The Effects of Schedule Density of Reinforcement for Alternative Behavior on Resurgence

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THE EFFECTS OF SCHEDULE DENSITY OF REINFORCEMENT FOR ALTERNATIVE BEHAVIOR ON RESURGENCE

by

Kathryn M. Kestner

A dissertation submitted to the Graduate College in partial fulfillment of the requirements for the degree of Doctor of Philosophy
Psychology
Western Michigan University
June 2015

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THE EFFECTS OF SCHEDULE DENSITY OF REINFORCEMENT FOR ALTERNATIVE BEHAVIOR ON RESURGENCE

Kathryn Marie Kestner, Ph.D.
Western Michigan University, 2015

Resurgence is the reemergence of a previously extinguished response when an alternative response no longer produces reinforcement. Although returning to previously successful methods for obtaining reinforcement is likely advantageous, resurgence also occurs in the form of treatment relapse. An individual may return to problematic behavior (e.g., aggression, self-injury, drug use) when an alternative behavior (e.g., communication response, coping skill, social behavior, etc.) is no longer successful at producing a reinforcer. Behavior analysts rely on treatments based on differential reinforcement of alternative behavior, and resurgence has been demonstrated following changes to reinforcement schedules due to errors in treatment integrity or intentional fading of the schedule, which is often recommended for the ease of treatment delivery. Identifying effective behavior-change methods that also reduce the potential for treatment relapse would contribute to the social utility of these interventions. Research with nonhuman animals suggests that the arrangement of alternative reinforcement affects the degree of resurgence obtained during an extinction test. Little research has been done on this question with humans. Experiment 1 compared three different alternative reinforcement schedules to determine the effects on resurgence (RI 5 s, RI 30 s, or RI 60
s). Experiment 2 assessed the effects of the addition of an aversive auditory stimulus with
two different groups of alternative reinforcement density (RI 5 s or RI 60 s).
I would like to thank my mentor and dissertation chair, Dr. Stephanie Peterson, for her support throughout my time as a doctoral student. It has been a pleasure working with my committee members Dr. Alan Poling, Dr. Cindy Pietras, and Dr. Claire St. Peter. I have greatly appreciated their feedback on my data analysis, manuscript, and the oral presentations. I would like to thank Dr. Claire St. Peter for generously sharing her human operant software and providing consultation on procedures based on her experience running research in this area. Thank you to Dr. Stephanie Peterson for helping me to secure a computer and workspace for this study to take place. The frequent cheerleading from my lab mates and friends was invaluable to surviving the dissertation process (especially Becky Kolb, Katie Suszek, Daniel Maitland, and Adam Bennett). Thanks to my parents for tolerating my move to the Midwest to pursue my graduate career and for raising me to value education. Lastly, thank you to Joe Shane for his endless encouragement and patience; I hope I can show him as much support through his dissertation process.

Kathryn M. Kestner
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THE EFFECTS OF SCHEDULE DENSITY OF REINFORCEMENT FOR ALTERNATIVE BEHAVIOR ON RESURGENCE

The term resurgence refers to a phenomenon of behavioral relapse, in which a previously reinforced behavior reemerges when an alternative source of reinforcement is introduced and then removed (Epstein & Skinner, 1980). In a simple resurgence arrangement, a particular behavior (B₁) has a history of producing reinforcement. Next, B₁ is extinguished and reinforcement is subsequently produced by alternative behavior (B₂). Resurgence is tested in a third phase in which neither B₁ nor B₂ result in reinforcement. If an increase in B₁ responding is observed, resurgence is said to have occurred. For example, a rat may earn food pellets on a VI 30-s schedule contingent on responses on a lever (B₁). During the second phase, there are no programmed consequences on the B₁ lever-press, and a nose-poke (B₂) response is reinforced on a VI 30 s. During a third phase, both the B₁ lever-press and B₂ nose-poke are on extinction, and resurgence is demonstrated if the rat engages in increased responding on the B₁ lever (Epstein, 1983). In an applied example, a child may engage in aggression maintained by attention. A differential reinforcement of alternative behavior (DRA) procedure could be implemented in which attention is no longer delivered following aggression, and a communication response is taught and reinforced with attention. Resurgence of aggressive behavior may occur if the communication response is no longer reinforced (e.g., a lapse in treatment in treatment integrity).

Although an organism’s propensity toward resurgence is likely adaptive under
many circumstances, some instances of resurgence may be considered problematic. In general terms, it is likely beneficial for an organism to return to old sources of reinforcement when more recent sources no longer produce reinforcement. Whether a particular instance of resurgence is viewed as adaptive or maladaptive in the social context is usually dependent on the topography of behavior. Bruzek, Thompson, and Peters (2009) demonstrated resurgence of socially acceptable childcare behaviors (e.g., rocking, feeding, playing) reinforced by negative reinforcement in the form of the cessation of crying. When adaptive responses reemerge, resurgence may be seen as problem-solving or creativity (Donahoe & Palmer, 1994, Epstein, 1987; Epstein, 1985; Epstein 1991; 1987, Lieving & Lattal, 2003, Shahan & Chase, 2002). One example of problematic resurgence demonstrated in the literature is relapse of severe problem behavior in individuals diagnosed with developmental disabilities (Mace et al., 2010, Volkert, Lerman, Call, & Trosclair-Lasserre, 2009; Wacker et al., 2013). When maladaptive behaviors reemerge in the context of behavior change programs (e.g., drug cessation, treatment of severe problem behavior), resurgence is framed as a form of treatment relapse (Volkert et al., 2009).

The phenomenon of resurgence has been demonstrated in a variety of behaviors, contexts, and contingencies. Resurgence has been shown with a variety of positive and negative reinforcers, including food (Lieving & Lattal, 2003), alcohol (Podlesnik, Jimenez-Gomez, & Shahan, 2006), cocaine (Quick, Pyszczynski, Colston, & Shahan, 2011), computer points (Marsteller & St. Peter, 2012), social attention and socially mediated escape (Volkert, Lerman, Call, & Trosclair-Lasserre, 2009). There is evidence of resurgence of derived stimulus relations (Wilson & Hayes, 1996), as well as rule-
following (Dixon & Hayes, 1998), suggesting resurgence may play a role in complex behavior patterns including covert processes and responses not directly trained. The phenomenon of resurgence has recently gained more attention in the research literature, as resurgence may provide insight and practical suggestions for clinically relevant behaviors in humans (Lattal & St. Peter Pipkin, 2009).

**Resurgence of Aberrant Behavior with DRA**

Among the most commonly used interventions for severe problem behavior are DRA procedures, in which a functional reinforcer is withheld for an undesired behavior and delivered contingent on a replacement response, such as a pro-social communication response (Carr & Durand, 1985; Petscher, Rey, & Bailey, 2009). Resurgence may have relevance to DRA interventions, because resurgence of a problem behavior may occur if the replacement response, once taught and reinforced, is no longer reinforced.

Consumers may encounter a series of events similar to the resurgence study: baseline reinforcement in the natural environment of the problem behavior is followed by an intervention phase of DRA, and this process mirrors the procedures in Phases 1 and 2 of a basic resurgence study. A “resurgence test” could be presented if reinforcement for the alternative behavior is not delivered as planned (e.g., lapses in treatment integrity) (Sprague & Horner, 1992). Analyses of differential reinforcement provide evidence that although DRA is an effective intervention for shifting response allocation, it can have the unintended effect of increasing the persistence of the problem behavior (Mace et al., 2010). This paradoxical effect of DRA becomes problematic when alternative reinforcement is removed or altered.
Resurgence of problem behavior during DRA treatment has been demonstrated in the applied literature. Volkert and colleagues (2009) published one of the first direct studies of resurgence in an applied human population. In this study, Volkert and colleagues demonstrated resurgence of problem behavior in 2 of 3 participants treated with functional communication training (FCT). There have been other demonstrations of resurgence of problem behavior within response class hierarchies (Lieving, Hagopian, Long, & O’Connor, 2004), during tests of extinction (Mace et al., 2010), and lapses in treatment integrity (Marsteller & St. Peter Pipkin, 2012).

