternative letter-sounds. The same procedures that were used to teach the original letter-sounds were used to teach the alternative label. Accuracy training for both original and alternative letter-sounds lasted approximately one week each.

**Dependent Variable**

The dependent variables were the frequency of original letter-sounds emitted during extinction following DRA and the magnitude of resurgence represented as a log proportion of baseline. Count per minute of the original letter-sounds, and the alternative letter-sounds was the dependent measure. The original and alternative letter-sounds were counted during all conditions—baseline, differential reinforcement of alternative behavior, and extinction.

**Interobserver Agreement**

A second observer provided interobserver agreement (IOA) for approximately 36% of the total sessions (range, 30% to 40% per condition). A session was defined as
completing both components of the multiple schedule of reinforcement. IOA was calculated using total agreement—the smaller count divided by the larger count \( \times 100 \) for each schedule component. For Participant 1, mean agreement per component was 99% (range, 95% to 100%). For Participant 2, mean agreement per component was 99% (range, 96% to 100%). For Participant 3, mean agreement per component was 99% (range, 95% to 100%). The nature of the disagreements involved the two observers hearing a different consonant-vowel blend.

**Independent Variable**

The independent variables were the relative rates of reinforcement during DRA conditions as well as the sequence effect commonly used to evoke resurgence. During the baseline condition, responding for both sets of Greek letters was reinforced on a two component multiple VI 11-s VI 11-s schedule of reinforcement. Green colored paper for both sets of letters served as the discriminative stimuli during baseline. During the DRA condition, identifying alternative letter-sounds was reinforced on a two component multiple VI 5-s and VI 20-s schedule of reinforcement. During the first test of resurgence the high-density schedule of reinforcement corresponded with red colored paper and Greek letter Set 1 and the low-density schedule of reinforcement corresponded with blue colored paper and Greek letter Set 2. During the second test of resurgence the high-density schedule of reinforcement was associated with the blue paper and Greek letter Set 2 and the low-density schedule of reinforcement was associated with the red paper and Greek letter Set 1. The schedules of reinforcement associated with a set of Greek letters
were switched to control for the development of color and letter-set preferences. During
extinction, both Greek letter sets were arranged on yellow paper.

**Procedural Fidelity**

A second observer collected procedural fidelity data for 36% of the total sessions
(range, 30% to 40% per condition). Procedural fidelity was collected across baseline,
DRA, and extinction. A checklist was used to monitor procedural fidelity. The items on
the checklist included: (a) the correct discriminative stimulus and schedule of
reinforcement was applied for both components of the multiple schedule of
reinforcement, (b) the participant received the correct number of tokens based on his or
her performance and the schedule of reinforcement, (c) the 2:1 token to food item
exchange occurred immediately after completing a schedule component, and (d) no
additional contingencies (e.g., verbal praise, high-fives) were arranged before, during, or
subsequent to responding. A percentage of correctly administered items on the checklist
was calculated by dividing by the total number of correctly administered items by the
total number of items. Procedural fidelity for Participant 1 averaged 98% across all
conditions (range, 75% to 100%). Procedural fidelity for Participant 2 was 100% across
all conditions. Procedural fidelity for Participant 3 averaged 97% across all conditions
(range, 75% to 100%). The participants at times would skip lines and then backtrack to
the point where he or she skipped. At this time there were disagreements between the two
observers regarding the application of a token, thereby contributing to the lower
percentages of procedural fidelity during those sessions. However, the discrepancy
between both observers was never greater than one token.
**Design and Procedures**

A reversal design was implemented to evaluate resurgence of error-responding. There were three conditions—baseline reinforcement of the original letter-sounds, differential reinforcement of alternative letter-sounds, and extinction (Leitenberg, Rawson, & Mulick, 1975; Lieving & Lattal, 2003). The participants experienced each condition in the sequence previously mentioned. Then the participants were exposed to the same three conditions similar to Experiment Two of Lieving and Lattal (2003). Given the combination of the embedded two-component multiple schedule of reinforcement and the repeated exposure of the three experimental conditions, replications could be demonstrated in two ways: the resurgence of both components (i.e., Greek letter Sets 1 and 2) and resurgence across repeated extinction conditions.

**Baseline.** Each participant was provided a green-colored paper containing a matrix of Greek letters. Then, the experimenter said, “Tell me letter-sounds” and immediately activated the count-down timer which was set for 2 min and the MotiAider. A token was dropped in the container immediately after the first correctly identified letter-sound based on a VI 11-s schedule of reinforcement (i.e., MI 20 s). The tokens were then immediately exchanged for food items after the termination of the 2-min time interval. The token-food exchange was a 2:1 ratio—two tokens were exchanged for one food item.