It is important to study how resurgence can be avoided following DRA treatment given that it is a commonly used treatment for problem behavior (Petscher, Rey, & Bailey, 2009), and because lapses in treatment integrity can occur when behavior change agents have difficulty delivering the treatment components consistently (Hasting, 2005; St. Peter Pipkin, Vollmer, & Sloman, 2010).

Mace and colleagues (2010) suggested that one way to avoid resurgence following DRA is to introduce DRA that includes a dense reinforcement schedule in a context separate from the natural environment where the problem behavior occurs and then fade to a low-rate schedule before implementing DRA in the natural context using the leaner schedule of reinforcement. For example, DRA could first be conducted in a clinic with a rich schedule of reinforcement and then thinned before it is implemented in the natural environment (e.g., classroom, home). Mace and colleagues implemented such an arrangement first with nonhuman animals and then with humans and found, in both cases, this arrangement effectively reduced the occurrence of resurgence. Another recommendation Mace and colleagues made but did not test was to introduce a lean DRA
schedule from the outset in order to limit the persistence-increasing effect of a rich DRA schedule and subsequently reducing resurgence of problem behavior.

**Schedule Thinning in DRA**

Rich schedules of reinforcement for the alternative behavior are typically used early in the DRA procedure (e.g., FR 1). A common recommendation for creating a manageable procedure for behavior-change agents such as parents and teachers is to thin the reinforcement schedule for the alternative behavior. There are several different methods of thinning used for a DRA treatment. Common methods of thinning include increasing the response requirement (e.g., increasing the FR requirement) (Lalli, Casey, & Kates, 1995; Volkert et al., 2009) or increasing the delay between the response and delivery of reinforcer in order to help the client learn to tolerate longer delays (Fisher, Thompson, Hagopian, Bowman, & Krug, 2000; Hanley, Iwata, & Thompson, 2001; Hagopian, Fisher, Thibault Sullivan, Acquisto, & LeBlanc, 1998).

Recommendations for the schedule of alternative reinforcement have often been determined by selecting schedules that will quickly suppress the problem behavior and shift response allocation to the more desired appropriate behavior. However, these recommendations should also consider schedule effects related to the risk of relapse. Exploring the relationship between alternative reinforcement schedules and resurgence would help refine these guidelines.

In addition to thinning a rich reinforcement schedule for the purpose of creating a more manageable intervention, another benefit of thinning the reinforcement schedule for the alternative response is that it reduces the degree of resurgence when the alternative
behavior intentionally or unintentionally fails to produce reinforcement. Winterbauer and Bouton (2012) compared resurgence in a thinning group compared to a non-thinning group of rats and found resurgence of the B₁ response to be relatively small. However, they noted that suppression of B₁ was less effective during the progressive thinning group compared to the group with no thinning. This limitation seems to be demonstrated in applied studies on DRA and thinning, and increases in problem behavior (B₁) have been noted during thinning transitions (Fisher, Thompson, Hagopian, Bowman, & Krug, 2000; Hagopian, Toole, Long, Bowman, & Lieving, 2004; Hanley, Iwata, & Thompson, 2001). Volkert et al. (2009) and St. Peter (in preparation) evaluated the effects of schedule thinning in an applied study and in a human operant study, respectively. Similar to the nonhuman studies (Lieving & Lattal, 2003, Exp. 4; Sweeney & Shahan, 2013; Winterbauer & Bouton, 2012), increases in B₁ were observed at local periods of extinction during schedule thinning. In other words, thinning of the reinforcement schedule, prior to a resurgence test, may reduce the likelihood or degree of resurgence later observed during an extinction test (e.g., lapse in treatment integrity). Thinning the reinforcement schedule may protect against relapse. However, this potential benefit introduces the potentially undesirable trade-off that bouts of B₁ problem behavior may be observed during the thinning process as discrete periods of extinction are introduced when a schedule is thinned.

**Alternative Reinforcement Schedule Density**

One limitation of the study on schedule thinning by Winterbauer and Bouton (2012) was the lack of a comparison to a group that experienced a fixed low rate of
alternative reinforcement, making it unclear whether the decreased suppression of $B_1$ during the second phase was due to thinning alternative reinforcement or related to low rates of reinforcement at the end of the phase. It is possible that a lean reinforcement schedule in Phase 2 is responsible for preventing resurgence in Phase 3. Research on behavioral momentum theory (BMT) suggests that resistance to change is controlled by a stimulus-reinforcer association, and persistence of a behavior is governed by the history of reinforcement in the given context (Sweeney & Shahan, 2013a). A behavior should be more resistant to change in a context with a history of rich reinforcement compared to a context with a history of lean reinforcement. Following this proposed effect predicted by BMT, Sweeney and Shahan (2013b) extended Winterbauer and Bouton’s findings by comparing responding under fixed high rate, fixed low rate, and progressively thinned reinforcement schedules, as well as no alternative reinforcement. Data were collected on target response elimination of $B_1$ as well as rate of engagement in the alternative behavior $B_2$ in rats. Richer reinforcement rates for the alternative behavior resulted in quicker initial suppression of the target behavior, but resulted in more resurgence during the Phase 3 test. Both the low and thinning schedules resulted in slower initial response suppression, but did not result in resurgence of the target response.

One human study by Reed and Clark (2011) assessed the effects of schedule density on resurgence of appropriate behavior in children diagnosed with an autism spectrum disorder. Schedule density and phase duration were varied between three groups. Contrary to the results that would be predicted by Sweeney and Shahan (2013b), these data indicated the more reinforcers for $B_2$, the less resurgence observed. The explanation for this difference is unclear. Thus, it would be worth investigating further to
what extent conclusions regarding variables affecting resurgence in nonhuman animals generalize to human behavior.

**Summary and Purpose**

DRA is a common and effective procedure for decreasing problem behavior. However, treatment relapse in the form of resurgence may occur if errors in treatment integrity or planned thinning of schedules occur. One potential method for avoiding resurgence suggested by the nonhuman literature would be to thin the reinforcement schedule as part of the DRA treatment. However, instances of resurgence may be observed during discrete instances of extinction during the thinning process. Another possible method may be to start out reinforcing the alternative behavior on a relatively lean schedule of reinforcement (Mace et al., 2010). This option has been studied in nonhuman animals, but to this date, little research has been conducted with humans on this research question. The current study evaluated the effects of different DRA schedules during Phase 2 on resurgence in a laboratory task with adult humans.
EXPERIMENT 1

The purpose of Experiment 1 was to compare the effects of 3 densities of reinforcement (RI 5 s, RI 30 s, and RI 60 s) of B₂ during Phase 2 on levels of resurgence of B₁ during the initial portion of Phase 3 in a human operant arrangement. Additionally, data were analyzed to determine the effects schedule density had on B₁ and B₂ responding in Phase 2 related to suppression of B₁ and allocation to B₂ during DRA.

Method

Participants. Participants were 31 university students (9 males and 22 females, range 18 through 42 years of age, \( \bar{x} = 20.5 \)). One participant failed to acquire the response of clicking the circles to earn points. The remaining 30 participants were included in the analysis. Participants were recruited to participate in the study through flyers on campus and verbal presentations in classes. The majority of participants were undergraduate students in the psychology department who were able to submit hours of participation for extra credit in a psychology course. Psychology students were not eligible for participation if they had taken or were currently enrolled in undergraduate courses that include advanced behavior analytic principles. Participation took approximately 3 hours, and participants were compensated $7 per hour for attending the single research session. Participants who completed the session were entered into a random drawing in which 1 in 5 earned a $25 bonus. Participants were randomly
assigned to one of three experimental groups, with 10 participants assigned to each group.

**Apparatus and Experimental Task.** Experimental sessions were conducted in a 3 x 1.5 m room with no windows and minimal distractions. The room included a desk, 56 cm computer monitor, chair, and computer mouse. Participants were asked to leave their belongings (including cell phones, watches, and other electronics) in a separate room. The experimental task was presented using Microsoft Visual Basic® software on a Dell® Desktop computer running Microsoft Windows 7® operating software.

The experimental task consisted of a computer program displaying two moving circles (red and black) and a counter displaying the cumulative total of points earned on a computer screen (see Appendix A). The circles were 25mm in diameter and moved across the screen at a speed of 25 mm/s. Participants could earn points by clicking on the circles; the schedule of point delivery depended on group membership and phase of the study. The experimenter instructed the participants to earn as many points as possible using the computer mouse. Each time a point was earned, it was displayed on the cumulative counter that appeared on the screen. At the end of the session, a time-stamped record was generated that summarized the occurrence of dependent variables.

**Dependent Variables.** The dependent variables were the number of clicks on each circle, as well as clicks made on the background space. Clicks made on the background space were used to detect general variability of responding in response to extinction. The computer program collected all data, and the data were summarized for analysis as frequency of responses per minute. The computer program was assessed periodically throughout the study to ensure proper functioning.
**General Procedures and Independent Variables.** All study procedures and materials were approved by the Human Subject Institutional Review Board (Appendix B). Prior to enrolling in the study, potential participants attended a 15-minute meeting to complete an informed consent form. The experimenter summarized the information presented on the consent form, provided a copy of the form for the individual to review, and answered any questions the volunteer had (see Appendix C). After signing the consent form, participants completed a health questionnaire (Appendix D) to screen for psychoactive substances that would disqualify the individual from the study and provided general information (Appendix E). Eligible participants were scheduled to attend the experimental session at a later date.

Prior to beginning the session, participants were asked to respond to a screener (Appendix F) and report whether they had taken any psychoactive medications or substances that would result in their session being rescheduled. At the beginning of the session, the experimenter read the instructions for the experimental task out loud and provided the participant with a copy to keep on the desk during the session (Appendix G). There were three experimental phases, and each participant experienced the sequence of phases twice. Participants were given a 15-minute break half way through the experimental session, after first sequence of phases. Phase 1 involved reinforcement of $B_1$ responses only, Phase 2 included reinforcement for $B_2$ responses on one of three density schedules depending on group membership, and Phase 3 was the resurgence test in which neither response resulted in programed consequences.

The independent variable was the density of alternative reinforcement $B_2$. All participants experienced the same reinforcement schedules during Phases 1 and 3. The
reinforcement schedule for the alternative behavior in Phase 2 varied across groups and participants were randomly assigned to either RI 5 s, RI 30 s, or RI 60 s.

Participation lasted approximately 3 hours. At the end of the session, participants were asked to complete a post-session questionnaire (Appendix F) and were provided a debriefing form (Appendix G) describing the general purpose of the study. Participants were instructed to refrain from discussing the task with others as doing so could affect the behavior of others who decided to participate.

**Design and Experimental Phases.** Experimental phases were presented in an ABCABC design. Each participant experienced the three phases twice in the same sequence. There were no programmed signals in place to inform participants of a phase change. All phases were 25 minutes in duration. The assignment of B₁ and B₂ to each color was counterbalanced across participants. Contingencies are described below with the example of B₁ assigned to black and B₂ assigned to red for simplicity.

**Phase 1.** During this phase, responses on the black circle (B₁) were reinforced on an RI 5 s schedule for all participants. There were no programmed consequences (extinction) for responses on the red circle (B₂).

**Phase 2.** There were no programmed consequences for responses on B₁. The reinforcement schedule for B₂ depended on group assignment. Responses on B₂ for were reinforced on a RI 5 s, RI 30 s, or RI 60 s.

**Phase 3.** This phase represented the resurgence test. There were no programed consequences for responses on either circle (B₁ or B₂) for all participants.

When the participant had completed all three phases, he or she was given a 15-minute break. He or she was invited to take care of personal needs such as visiting the
restroom or having a drink of water. At the end of this time, the experimenter prompted the participant to return to the experimental room and task. The 3-phase sequence was then repeated in the same order.

Results

Individual participant data for each phase including frequency of responses on B₁ and B₂ were plotted for visual inspection (Appendices J, K, and L). During Phase 1, participants across the three groups acquired and allocated most responding to B₁. One participant only engaged in two instances of clicking on a circle during the 3-hour session and did not earn any points; her data were not included in further analysis. Most participants also allocated some responding to B₂ despite the lack of points delivered contingent on this response.

During Phase 2 when reinforcement was shifted from B₁ to B₂, participants in the RI 5-s and RI 30-s groups showed a consistent pattern of decreased responding on B₁ in favor of increased allocation to B₂. Some participants responded at near-zero levels on B₁ during this phase, while some still allocated a moderate, albeit relatively lower, amount of responding to B₂. Participants in the RI 60-s group, tended to show slower or less pronounced differentiation between B₁ and B₂ responding during Phase 2. In general, participants in all groups showed decreased responses on B₁ and increased responses on B₂ from Phase 1.

During Phase 3, all participants except one in the RI 5-s group, showed increased variability in responding on B₁ and several minutes of a higher frequency of responding on B₁ compared the first few minutes of Phase 2. The pattern was generally more
pronounced during the second exposure to Phase 3. Participant 031 showed an increase in B₁ responding at the end of the first exposure to Phase 2 and a similar level of responding on B₁ during the following Phase 3. During the second replication, Participant 033 maintained a high level of responding on B₁ during Phase 2 and a lower level of responding on B₁ during the first exposure to Phase 3. Low levels of responding on B₁ were demonstrated during the second exposure to Phase 2 and an increase in responding was demonstrated in Phase 3, suggesting resurgence of B₁ during the second exposure. Similar to the RI 5-s group, most of the participants in the RI 30-s group demonstrated increased variability and points of increased rate of B₁ responding in Phase 3 compared to Phase 2. Participant 030 still showed somewhat variable responding at moderate rates of B₁ during the first exposure to Phase 2 but did seem to demonstrate resurgence during the first exposure to Phase 3. Based on visual inspection, variably and rates of responding during the second exposure to Phase 2 and 3, and lacked a clear indication of resurgence. Visual inspection of the individual data from the RI 60-s group were more difficult to interpret given that many of the participants demonstrated highly variable responding on B₁ during Phase 2. Several participants did show a clear indication of resurgence in at least one exposure to Phase 3.

One interesting observation based on visual analysis of the individual graphs was the similarity of the overall pattern of responses on B₁ and B₂. It was common to see the general pattern of increasing or decreasing trend each minute to be similar between the data paths for both B₁ and B₂. Further analysis of resurgence in Phase 3, as well as group summary data and inferential statistics for Phases 2 and 3 are presented in the following results sections. Background clicks, defined as responding outside of the designated
circles, are reported in table form (see Tables 1, 2, and 3). A few participants demonstrated an increase in background clicks in Phase 3, suggesting some extinction-induced variability of responding, but this did not seem to be a pervasive pattern across participants and did not appear to systematically differ between groups.