**DRA.** Following the baseline condition, alternative letter-sounds were instructed using the aforementioned accuracy training procedures. During the DRA, the experimenter placed a matrix of Greek letters in front of the participant and said, “Tell me
letter sounds” and immediately activated the count-down timer set for 2 min and the MotiAider. During the first DRA condition, Greek letter Set 1 was on red-colored paper and associated with the VI 5-s schedule of reinforcement (i.e., MI 10 s). Greek letter Set 2 was on blue-colored paper and associated with the VI 20-s schedule of reinforcement (i.e., MI 30 s). During the second exposure to DRA, the VI 5-s schedule of reinforcement was associated with Set 2 and the VI 20-s schedule of reinforcement was associated with Set 1. While saying letter-sounds, a token was dropped in the container immediately after the first correctly identified letter-sound based on the respective schedules of reinforcement. The tokens were then immediately exchanged for food items after the termination of the 2-min time interval. The token-food exchange was a 2:1 ratio—two tokens were exchanged for one food item.

**Extinction.** Extinction of both the original and alternative letter-sounds occurred after the DRA. Extinction was introduced after the original letter-sound responding was at zero for at least two sessions; similar to Podlesnik and Shahan (2009)—the authors introduced extinction when responding was below 10% of baseline. During the extinction condition, the experimenter handed the participants yellow-colored paper and set the timer for 2 min. The experimenter said, “Tell me letter sounds,” and then activated the timer. No contingencies of reinforcement were arranged for responding during this condition.

**Social Validity**

Applied behavior analysis solves problems and selects target behaviors based on the socially meaningful impact of the behavior change. Currently, little is known
regarding the extent to which academic-based resurgence occurs in a school environment in addition to the extent to which educators identify resurgence as a problem. As a guide for future applied research, an eight-item survey was developed to: (a) ascertain teacher-perception of error-responding with respect to student-performance, (b) evaluate the extent to which teachers provide error-correction, (c) evaluate if error-responding continued in spite of using error-correction and if so, (d) how problematic did educators rate continued error-responding. The survey was given to 20 urban, pre-kindergarten through sixth grade, elementary school teachers. Of those who received the survey, four teachers completed the survey—two regular educators teachers and two special educators. Of the regular educators, one was male and the other female. The male teacher taught first grade and the female teacher taught second grade. Both regular educators taught reading. Both special educators were female. One teacher provided remedial reading and math instruction for students in second and third grade and the other special educator provided remedial reading and math instruction for students in fourth through sixth grade. The social validity survey can be found in Appendix A.
Chapter 4: Results

Reinforcer Assessment

MSWO. After four exposures to the MSWO, a pretzel was determined to be the most preferred food item for Participant 1. After five exposures to the MSWO, a dried mango was determined to be the most preferred food item for Participant 2. After three exposures to the MSWO, pretzel was determined to be the most preferred food item for Participant 3.

Multi-element design. The results of the multi-element design in which a fixed ratio (FR)-5 schedule of reinforcement was introduced after baseline and alternated with a no reinforcement condition are displayed in Figures 1–3. The unit of responding was saying numbers correct (NC). Figure 1 displays the results of Participant 1. During baseline, responding was stable with no trend and little variability ($M = 59$ NC; range, 58 to 60 NC). However, when the FR-5 schedule of reinforcement was introduced responding increased with respect to level and trend ($M = 82.6$ NC; range, 80 to 85 NC). Responding during the no reinforcement condition decreased with respect to level and trend; thus showing visual separation from the FR-5 schedule of reinforcement condition ($M = 35$ NC; range, 30 to 40 NC). The final datum displays the results of token economy. Tokens were provided based on a FR-5 arrangement. The datum shows that responding in the presence of tokens remained at the same level as the FR-5 schedule of reinforcement.
condition. Based on these results, the pretzel and the token were determined to be reinforcers for see-say responding. Figure 1 is displayed below.

![Graph](image)

**Figure 1.** See-say numbers correctly across baseline, reinforcement, and no reinforcement conditions for Participant 1.

Figure 2 displays the results of Participant 2. During baseline, responding showed a slight decreasing trend and some variability ($M = 70.5$ NC; range, 58 to 104 NC). However, when the FR-5 schedule of reinforcement was introduced responding increased with respect to level and trend ($M = 133.6$ NC; range, 108 to 153 NC). Responding during the no reinforcement condition decreased with respect to level and trend; thus showing visual separation from the FR-5 schedule of reinforcement condition ($M = 32$ NC; range, 17 to 60 NC). The final datum displays the results of token economy. Tokens were provided based on a FR-5 arrangement. The datum shows that responding in the presence of tokens remained at the same level as the FR-5 schedule of reinforcement.
condition. Based on these results, the mango and the token were determined to be reinforcers for see-say responding. Figure 2 is displayed below.