Table 1

*Frequency of Background Clicks During the First and Second Exposures of All Three Phases for Participants in the RI 5-S Group*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>480</td>
<td>355</td>
<td>142</td>
<td>806</td>
<td>58</td>
<td>25</td>
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<tr>
<td>006</td>
<td>21</td>
<td>7</td>
<td>248</td>
<td>2</td>
<td>3</td>
<td>333</td>
</tr>
<tr>
<td>007</td>
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<td>1</td>
<td>21</td>
<td>21</td>
<td>21</td>
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Table 2

*Frequency of Background Clicks During the First and Second Exposures of All Three Phases for Participants in the RI 30-S Group*

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Table 3

*Frequency of Background Clicks During the First and Second Exposures of All Three Phases for Participants in the RI 60-S Group*

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When asked about the study during the post experiment survey (Appendix H), a majority of the participants were able to provide an anecdotal report that was fairly consistent with the contingencies they experienced according to group assignment. When responding to the prompts, “please describe what happened and what you did during
experimental sessions” and “describe any strategies that you may have used to earn points”, most participants described clicking on moving red and black circles to earn points. A majority of the participants accurately described which color earned a point-delivery during each phase, and described that the color earning points switched after a period of time (often indicating close to every 20-30 minutes), and described that there were times in which they earned zero points. Most described a duration of time that was approximately accurate depending on the schedule in each phase (e.g., when referring to Phase 1 with an RI 5-s schedule, many participants said something like, “I earned a point clicking on the red circle every 4 or 5 seconds”). When asked if they continued clicking during times in which points were not being delivered, a majority of participants indicated that they clicked periodically to test whether the rules had changed. The final question asked participants to describe what they thought the research question was. Responses to this question varied; many participants said they did not know or provided guesses involving the study of rewards, attention, or patience, and no participants accurately guessed the true purpose of this study.

**Extinction of B₁ During Phase 2.** Data were analyzed to determine the extinction pattern of B₁ during Phase 2, in which alternative reinforcement was introduced for B₂. These data show the extent to which B₁ was extinguished in this phase. Figure 1 provides a graphic representation mean responses and standard error, for B₁ during the first exposure to Phase 2. (Mean responding and standard error for each participant during Phase 2 are summarized in Appendix M and presented in graphic form in Appendix N). Mean responding for all three groups was similarly high, around 40 responses per minute ($\bar{x} = 38.1, 37.7, 41.3$) in the first minute of Phase 2. An immediate decrease in
responding of at least 50% was observed during the second minute in for each group (\( \bar{x} = 16.1, 12.4, 18.2 \)). Responding was then markedly lower throughout the rest of the phase for the RI 5-s group compared to the RI 60-s group, suggesting extinction of B\(_1\). The RI 30-s group showed more variability than the RI 5-s group. A repeated-measure ANOVA comparing the responses per minute across groups in Phase 2 revealed that the differences were not statistically significant difference between groups [F (2, 749 = 4.08, p = .017).

Figure 1. Mean \( B_1 \) responses during the first exposure of Phase 2 for each group.

Figure 2 displays the mean responses and standard error for \( B_1 \) during the second exposure to Phase 2. The pattern during the second exposure shows more differentiation in responding during the first minute (\( \bar{x} = 20, 31.2, 39.2 \)) of Phase 2, with less differentiation between all three groups through the remainder of the phase. A repeated-measures ANOVA comparing the responses per minute across groups in Phase 2 revealed a significant difference between groups [F (2, 749 = 11.95, p < .01]. A Tukey’s Multiple
Comparison Test showed that the RI 5-s group had significantly lower mean of responses compared to the RI 30-s and RI 60-s group. Again, there was no significant difference in overall mean between the RI 30-s and RI 60-s group.

![Graph showing mean responses over time for RI 5, RI 30, and RI 60 groups.]

**Figure 2.** Mean B₁ responses during the second exposure of Phase 2 for each group.

**Acquisition of B₂ During Phase 2.** Data demonstrating allocation to the alternative response, B₂ during Phase 2 were analyzed. These data are important to examine to determine the extent to which B₂ was acquired in this phase. Figure 3 shows the mean responses for each group during the first exposure of Phase 2. (Appendix O provides mean and standard error of responding for each group. Appendix P shows participant data for B₂ responding during the first and second exposures to Phase 2.) As expected, the RI 5-s group demonstrated the highest rate of responding during this phase. Responses in the RI 30-s and RI 60-s groups were similar throughout the phase. A repeated measures ANOVA comparing the responses per minute across groups during the first exposure to Phase 2 revealed a significant difference between groups [F (2, 749 =
54.72, p < .01]. A Tukey’s Multiple Comparison Test showed that the RI 5-s group had significantly higher mean of responses compared to the RI 30-s and RI 60-s group and the RI-30 group had significantly higher responding than the RI 60-s group.

Figure 3. Mean B2 responses during the first exposure of Phase 2 for each group.

Figure 4 shows the data for the second exposure to Phase 2, with a similar pattern observed in the first exposure. A repeated-measure ANOVA comparing the responses per minute across groups in Phase 2 revealed a significant difference between groups [F (2, 749 = 19.80, p < .01]. A Tukey’s Multiple Comparison Test showed that the RI 5-s group had significantly higher mean of responses compared to the RI 30-s and RI 60-s group. During the second exposure, there was a statistically significant difference in overall mean between the RI 30-s and RI 60-s group (p < .01).
Figure 4. Mean B\textsubscript{2} responses during the second exposure of Phase 2 for each group.

Resurgence of B\textsubscript{1} During Phase 3. A primary variable of interest was the pattern of resurgence during Phase 3 between the three groups. Resurgence is often observed as an initial increase of responding on B\textsubscript{1} during the resurgence test followed by a return to low levels or cassation of responding. Figure 5 shows mean B\textsubscript{1} responses during the first exposure of Phase 3. A repeated-measures ANOVA indicated that there was an interaction effect of group and minute, RI 5-s group responding during the first minute of Phase 3 were significantly higher than the RI 30-s and RI 60-s groups (p < .01).
Figure 5. Mean $B_1$ responses during the first exposure of Phase 3 for each group.

Figure 6 shows mean $B_1$ responses during the second exposure of Phase 3. A repeated-measures ANOVA indicated a similar effect to the first exposure and RI 5-s group responding during the first minute of Phase 3 was significantly higher than the RI 30-s and RI 60-s groups ($p < .01$).

Figure 6. Mean $B_1$ responses during the first exposure of Phase 3 for each group.
Resurgence was also assessed as defined as a detectable increase in $B_1$ responding between the last 5 minutes of Phase 2 and the first 5 minutes of Phase 3. Figure 7 shows mean $B_1$ responding for each participant in each group during the last 5 minutes of Phase 2 and the first 5 minutes of Phase 3. There was generally less variability between participants during the second exposure compared to the first exposure.

During the first exposure, mean data for 7 of the 10 participants in the RI 5 s group showed an increase in $B_1$ between Phase 2 and 3. Two participants with high levels of mean responding during the last 5 minutes of Phase 2 demonstrated a slight detectable increase, and one participant demonstrated a mean decrease in responding. During the second exposure, nine of the ten participants demonstrated near-zero responding during the last 5 minutes of Phase 2 and showed a mean increase in responding in Phase 3. One participant with high mean responding during the last 5 minutes of Phase 2 again showed a decrease in the first 5 minutes of Phase 3. During the first exposure for the RI 30 s group, 9 of the 10 participants demonstrated an increase in responding between the last 5 minutes of Phase 2 and first 5 minutes of Phase 3. Eight of the 10 participants demonstrated an increase in responding during the second exposure. One participant during the first exposure, and 2 participants in the second exposure, shared steady mean responding between Phase 2 and 3. Responding during the last 5 minutes of Phase 2 was lower and less variable for participants during the first 5 minutes of Phase 3. Four participants in the RI 60 s group demonstrated an increase in responding, 6 participants demonstrated similar levels of responding between the Phases. Three participants during the second exposure showed an increase in mean responding, one with a high mean during Phase 2 showed a decrease in mean responding during Phase 3, and 6 participants
showed a similar rate between phases. Differences in slope of responding as an indication of degree of resurgence can be observed on Figure 7.