Figure 2. See-say numbers correctly across baseline, reinforcement, and no reinforcement conditions for Participant 2.

Figure 3 displays the results of Participant 3. During baseline, the responding was stable with no trend and some variability ($M = 30.5$ NC; range, 24 to 36 NC). However, when the FR-5 schedule of reinforcement was introduced responding increased with respect to level ($M = 41.6$ NC; range, 40 to 44 NC). Responding during the no reinforcement condition decreased with respect to level and trend; thus showing visual separation from the FR-5 schedule of reinforcement condition ($M = 16.3$ NC; range, 13 to 19 NC). The final datum displays the results of token economy. Tokens were provided based on a FR-5 arrangement. The datum shows that responding in the presence of tokens remained at the same level as the FR-5 schedule of reinforcement condition. Based on
these results, the pretzel and the token were determined to have reinforcing properties for see-say responding. Figure 3 is displayed below.

![Graph showing see-say numbers correctly across baseline, reinforcement, and no reinforcement conditions for Participant 3.](image)

Figure 3. See-say numbers correctly across baseline, reinforcement, and no reinforcement conditions for Participant 3.

**Reinforcement Analysis**

**Mean MotivAider interval duration.** When setting a random time interval, the MotivAider arranged the maximum interval (MI) duration. Therefore, the mean interval duration was calculated in order to calibrate conceptually systematic variable interval (VI) schedules of reinforcement. The MotivAider was set for each of the three arrangements of the experiment—10 s, 20 s, and 30 s. The random interval durations were written down during a 2-min timing, three times each. The mean interval duration, in seconds, was calculated by adding each value and dividing the sum by the total number of intervals. The results of calibrating VI schedules are displayed in Figure 4. When the
MotivAider was set to arrange a random MI of 10 s, the mean interval duration was 4.83 s; approximating a VI 5-s schedule of reinforcement. When the MotivAider was set to arrange a random MI of 20 s, the mean interval duration was 11.19 s; approximating a VI 11-s schedule of reinforcement. When the MotivAider was set to arrange a random MI of 30 s, the mean interval duration was 20.21 s; approximating a VI 20-s schedule of reinforcement.

Figure 4. The mean interval duration, in seconds, for each time arrangement of the MotivAider.

**Reinforcement density per schedule component.** The mean number of tokens earned during each VI schedule of reinforcement was calculated. During the token exchange, the experimenter tracked the number of tokens earned for the purposes of procedural fidelity, but also, given the relatively small degree of separation between the mean interval durations, it was important to ensure that the number of tokens earned
varied inversely with the VI schedule—the number of tokens earned decreased as the VI schedule of reinforcement increased. The data from each participant across all conditions were aggregated in which the mean tokens earned per schedule of reinforcement was derived. The results of this calculation are displayed in Figure 5. The mean number of tokens earned during VI schedules 5 s, 11 s, and 20 s were 16.2, 8, and 4, respectively.

![Figure 5. The mean number of tokens earned per schedule of reinforcement.](image)

**Reversal Design**

Displayed in Figures 6–8 are the results of the experiment. Each figure shows the two-component multiple schedule of reinforcement (i.e., Greek letter sets one and two) arranged for both the original and alternative letter-sounds. Differential reinforcement of alternative behavior was arranged on a multiple VI 5-s VI 20-s schedules of reinforcement which are labeled as such on each graph for the alternative letter-sounds—solid black dots corresponded with the VI 5-s schedule of reinforcement and open diamonds corresponded with the VI 20-s schedule reinforcement. The marker shapes for
the original letter-sounds remained consistent—the high-density schedule of DRA is represented by solid black dots and the low-density schedule of DRA is represented by open diamonds. The horizontal dashed-line represents 1 response during the 2-min time floor. Data below the floor functioned as a place-holder indicating zero responses emitted.