**Figure 7.** Total number of B₁ responses during the last 5 minutes of Phase 2 and the first 5 minutes of Phase 3 during the first exposure (left panel) and second exposure (right panel) for each group.
Figure 8 shows mean $B_1$ responding and standard error for each group the last 5 minutes of Phase 2 and the first 5 minutes of Phase 3 during the first exposure to Phases 2 and 3. The RI 5-s and RI 30-s groups demonstrated similar slopes, suggesting resurgence was demonstrated. However, mean responding for the RI 60-s participants demonstrated a more moderate slope, suggesting less of a resurgence effect. Figure 9 shows the mean $B_1$ responding and standard error for the last 5 minutes of Phase 2 and the first 5 minutes of Phase 3 during the second exposure to Phases 2 and 3. Again, the RI 5-s and RI 30-s groups showed a similar slope indicating a resurgence of $B_1$, while the RI 60-s group demonstrated an increase in responding that was barely detectable by visual inspection.
Figure 8. Mean B₁ responding and standard error during the last 5 minutes of the first exposure to Phase 2 and the first 5 minutes of Phase 3. An increasing slope indicates resurgence.
Figure 9. Mean $B_1$ responding and standard error for the second exposure last 5 minutes of Phase 2 and the first 5 minutes of Phase 3. An increasing slope indicates resurgence.
Discussion

The purpose of Experiment 1 was to compare the effects of 3 densities of reinforcement (RI 5 s, RI 30 s, and RI 60 s) on resurgence of B₁ during the initial portion of Phase 3. Participants in all groups showed acquisition to B₁ in Phase 1 and extinction of B₁ and acquisition of B₂ in Phase 2, despite the different reinforcement schedules implemented during Phase 2 (RI 5 s, RI 30 s, and RI 60 s). Of interest were the effects the differing schedules had on B₁ suppression and allocation to B₂ during Phase 2. One of the expected limitations to using lean schedules during Phase 2, was that B₂ might not be acquired effectively on the leanest schedules and that relatively more responding would be allocated toward B₁. The results of Experiment 1 indicated that the richer schedule of RI 5 s indeed resulted in more rapid suppression of B₁ during Phase 2 (during the second exposure) and more responding on B₂ compared to the lean RI 60 s group. However, participants still acquired B₂ in Phase 2, even on the leaner schedule (albeit more slowly in some cases). B₁ was effectively suppressed in some participants, while B₁ was still emitted at relatively high rates throughout both exposures of DRA for others.

Phase 3 was the primary phase of interest, however, and was implemented to test for resurgence of B₁. Moreover, this phase was implemented to identify whether differences in resurgence would be observed as a function of the reinforcement schedule implemented in Phase 2. Although a significant difference in resurgence between mean responding of participants in the RI 5 s and RI 30 s groups was not detected, lower levels of resurgence were observed in RI 60 s group as compared to the RI 5 s and RI 30 s groups. These results were congruent with what was expected based on the results of Sweeney and Shahan (2013b), who demonstrated quicker initial suppression of B₁ with
richer alternative reinforcement rates, but more resurgence during the Phase 3 compared to leaner schedules.
EXPERIMENT 2

Experiment 1 demonstrated that lean schedules of reinforcement may help reduce the risk of relapse in the form of resurgence. Lower suppression of $B_1$ during DRA may not be ideal in some situations, especially when treating a problem behavior that puts the client or others at risk. Experiment 2 further assessed alternative reinforcement schedule density with the addition of a reductive strategy to determine whether low levels of $B_1$ can be obtained during both Phase 2 and Phase 3. Often, applied researchers and practitioners utilize reductive strategies in combination with DRA to eliminate target problem behavior ($B_1$) during treatment. For example, Wacker et al. (1990) and Fisher et al. (1993) demonstrated the use of mild reductive strategies (e.g., brief time out or mild overcorrection) was often necessary as a component to functional communication training packages to produce desired effects (acquisition of the $B_2$ replacement response with simultaneous suppression of the $B_1$ problem behavior). Furthermore, Hagopian, Fisher, Thibault, Sullivan, Acquisto, and Leblanc (1998) found in an analysis of inpatient cases, that DRA including extinction (similar to Experiment 1) was effective with about half of the cases, however these treatment gains were compromised when schedule thinning was implemented and problem behavior reemerged. Adding a punishment procedure to DRA resulted in effective treatment in all cases to which it was applied, and treatment gains were maintained even when the schedule-thinning phase was implemented. Few researchers have studied resurgence in the presence of a punishment contingency. One example, however, is Kestner, Redner, Watkins, and Poling (2015),
who compared resurgence in rats experiencing DRA alone or DRA + Punishment of B1. Results of this study showed lower rates of resurgence with the addition of punishment. However, in this study, only one reinforcements schedule was implemented for DRA, so it is unclear how the punishment contingency would interact with various reinforcement contingencies.

Further investigation of procedural variations that minimize resurgence in Phase 3, while also minimizing responding on B1 during Phase 2, may lead to more efficient applied procedures. The purpose of Experiment 2 was to compare the effects of 2 densities of reinforcement (RI 5 s and RI 60 s) during Phase 2 with the addition of an aversive auditory stimulus contingent on B1 on resurgence of B1 in the initial portion of Phase 3. Data on B1 and B2 responding were again analyzed during Phase 2. An additional analysis was completed to assess whether the auditory stimulus likely functioned as a punishing stimulus or SΔ increasing the saliency of extinction of B1.

Method

Participants. Participants were 10 students (7 females and 3 males; 19-32 years of age, \( \bar{x} = 21.9 \)). The same inclusion and exclusion criteria were applied as described in Experiment 1. None of the participants in Experiment 2 participated in Experiment 1. Participants were randomly assigned to one of two experimental groups, with 5 participants assigned to each group.

General Procedures and Independent Variables. The setting, apparatus, experimental task, dependent variables, and general session procedures were identical to Experiment 1. Procedures were the same across the two experimental groups, with the
exception of the reinforcement schedule in Phase 2. Participants were assigned to either a RI 5-s or RI 60-s reinforcement schedule. These two schedule values were selected because they displayed the greatest difference in responding in Experiment 1. During Phase 2 responses on B₁ were consequated with a computer sound on a RI 5-s schedule and no points were delivered. The computer sound was a brief tone that is associated with an “error” in Microsoft Windows©. It was assumed that many participants likely had prior experience with this sound as a conditioned punisher or signal that reinforcement was not available for the preceding response. An additional analysis was conducted to assess whether this sound was more likely functioning as an $S^\Delta$, perhaps increasing the saliency of the extinction, or as a punishing stimulus.

**Experimental Phases.** The phases were implemented in an ABCABC design. Other than the sound being presented following B₁ responses in Phase 2, which may have increased saliency of a change in contingencies, there were no programmed signals in place to inform participants of phase changes. All phases were 25 minutes in duration. The assignment of B₁ and B₂ to each color was counterbalanced across participants (colors are assigned below as an example).

**Phase 1.** Responses on the black circle (B₁) were reinforced on a RI 5 s schedule for all participants; there no programmed consequences for responses on the red circle (B₂).

**Phase 2.** No points were delivered for responses on B₁ and the computer “error” sound was delivered on a RI 5-s schedule. Responses on the red circle (B₂) were reinforced on either a RI 5 s or RI 60 s, depending on group membership.
Phase 3. There were no programmed consequences for responses on either circle (B₁ or B₂) for all participants in order to assess for resurgence of B₁. Participants were given a 15-minute break after completed the first Phase 3 and then the 3-phase sequence was then repeated.

Stimulus Assessment. At the conclusion of this experiment, a stimulus assessment was conducted to determine the likely function of the auditory stimulus. The sound stimulus used in Phase 2 of Experiment 2 was intended to serve as a punisher for B₁. This assessment was conducted in an attempt to verify that the sound utilized served as a punisher and did not simply increase the saliency of the schedule change for B₁ from an RI 5-s reinforcement schedule to extinction (becoming an SΔ).