**Participant 1.** The tests of resurgence are displayed in the graph labeled original letter-sounds and occurred in the second and fourth extinction conditions. Extinction is abbreviated on both graphs as Ext and multiple is abbreviated as Mult, when necessary. The resurgence of the original letter-sounds was not reliably demonstrated for Participant 1. The original letter-sounds did resurge during the first test of resurgence (i.e., the second extinction condition), but for only one of the two schedule components. However, resurgence for both sets of Greek letters was demonstrated during the second test of resurgence (i.e., the fourth extinction condition). The data for Participant 1 are displayed in Figure 6.
Figure 6. Count per minute of see-say original and alternative letter-sounds for Participant 1. Greek letter Set 1 was associated with the VI 5-s schedule of reinforcement during the first three conditions and then associated with the VI 20-s schedule of reinforcement during the following three conditions. Greek letter Set 2 was associated with the VI 20-s schedule of reinforcement during the first three conditions and then associated with the VI 5-s schedule of reinforcement during the following three conditions. Ext is an abbreviated label for extinction and Mult is an abbreviated label for multiple.
Participant 2. The tests of resurgence are displayed in the graph labeled original letter-sounds and occurred in the second and fourth extinction conditions. Extinction is abbreviated on both graphs as Ext and multiple is abbreviated as Mult, when necessary. The resurgence of the original letter-sounds was reliably demonstrated for Participant 2. The original letter-sounds resurged during the first and second tests of resurgence (i.e., the second and fourth extinction conditions) for both sets of Greek letters. The data for Participant 2 are displayed in Figure 7.
Figure 7. Count per minute of see-say original and alternative letter-sounds for Participant 2. Greek letter Set 1 was associated with the VI 5-s schedule of reinforcement during the first three conditions and then associated with the VI 20-s schedule of reinforcement during the following three conditions. Greek letter Set 2 was associated with the VI 20-s schedule of reinforcement during the first three conditions and then associated with the VI 5-s schedule of reinforcement during the following three conditions. Ext is an abbreviated label for extinction and Mult is an abbreviated label for multiple.
**Participant 3.** The tests of resurgence are displayed in the graph labeled original letter-sounds and occurred in the second and fourth extinction conditions. Extinction is abbreviated on both graphs as Ext and multiple is abbreviated as Mult, when necessary. The resurgence of the original letter-sounds was reliably demonstrated for Participant 3. The original letter-sounds resurged during the first and second tests of resurgence (i.e., the second and fourth extinction conditions) for both sets of Greek letters. The data for Participant 3 are displayed in Figure 8.
Figure 8. Count per minute of see-say original and alternative letter-sounds for Participant 3. Greek letter Set 1 was associated with the VI 5-s schedule of reinforcement during the first three conditions and then associated with the VI 20-s schedule of reinforcement during the following three conditions. Greek letter Set 2 was associated with the VI 20-s schedule of reinforcement during the first three conditions and then associated with the VI 5-s schedule of reinforcement during the following three conditions. Ext is an abbreviated label for extinction and Mult is an abbreviated label for multiple.
Log Proportion of Baseline: Magnitude of Resurgence

The log proportion of baseline frequency was calculated to determine if any systematic relations existed between the rate of DRA and the subsequent magnitude of resurgence during extinction. The mean frequency of responding for each component of the two-component VI 11-s VI 11-s schedules of reinforcement for the original letter-sounds was calculated. The mean frequency of responding was used in the denominator of the equation: \( \log(\text{FR}/\text{FB}) \); where the logarithm base 10 of the quotient of FR, the response frequency during the test of resurgence, divided by FB, the mean response frequency during baseline, was calculated. The results of these calculations are displayed in Figures 9–11. The graphs for each participant show the results of the first and second baseline to resurgence calculations, which are separated by a solid vertical line. In some cases, the log proportion of baseline could not be calculated due to zero responses emitted during the resurgence test. Zero responses emitted yielded the equation: \( \log(0/\text{FB}) \), which is an undefined value. Therefore, all undefined values were assigned a value below \( \log(0.5/\text{FB}) \)—0.5 refers to 1 response emitted during a 2-min timing. The assigned value for zero was –2. The labels remained consistent with Figures 6–8 in which the VI 5-s schedule of reinforcement corresponds with solid black dots and the VI 20-s schedule of reinforcement corresponds with open diamonds.

Participant 1. The low-density DRA (i.e., VI 20 s) resurged at a greater magnitude compared to the magnitude of resurgence of the high-density DRA (i.e., VI 5 s) during the first test of resurgence. However, during the second test of resurgence, the Greek letters associated with the high-density DRA resurged at a greater magnitude.
compared to the Greek letters associated with the low-density DRA. The results for Participant 1 are displayed in Figure 9.

![Graph showing log proportions of baseline frequency demonstrating the magnitude of resurgence in relation to the previous rate of DRA for Participant 1.](image)

**Participant 2.** During both tests of resurgence, the Greek letters associated with the high-density DRA resurged at a greater magnitude compared to the Greek letters associated with the low-density DRA. The difference of magnitude was slightly greater for the letter-sounds associated with the high-density DRA during the first test of resurgence. However, during the second test of resurgence, the difference of magnitude between the high- and low-density DRAs was large. The results for Participant 2 are displayed in Figure 10.
Participant 3. During both tests of resurgence, the Greek letters associated with the high-density DRA resurged at a greater magnitude compared to the Greek letters associated with the low-density DRA. The difference of magnitude between the letters associated with the high-density and low-density schedules of reinforcement were relatively equal across both tests of resurgence. The results for Participant 3 are displayed in Figure 11.
Figure 11. The log proportions of baseline frequency demonstrating the magnitude of resurgence in relation to the previous rate of DRA for Participant 3.

### Standard Celeration Charts

The Standard Celeration Chart (SCC) is based on standard units of time, which can be expressed as successive calendar days, weeks, months or years. Each SCC has a six-cycle, base 10, logarithmic scale along the y-axis and includes standard slopes for measuring acceleration and deceleration (Pennypacker, Gutierrez, & Lindsley, 2003). The chart utilized for analysis in this study was a Microsoft Excel approximation of the Daily per minute Chart™ (Dpmin-12EC).

Displayed on each SCC is the counting time floor represented by an underscore and the frequency of see-say original letter-sounds for both components of a two-component multiple schedule of reinforcement. The high-density DRA is represented by a black dots and the low-density DRA is represented by X’s. The SCC can be found in Appendix C of this document.
Social Validity

The results of the social validity survey demonstrated that teachers were concerned with academic error-responding. When asked to rate how problematic reading or math errors were with respect to student performance, three teachers replied errors were problematic and one teacher replied that errors would have severe long-term consequences. The next question asked if teachers corrected errors during instruction. All four teachers replied that errors are corrected to the greatest extent possible; but not every error is corrected. In spite of their attempts to correct error-responding all four teacher replied that students continue to make some errors. One teacher replied that continued error responding was problematic and three teachers replied that continued error responding was very problematic. All four teachers said that procedures eliminating error-responding would be valuable procedures. Refer to Appendix A for the Social Validity Survey.
Chapter 5: Discussion

The purpose of this study was to evaluate whether resurgence of academic-based responding was possible and if the magnitude of resurgence was systematically related to the rate of differential reinforcement of alternative behavior (DRA). With the exception of one component of a two-component multiple schedule of reinforcement for Participant 1, resurgence was reliably demonstrated within and across participants. The demonstration of resurgence in this study was consistent with other basic and translational demonstrations of resurgence (Bruzek, Thompson, & Peters, 2009; Epstein 1983; Epstein & Skinner, 1980; Leitenberg, Rawson, & Mulick, 1975; Lieving & Lattal, 2003; Podlesnik & Shahan, 2009; Rawson, Leitenberg, Mulick, & Lefebvre, 1977; Sweeney & Shahan, 2013).

Lieving and Lattal (2003), Experiment Two, examined whether resurgence was repeatable with a second exposure to the resurgence test. Based on their finding, resurgence was repeatable across subsequent tests of resurgence. Furthermore, Lieving and Lattal found that the effects of resurgence did not diminish during the second resurgence test. With respect to the results of this current study, resurgence was repeatable within participants—Figures 6–8 demonstrated repeated resurgence within and across participants. In addition, the magnitude of resurgence did not diminish during the second resurgence test. At times, the magnitude of resurgence was greater during the second test of resurgence compared to the first test (see Figures 9–11). The height or level
of the data with respect to the y-axis of Figures 9–11 demonstrated the magnitude of resurgence of the original letter-sounds. Visual analysis of the data did not suggest systematic decreases of level during the second resurgence test.

Leitenberg, Rawson, and Mulick (1975), Experiment Three, evaluated the effects of a high-density DRA—variable interval (VI) 30-s schedule of reinforcement—and a low-density DRA—VI 4-min schedule of reinforcement—on the subsequence level of resurgence. Although not expressed as log proportions of baseline responding, Leitenberg, Rawson, and Mulick concluded that resurgence was greater for the group of pigeons that received the high-density schedule of DRA. With respect to the results of this study, there is evidence to suggest that the density of DRA has a direct relation with the magnitude of resurgence—the greater the density of DRA the greater the magnitude of resurgence. Of the six tests of resurgence (see Figures 9–11) four log proportion of baseline comparisons clearly demonstrated that the high-density DRA resurged at a greater magnitude compared to the low-density DRA, one log proportion of baseline comparison demonstrated a slightly greater magnitude for the high-density DRA (see Participant 2; Figure 10), and one log proportion of baseline comparison demonstrated a greater magnitude of resurgence for the low-density DRA (see Participant 1; Figure 9).