An additional 6 participants were recruited for this analysis (5 females and 1 male; 19-25 years of age, \( \bar{x} = 20.3 \) years). One recruited participant failed to acquire the response of clicking on the circles, and thus her data were not included in analysis. As a result, 5 participants remained in the stimulus assessment.

During the first phase of the stimulus assessment, responses on the black circle were reinforced on a FR 5 schedule. Responses on the red circle were consequated with a point delivery and the auditory stimulus on a FR 5 schedule. The consequences were for each colored circle were switched each phase (e.g., during Phase 2, responses on the red circle was consequated with a point delivery on a FR 5 and the responses on the red circle were consequated with both a point delivery and sound stimulus), to ensure any differences in response allocation followed the respective consequences each phase. Phases were 25 minutes in duration. With the reinforcer delivery schedules equated.
between the response options, consistent allocation away from the auditory stimulus would suggest a punishing effect of the stimulus.

Results

Single subject participant data for each phase of responses on $B_1$ and $B_2$ are displayed in Appendices Q and R. During Phase 1, participants across the three groups acquired and allocated most responding to $B_1$, and most participants continued to allocate some responding to $B_2$ despite the lack of points delivered for this response. One participant (050) demonstrated a high level of variability of $B_1$ and $B_2$; $B_2$ responses exceeded $B_1$ responses during some minutes in the first exposure of Phase 1 and this pattern was more pronounced in the second exposure of Phase 1. During Phase 2 when reinforcement was shifted from $B_1$ to $B_2$, and the aversive sound was produced on a RI 5 s by clicks on $B_1$, participants in both groups showed a pattern of decreased responding on $B_1$ in favor of increased allocation to $B_2$. There did not appear to be a systematic difference in this pattern between the RI 5-s and RI 60-s group members.

During Phase 3, all participants in the RI 5-s group, except for one, showed variability in responding on $B_1$ and several minutes of more frequent responding on $B_1$ than after the first few minutes of Phase 2. Participant 043 showed moderate responding on $B_1$ during Phase 2 and a similar level of responding on $B_1$ during the first few minutes of Phase 3 until responding was eliminated. During the second exposure, Participant 043 showed an increase in responding on $B_1$ during the last few minutes of Phase 2 but did not appear to display at least one data point of resurgence during Phase 3. It appears that all
participants in the RI 60-s group showed some evidence of resurgence in at least one exposure of Phases 2 and 3.

Shifts in responding across each phase were generally replicated within-subject across the first and second exposures to each phase. Further analysis of resurgence in Phase 3, as well as group summary data and inferential statistics for Phases 2 and 3 are presented in the following results sections. Background clicks, defined as responding outside of the designated circles, is reported in table form (see Table 1, 2, & 3). A few participants demonstrated an increase in background clicks in Phase 3, suggesting some extinction-induced variability of responding, but this did not seem to be a pervasive pattern across participants.

Table 4

*Frequency of Background Clicks During the First and Second Exposures of All Three Phases for Participants in the RI 5-S + Sound Group*

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<th>Phase 1</th>
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Table 5

*Frequency of Background Clicks During the First and Second Exposures of All Three Phases for Participants in the RI 60-s + Sound Group*

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</table>

When asked about the study during the post-experiment survey (Appendix H), as with participants in Experiment 1, a majority of the participants were able to provide descriptions of phase contingencies that were relatively accurate according to group assignment. Responses to the prompt to describe what they thought the experimental question varied and were similar to responses in Experiment 1.

**Responding on B₁ in Phase 2.** Data were analyzed to determine if there were differences in the extinction pattern of B₁ during Phase 2 between groups as had been observed during Study 1. Mean responding and standard error are summarized in Appendix S and in graphic form in Appendix T.

Figure 10 is a graphic representation of group data, including mean response and standard error, for B₁. Mean responding for both groups was higher during the first minute of the Phase ($\bar{x}_{RI 60 \text{s}} = 39.2; \bar{x}_{RI 5 \text{s}} = 18.2$). An immediate decrease in responding occurred during the second minute for each group ($\bar{x}_{RI 60 \text{s}} = 21.2; \bar{x}_{RI 5 \text{s}} = 4.6$). Responding was then relatively low for both groups, with the RI 5-s group showing a pattern of more variability. A repeated-measures ANOVA comparing the responses per
minute for the first exposure to Phase 2 revealed significantly lower responding in the RI 5-s group compared to the RI 60-s group \[F (1, 249) = 7.91 \ p < .01\].

**Figure 10.** Mean B₁ responses during the first exposure to Phase 2 for both groups.

Figure 11 shows B₁ data for the second exposure of Phase 2. Mean responding was slightly higher for the RI 60-s group compared to RI 5-s during the first minute of Phase 2 (\( \bar{x}_{RI \ 60} = 8.4; \bar{x}_{RI \ 5} = 3.2 \)) with similar levels of responding throughout the remainder of the phase. There was a slight increase in variability of responding in the RI 5-s group compared to RI 60-s. A one-way ANOVA revealed no significant difference between groups \[F (1, 249) = 5.12 \ p = 0.025\].
Figure 1. Mean $B_1$ responses during the second exposure to Phase 2 for both groups.

**Responses on $B_2$ in Phase 2.** Figure 12 shows mean responding on $B_2$ during the first exposure to Phase 2 as being higher in the RI 60-s group compared to RI 5-s. The mean responses and standard error are presented in Appendix U and graphic form in Appendix V. A repeated-measure ANOVA comparing the responses per minute for indicated a significant difference between groups [F (1, 249 = 8.47 p < 0.01]. Figure 13 shows higher responding at the beginning of the second exposure to Phase 2 for the RI 60-s group, but responding becomes more variable between both groups toward the middle and end of the phase. A one-way ANOVA comparing the responses per minute across groups during the second exposure revealed no significant difference between groups [F (1, 249 = 01.41 p = 0.237].
**Figure 12.** Mean $B_2$ responses during the first exposure to Phase 2 for both groups.

**Figure 13.** Mean responses during the second exposure of $B_2$ in Phase 2 for both groups.

**Resurgence of $B_1$ During Phase 3.** Figures 14 and 15 show mean $B_1$ responses during the first and second exposure of Phase 3. A repeated-measures ANOVA for the first 5 minutes of each exposure indicated there was not a statistically significant
difference in responding between groups [F (1, 49 = 3.82 p = 0.058); F (1, 49 = 0.15 p = 0.704)].

**Figure 14.** Mean B₁ responses during the first exposure of Phase 3 for each group.

**Figure 15.** Mean B₁ responses during the second exposure of Phase 3 for each group.
Figure 16 shows mean participant responding on B₁ during the last 5 minutes of Phase 2 and the first 5 minutes of Phase 3. There was one participant outlier noticed in the RI 5-s group during the second exposure of Phase 2. This participant demonstrated comparatively high responding on B₁ during both Phases 2 and 3. Figures 17 shows mean responding and standard error for both groups. The RI 5-s group demonstrated a steeper resurgence slope compared to RI 60-s during the first exposure.

During the first exposure, mean data for all participants in the RI 5-s group showed an increase in B₁ between the last 5 minutes of Phase 2 and the first 5 minutes of Phase 3. During the second exposure, all participants demonstrated a mean increase in responding in Phase 3. Three participants in the RI 60-s group demonstrated an increase in responding, one of which was slight, and two participants demonstrated similar levels of responding between these Phases. Two participants during the second exposure showed an increase in mean responding during Phase 3. Differences in slope of responding as an indication of degree of resurgence can be observed in Figure 17.