Behavioral momentum theory (BMT) provides a potential explanation as to why the density of DRA directly corresponded with the magnitude of resurgence. Nevin, Tota, Torquato, and Shell (1990) and Podlesnik and Shahan (2009) demonstrated that resistance to change is a function of the context-reinforcer relation. Although the color of the paper changed when the alternative letter-sounds were reinforced, the letter shapes
remained the same providing a consistent context across reinforcement schedules for both original and alternative letter-sounds. The letters shapes (i.e., graphemes) associated with the most reinforcers throughout the total sequence effect resurged at a greater magnitude. However, beyond the controlled variation of DRA in this study, other basic mechanisms that could have contributed to the magnitude of resurgence were not evaluated. For example, there was no systematic analysis of the frequency of responding (da Silva, Maxwell, & Lattal, 2007; Reed & Morgan, 2007), baseline density of reinforcement (Podlesnik & Shahan, 2009), or the length of the behavioral history (Bruzek, Thompson, & Peters, 2009)—all of which have been shown to relate to the magnitude of resurgence.

**Social Validity**

The goals of the survey were to (a) evaluate teacher opinion regarding student error-responding, (b) evaluate the extent to which teachers provide error-correction, (c) evaluate if error-responding continued in spite of using error-correction, and if so, (d) how problematic did teachers rate continued error-responding. Although limited, the results of the survey suggested that teachers in a low performing school are concerned with error-responding. Furthermore, in spite of experiencing correction procedures, students continued to emit errors. There are a number of reasons as to why students continue to emit errors—there are reinforcers available that maintain the response, the correction procedures were not implemented with fidelity, or resurgence could have been evoked. Given the immediate intended effects of error-correction procedures—a deceleration of the error-response—the negative consequences of the environmental arrangement (i.e., students cycling across tiers of instruction) may be occurring
undetected by educators. Future research is needed to understand failures of error-correction procedures and ultimately, generalization failures in order to understand the controlling variables that foster error-responding in a student’s repertoire.

**Implications: Response to Intervention**

The purpose of this translational study was to evaluate if phonetic responding could resurge given the following sequence effect: (a) baseline reinforcement of an original behavior, (b) DRA, and then (c) extinction of both original and alternative behaviors. The sequence previously mentioned could be experienced during response to intervention (RTI) (Fuchs & Fuchs, 2006), in which a student is exposed to alternating tiers of instruction; each tier providing separate contingencies for responding. Hypothetically, decoding errors or reading words incorrectly could be unintentionally reinforced while a struggling reader is exposed to tier one instruction. This situation is analogous to baseline reinforcement of an original behavior. Upon assessment, the struggling reader is identified as needing remedial, tier two or three, services. During tier two or three instruction, the student experiences error-correction procedures, which function as DRA. Tier two or three instruction is analogous to the DRA phase of the sequence effect. If the contingencies arranged during tier two or three instruction (i.e., DRA) are not found in the tier one environment, then error-responding could relapse. The type of relapse depends on the contingencies of the tier one environment when the student cycles back into that setting. If the tier one setting does not support the skill level a student needs in order to achieve reading success, then essentially the skills taught during tier two or three instruction are placed on extinction, therefore evoking
resurgence. This situation is analogous to the final phase of the sequence effect in which both behaviors are placed on extinction. However, if the tier one setting supports some, but not all of the tier two or three contingencies then errors could still relapse; this type of relapse is called renewal. For example, if extinction of error-responding occurs in a context different than the tier-one environment even though tier-one discriminative stimuli remain in effect, then error responding would relapse (i.e., renewal).

The arrangement of contingencies given the scenario previously mentioned is complex. Conceptually, the combination of correct and incorrect responding within a larger cycle of inconsistent contingencies (e.g., tier one and two instruction) creates two concurrent schedules of reinforcement embedded within a larger multiple schedule of reinforcement. The concurrent schedules of reinforcement are embedded within each instructional tier and are arranged by the contingencies of reinforcement for correct and incorrect responding. The multiple-schedule is arranged as a student cycles between tier one and two instruction, for example. This complex arrangement could have some socially meaningful benefits. For example, the DRA experienced during tier-two instruction could successfully decelerate reading errors. At the same time, however, this complex arrangement could perpetuate the need for tier two or three services if errors continuously relapse in the tier one setting, or in settings outside of the tier two or three setting (e.g., during assessment). The relapse of error-responding does not support the generalization of correct responding across environments; thus, adding further concern and need for research regarding the unintentional relapse of error-responding in applied settings.
The implications of resurgence extend beyond error-responding. Students with communication and social behavior deficits may acquire inappropriate behaviors within one setting (e.g., the tier one setting, or natural environment), and then an alternative form of communication is learned in another setting (e.g., tiers two or three). The transition back into the original context could evoke the relapse of the original behavior. Procedures that minimize the probability and magnitude of relapse are especially important research for maximizing the probability that behaviors generalize across settings.

**Limitations**

The limitations of this study included a failure to demonstrate resurgence for one of the components of a two-component multiple schedule of reinforcement, omitted reinforcers, superimposed schedules of reinforcement, participant assessment of color blindness and academic performance, and social validity. Each limitation is addressed in the following sections.

**Failure to demonstrate resurgence.** There were 12 opportunities to demonstrate resurgence—two components per six tests of resurgence. Of the 12 opportunities, resurgence was demonstrated 11 times. Figure 6 displays the results of the experiment for Participant 1. As displayed on the graph for the original letter-sounds, one of the components of the two-component schedule of reinforcement did not surge during extinction. The failure to demonstrate resurgence weakened reliability of the results with respect to demonstrating resurgence within participants and the magnitude of resurgence in relation to the rate of DRA.
There are two possible explanations for why resurgence was not demonstrated during one of the components for Participant 1. The first explanation is the more parsimonious of the two and involves the lack of attention and rule-governed behavior. Participant 1 may not have attended to the change of both the discriminative stimuli and the contingency arrangement during extinction. The lack of attention might have indicated that the behavior of Participant 1 was rule-governed by the instructions of the experimenter. During extinction, the experimenter said, “Tell me letter-sounds.” If the participant was not attending to the change of color and contingencies and identified the alternative letter-sounds based on his previous response-history, then this could have contributed to the resurgence failure.

The second explanation for the failure of resurgence could be BMT. Classic behavior momentum research has demonstrated that, following disruption (e.g., extinction), high-density schedules of reinforcement show greater resistance to change compared to low-density schedules of reinforcement (Nevin, 1974; Nevin, Mandell, & Atak, 1983; Nevin Tota, Torquato, & Shell, 1990). The final extinction condition could have functioned as a disruptor for the alternative letter-sounds. Further analysis of those data, expressed as log proportion of baseline responding, demonstrated a similar finding regarding resistance to change following extinction found in basic research (Nevin Mandell, & Atak, 1983). Based on this finding, the reinforcement history associated with the alternative letter-sounds could have generated resistance, thereby inhibiting resurgence of the original letter-sounds for the high-density DRA component.
**Omitted reinforcers.** At times, inter-response time (IRT) was longer in duration compared to the interval arranged by the MotiAider. Therefore, some opportunities to earn a reinforcer were missed. This occurred much more noticeably during the variable interval (VI) 5-s schedule of reinforcement when some of the intervals arranged by the MotiAider were 1–2 s. Although, the reinforcer analysis provided in Figure 5 demonstrated clear changes of reinforcement densities between the VI schedules, the data are somewhat of an artifact of earned and omitted reinforcers.

**Superimposed schedules of reinforcement.** Although the data in Figures 1–3 demonstrated that the food items functioned as reinforcers for see-say responding, the data for the token is not as reliable. The token and the food should have been alternated to demonstrate reliability of the level of responding for both items. In addition, the introduction of these contingencies (i.e., using food as a consequence for academic-based responding) is not natural in educational settings. Typically, verbal praise is used during academic responding. However, food items were selected in order to be conceptually systematic with basic research. Future research should investigate resurgence using verbal praise instead of food items. However, it will be important to demonstrate that praise functions as a reinforcer for responding prior to conducting the experiment.

**Participant assessments.** There is missing information with respect to the participants which includes color blindness and academic performance. The participants were not assessed prior to the study for color blindness. If a participant was color blind then he or she could not have discriminated the colors associated with the sets of Greek letters, thereby creating mixed schedules of reinforcement instead of the intended
arrangement of multiple schedules of reinforcement. In addition, participants’ academic performance was not assessed (e.g., oral reading fluency). Systematic performance deficits could have been correlated with certain dynamics of responding. For example, the behavior of the participants with the greatest fluency deficits could have been more susceptible to resurgence compared participants who meet or exceed benchmark standards.

Social validity. There are three limitations with respect to social validity which include confidentiality, low number of respondents, and the lack of social validity data regarding the participants. After completing the social validity survey, the teachers were instructed to place the survey back into their mailbox. These instructions did not keep responses confidential. A folder should have been kept in the office where completed surveys could be returned.

The descriptive data obtained from the social validity survey must be interpreted with caution given the low number of respondents. The data obtained from the survey do not reflect the totality of teachers’ values and experiences, especially teachers from different schools, communities comprised of a different socio-economic status, different grades, and teachers who use different curricula or have a different pedagogy.

The experiences of the participants were not assessed. This information could have been useful for understanding the perception of the participants during the changing contingencies. Future translational and applied research should address the experiences of the participants in order to develop practical procedures that students will value, especially procedures that minimize the probability and magnitude of resurgence.
Future Research

There are numerous research opportunities with respect to relapse and resurgence, which include, but are not limited to: further translations of resurgence with other types of reading errors, math-related errors, and applied research.