Figure 18 shows the mean responding and standard error during the second exposure. The resurgence slope for RI 5-s group is relatively milder than during the first exposure, but is still steeper than the RI 60-s group, indicating a greater resurgence effect. When asked if the sound affected their strategy, a majority of participants indicated that they found the sound annoying, bothersome, or unpleasant.
Figure 16. Total number of responses during the last 5 minutes of Phase 2 and the first 5 minutes of Phase 3 during the first exposure (left panel) and second exposure (right panel) for each group.
Figure 17. Mean B₁ responding and standard error for the first exposure last 5 minutes of Phase 2 and the first 5 minutes of Phase 3. An increasing slope indicates resurgence.
**Figure 18.** Mean B₁ responding and standard error for the second exposure last 5 minutes of Phase 2 and the first 5 minutes of Phase 3. An increasing slope indicates resurgence.

**Stimulus Assessment.** Figure 19 displays the data for the 5 participants in the stimulus assessment. The dark bar indicates that responses on the designated circle were reinforced on an FR 5, and the grey bar indicates that responses were reinforced on an FR 5 with the addition of the potentially aversive sound. Four of the five participants
demonstrated a systematic difference in response allocation between the response option producing the auditory stimulus and the option did that did not. More responses were allocated to the response option that did not produce the auditory stimulus, and this allocation was reproduced across phases when the consequences were switched between circles. These participants tended to report on the post-experiment questionnaire that they found the sound to be “bothersome” or “annoying” to the question asking whether the sound affected their strategy. Participant 057 showed remarkably similar levels of responding during between response options in Phase 1 and Phase 2, with a slight preference toward the non-sound option in Phase 3. Interestingly, this participant responded anecdotally that she did not “mind the sound, it let [her] know [she] was getting points”. These data suggest that the auditory stimulus served as a punishing stimulus for 4 of 5 participants.
Figure 19. Total number of responses on each circle during each phase of the stimulus assessment. The dark bar indicates that responses on the designated circle were reinforced on an FR 5, and the grey bar indicates that responses were reinforced on an FR 5 with the addition of the auditory stimulus. Consequences were swapped between the two colored circles for each phase.
Discussion

Experiment 2 compared the effects of two densities of reinforcement (RI 5 s and RI 60 s) during Phase 2, with the addition of an aversive auditory stimulus contingent on B₁. Similar to the findings in Experiment 1, the group that experienced the leaner schedule of reinforcement showed a smaller resurgence effect compared to the group with the richer schedule of alternative reinforcement.

Experiment 1 had demonstrated that although the leaner reinforcement schedule decreased resurgence, there was a diminished suppression effect of B₁ during Phase 2. Continued allocation to B₁ during DRA would not be ideal in some situations. Experiment 2 showed that adding a punisher in the form of an auditory stimulus resulted in similar allocation to B₁ during Phase 2 in both groups within this experiment.

Since the analysis in Experiment 2 did not assess whether the sound suppressed responding in Phase 2 due to a punishing of discriminative effect, a supplementary analysis with naïve participants was conducted to assess the function of the sound. The results of the stimulus assessment found that the sound functioned as a punisher for 4 of the 5 participants, and suggested that the auditory sound was likely to function as a punisher during Experiment 2.
GENERAL DISCUSSION

Experiment 1 compared the effects of three densities of reinforcement (RI 5 s, RI 30 s, and RI 60 s) of B$_2$ during Phase 2, and found that the lean reinforcement schedule (RI 60 s) resulted in less resurgence during Phase 3 compared to the other two groups. An analysis of responding on B$_1$ and B$_2$ in Phase 2 showed the richer schedule resulted in a quicker suppression of B$_1$ during Phase 2, and more responding on B$_2$ compared to the lean RI 60-s group. Experiment 2 also showed less resurgence in the group experiencing a leaner reinforcement schedule. The addition of an aversive stimulus contingent of B$_1$ resulted in more similar suppression of B$_1$ across the rich and lean schedules for B$_2$ during Phase 2.

There are some applied implications of these data. Resurgence of problem behavior in the context of DRA has been demonstrated (e.g., Volkert, Lerman, Call, & Trosclair-Lasserre, 2009), including during planned thinning of the alternative reinforcement schedule (Fisher, Thompson, Hagopian, Bowman, & Krug, 2000; Hagopian, Toole, Long, Bowman, & Lieving, 2004; Hanley, Iwata, & Thompson, 2001). As discussed earlier, interventions that result in less relapse is an important advancement in the technology for decreasing problematic behaviors such as aggression and self-injury. Experiments 1 and 2 suggests that utilizing lean schedules of alternative reinforcement during DRA treatment may decrease resurgence in the event of schedule thinning or lapses in treatment integrity. This recommendation is contrary to the typical recommendation to implement DRA with rich schedules of alternative reinforcement.
The limitation to using lean schedules of alternative reinforcement in DRA may be a slower or less effective suppression of problem behavior and fewer alternative behavior responses. This drawback may be acceptable in some contexts, such as in the case of non-harmful target behaviors or when the DRA procedure could be initiated in a clinic setting with environmental safety precautions and trained professionals. Likewise, the additional effect of lower allocation to $B_2$ may be workable in some situations as extremely high rates of alternative responding can sometimes be problematic (e.g., with almost continuous mands for breaks from work or attention). However, Experiment 2 suggests that in situations where limited suppression of $B_1$ during DRA is not ideal, one solution might be to utilize other reductive strategies in addition to DRA with extinction to aid in reducing $B_1$.

There are a few limitations to consider when interpreting the results of this study. Several limitations are due to differences between the procedures in this study compared to the procedures that would be used in applied work-implemented DRA with individuals displaying problem behavior. The first difference is the scale of time use in this study. This study took place in 3 hours, whereas the history of reinforcement for a problem behavior is likely months or years. Likewise, the amount of time in which DRA was implemented was much shorter than in the natural environment, and the long-term effects were not assessed. Previous applied research has indeed demonstrated resurgence of target behaviors even after long treatment phases of DRA, but that the effect usually diminishes after an extended period of treatment (Wacker et al., 2011). Finally, both the target and alternative response were equated in topography and effort (clicking different colored circles), which is often not the case between target and alternative behavior in the
treatment of problem behavior (Geiger, Carr, & Leblanc, 2010). This is an important parameter for consideration in applied use of DRA procedures as response effort has been shown to be an important variable for whether the alternative behavior will compete for allocation with a target behavior (Horner & Day, 1991).

The effect of these potential limitations should be assessed by further research to determine the generalizability of these findings. Additional translational research on variables affecting resurgence has the potential to generate treatment recommendations to protect against relapse of unwanted behaviors. Human operant arrangements can be a useful tool for elucidating the effects of variables on resurgence in a quick and safe manner (Mendres & Borrero, 2010). Additional research on the translational spectrum should be completed prior to wide-spread implementation of recommendations coming from this research, although previous translational research in this area has shown promise for generalization (cf. Marsteller & St. Peter, 2014). As more is learned about parameters important to relapse, future research should assess these same variables with human participants engaged in clinically important behaviors.
REFERENCES


St. Peter (in preparation/unpublished data)


Appendix A

Screenshot of Experimental Task
Appendix A. Screenshot of the experimental task. The screen displayed two moving circles (red and black) and a counter displaying the number of points earned. The circles were 25mm in diameter and moved across the screen at a speed of 25 mm/s. Points were delivered contingent on the response of clicking the circles depending on the phase and reinforcement schedule.
Appendix B

HSIRB Approval Letter
Date: October 13, 2014

To: Stephanie Peterson, Principal Investigator
    Kathryn Kestner, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number 14-10-14

This letter will serve as confirmation that your research project titled "The Effects of Reinforcement Schedules on Resurgence" has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may only be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study"). Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

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

Approval Termination: October 12, 2015
Appendix C

Informed Consent Form
Appendix C. Informed Consent Form

Western Michigan University
Department of Psychology

Principle Investigator: Dr. Stephanie Peterson
Student Investigator: Kathryn Kestner
Title of Study: The Effects of Reinforcement Schedules on Resurgence

You have been invited to participate in a research project titled “The Effects of Reinforcement Schedules on Resurgence”. This project will serve as Kathryn Kestner’s dissertation for the requirements of the doctoral program in Psychology: Behavior Analysis. This consent document will explain the purpose of this research project and will go over all of the time commitments, the procedures used in the study, and the risks and benefits of participating in this research project. Please read this consent form carefully and completely and please ask any questions if you need more clarification.