Reading words incorrectly is not the only type of reading error. Readers can skip lines, insert words, or omit words during an oral reading task. Each of these types of errors could negatively impact reading comprehension. If these reading errors develop in the tier one instructional setting and are remediated during tier two or three instruction, then these errors could potentially relapse in the tier one setting. Future research can investigate whether other reading errors resurge. In addition, computational errors (e.g., incorrect addition or subtraction) could be researched with respect to relapse. The same concerns with cycling between instructional environments for reading apply for math-related errors as well.

Applied research should investigate resurgence within the context of RTI. From a research methodology perspective, the natural environment provides a strong design. For example, behavior measured continuously across the tier one and tier two settings provide multiple comparisons similar to a reversal design in which reliability can be established. However, there are concerns with this research regarding experimental control of certain variables, such as: schedules of reinforcement, reinforcement of error-responding, and extinction. For example, if applied research is conducted within a public school, is it ethical for an experimenter to arrange for reinforcement of error-responding, even for a brief period of time? However, if the researcher allows the natural
environment to conduct business as usual (i.e., the teacher incidentally reinforcer errors during instruction) then experimental control over the schedule of reinforcement may be reduced. However, even with the loss of experimental control if the data suggest errors maintaining in the tier one setting in spite of correction procedures in the tier two or three setting, then resurgence can still be concluded; especially in combination with translational studies like this. Together, translations and applied research of resurgence have the potential to enhance educational practices further by providing optimal environmental arrangements that maximize success by minimizing the negative, unintentional, consequences.
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APPENDIX A: SOCIAL VALIDITY SURVEY
Social Validity Survey

Please take a moment to fill out the information below. Do not put your name on this document. The purpose of this questionnaire is to understand your experiences with students who engage in error-responding, for example reading words or solving math facts incorrectly. Completing this survey is voluntary; however, if you choose to complete the survey then please return the completed survey in your mailbox in the office. Thank you.

- Circle one of the following: Currently, I am a regular – special educator.

- Circle all that apply: Currently, I teach the following academic content – math, reading, science, history.

- Please fill in the blank: Currently, I teach _______________ grade(s).

- Please rate the extent to which errors are problematic based on the following statement by circling the number that corresponds with your values: Reading and math errors for students are...
  1. Not at all an issue
  2. Somewhat problematic
  3. Problematic
  4. Have severe long term consequences on future academic performance

- Please circle the answer the best corresponds with your instructional pedagogy: During instruction, I typically…
  1. Do not correct errors
  2. Sometimes correct errors
  3. Correct errors to the greatest extent possible, but not all errors
  4. Correct every error

- Circle the answer that best corresponds with your experiences: Given my attempts to correct errors, students…
  1. Continue to make the same errors without much change
  2. Continue to make some errors
  3. Do not make many errors afterwards

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• If you circled 1 or 2 on the previous question, then please answer the following question based on your experiences: To what extent is continued error-responding, whether math or reading, a problem in your classroom?
   1. No problem
   2. A slight problem
   3. Problematic
   4. Very problematic

• Circle the number that best corresponds with your pedagogy. How valuable would you rate procedures that eliminated error-responding?
   1. Not valuable
   2. Somewhat valuable
   3. Valuable
   4. Greatly valuable

Thank you for your time and effort. Please place the completed survey back into your mailbox in the office.
APPENDIX B: GREEK LETTER MATRICES
\[ \alpha \beta \gamma \delta \gamma \beta \alpha \delta \alpha \delta \]
\[ \gamma \alpha \gamma \beta \alpha \beta \delta \gamma \beta \alpha \]
\[ \delta \gamma \beta \alpha \delta \delta \gamma \alpha \gamma \delta \]
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APPENDIX C: STANDARD CELERATION CHARTS
Participant 1; Male
Kindergarten; 5-years-old
See-say Original Letter-sounds
HD DRA = Soid Dots
LD DRA = Xs
Participant 2, Female
Kindergarten, 5-years-old
See-say Original Letter-sounds
HD DRA = Solid Dots
LD DRA = Xs
Multiple VI 11-s, VI 11-s Schedule of Reinforcement

Ext Ext Ext Ext

Mlt VI 11s VI 11s Extinction

0.001 0.005 0.01 0.1 1 10 100 1000

0.001 0.005 0.01 0.1 1 10 100 1000

COUNT PER MINUTE

SUCCESSIVE CALENDAR DAYS

COUNTING TIMES

0 7 14 21 28 35 42 49 56 63 70 77 84 91 98 105 112 119 126 133 140

Participants 3, Male
Kindergarten, 5-years-old
See-say Original Letter-sounds
HD DRA = Solid dots
LD DRA = Xs