What are we trying to find out in this study?
This is a behavioral research study interested in finding out how rewards affect performance on participants responding on a computer task to earn points.

Who can participate in this study?
You must be able to use a computer mouse and watch stimuli on a computer screen to participate. You must have not taken PSY 3600 or higher course with behavior analytic content in order to participate. The use of some psychoactive drugs may result in you not qualifying to participate (including some prescriptions). Before the study begins, you will be asked questions about your health and drug use. The results of these questionnaires will determine whether you qualify to take part in the study.

Where will this study take place?
On the day of participation you will meet with the researcher or research assistant in 2530 Wood Hall. The test session will be conducted in a small room in the same hallway as 2530. During test sessions you will be seated in a small room in front of a computer.

What is the time commitment for participating in this study?
You will participate in one session. Upon arrival to your session, you will be asked to take a few minutes to complete questionnaires. You will then participate in a computer tasks for approximately 75 minutes. You will then have a 15-minute break. Then you will participate in the computer task for approximately 75 minutes. You will be asked to take a few minutes at the end to complete a few more questionnaires. Your total participation time will be approximately 3 hours.

What will you be asked to do if you choose to participate in this study?
On the day of participation, you will check a form indicating whether you have taken any drugs of abuse within the past 72 hours, medications or other over-the-counter drugs that
may affect your mood or personality within the past 12 hours, alcoholic beverages within
the past 12 hours, or nicotine/caffeine within the past 2 hours. If so, we will ask you to
reschedule your session. Of course, you should continue to take any medications that
have been prescribed to you.

During test sessions you will be seated in a small room in front of a computer. You may
be asked to wear headphones while seated for noise reduction. There will be a counter on
the computer screen to show how many points you have earned during the session.
During test sessions you will be seated in a small room in front of a computer. You may
be asked to wear headphones while seated for noise reduction.

We also ask that you do not eat or drink tea, coffee, colas, or food or use tobacco
products while you are completing test sessions. These rules are important to the
research. If you continue to eat or drink these items you may be asked to leave the study.
Also, if you sleep during scheduled sessions you may be removed from the study.
Finally, it is very important that you do not discuss what you do in the study with others
or speak with the other participants about the study or about your money earnings. If you
talk to others who are participating in the project or who may participate in the future,
you may influence what they do and invalidate the results.

**What information is being measured during the study?**
This section will describe the measurements that we are going to take during your
participation in the study. The laboratory tasks will require that you use the mouse to earn
points on the computer screen. The computer will electronically monitor and record your
responses. Your behavior may also be visually monitored by video cameras in the room,
but will not be video recorded. Some information will be collected via self-report survey
before and after the computer task.

**What are the risks of participating in this study and how will these risks be
minimized?**
There are no anticipated risks from taking part in this study. There may be other
unforeseen risks to participants, however. If you suffer any injury while participating,
you should immediately report it to Dr. Stephanie Peterson who will report it to the
Human Subjects Institutional Review Board (269-387-8293)

**What are the benefits of participating in this study?**
There are no anticipated benefits for participants.

**Are there any costs associated with participating in this study?**
The only cost of participating in this study is that you will spending an average of 3 hours
in the laboratory participating in the study (when you could be doing something else) and
you may become bored with the experimental task.

**Is there any compensation for participating in this study?**
You will be compensated $7 per hour for your participation (including a 15-minute break). You will be provided this compensation at the end of session. If you decide to withdraw from the study before finishing the session, or are removed from the study, you will be compensated for the amount of time you have completed at that time. You will be asked to sign a form confirming you have received the compensation. You may receive extra credit for participating in this research from your psychology courses at Western Michigan University, depending on the policies of your instructors. Participants who complete the entire study will also have the chance to earn $25. When all five members of your group have completed the study, you will be notified by email whether or not you are the winner. There is no guarantee that you will earn the bonus money.

**Who will have access to the information collected during this study?**
All information you provide and data collected will be de-identified. Your identity will not be revealed in any publication based on this study. You will be given an identification number during the study. Dr. Stephanie Peterson will keep a separate master list of the names of participants and their identification numbers. Once data are collected and analyzed, the master list will be destroyed. All other obtained data will be retained for at least 3 years in a locked file cabinet in Wood Hall.

**What if you want to stop participating in this study?**
You can choose to stop participating in the study at anytime for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study. The investigator can also decide to stop your participation in the study without your consent (e.g., if you fall asleep or consume caffeine during participation). If you wish to discontinue, please inform the researcher or research assistant immediately.

If you decide to withdraw from the study before finishing the session, or are removed from the study, you will be compensated for the amount of time you have completed at that time, but you will not be eligible to win the bonus.

Should you have any questions prior to or during the study, you can contact the primary investigator, Dr. Stephanie Peterson at 269-387-4479 or stephanie.peterson@wmich.edu. You may also contact the Chair, Human Subjects Institutional Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.
Appendix D

Health Survey
Appendix D. Health Survey

Please note: The following questions are designed to assess your health. You may choose not to answer any of these questions. *This survey is completely confidential.*

1. Are you currently taking any medications prescribed by a doctor (e.g., diet aids, pain reliever, tranquilizer, antihypertensive, antidepressant, sleep aids, other drug)?
   
   No ______  Yes_______ (please specify)_____________________________

2. Are you currently taking any non-prescription medications (e.g., pain reliever, stimulants or diet pills, cold or allergy pills)?
   
   No _____  Yes______ (please specify)_____________________________

3. Are you currently taking any illicit drugs (e.g., marijuana, opioids, cocaine, ecstasy, hallucinogens)?
   
   No ______  Yes_______
Appendix E

Participant Information Form
Appendix E. Participant information form.

Please answer the following questions. *This information is completely confidential.*

Please indicate your gender:  Male _____  Female_______

Please indicate your current age in years: _______

Please indicate your ethnic background by checking one of the following:
☐ Hispanic or Latino
☐ Not Hispanic or Latino

Please indicate your racial background by checking one or more of the following:
☐ American Indian or Alaskan Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or other Pacific Islander
☐ White
Appendix F

Session Day Survey
Appendix F. Session Day Survey.

Please note: This survey is to check whether you have taken substances that may affect your mood or behavior. If so, we will ask you to reschedule your session.

This survey is completely confidential.

4. Have you taken any illicit drugs within the last 72 hours (e.g., marijuana, opioids, cocaine, ecstasy, hallucinogens)?
   No ______  Yes ______

5. Have you consumed alcohol in the last 12 hours?
   No ______  Yes ______

6. Have you had any nicotine or caffeine in the last 2 hours?
   No ______  Yes ______

7. Have you taken any medications prescribed by a doctor in the last 12 hours (e.g., diet aids, pain reliever, tranquilizer, antihypertensive, antidepressant, sleep aids, other drug)?
   No ______  Yes ______ (please specify)______________________________
Appendix G

Experimental Task Instructions
Appendix G. Experimental Task Instructions

You will be able to earn points by using the computer mouse. The way you earn points may change at times during the session. There may be points in time when no points are earned. You will be able to see the number of points you have earned on the bottom left-hand corner of the screen. Please remain seated. There is a random lottery and 1 in every 5 people who participate in this will win a $25 bonus.
Appendix H

Post-experiment Questionnaires
Appendix H. Post-experiment Questionnaires

Experiment 1

1. Please describe what happened and what you did during experimental sessions.

2. Please describe any strategies that you may have used to earn points. Did any of your strategies change across the experiment?

3. There were times at which no points were delivered. Did you keep clicking during these times? If so, why?

4. What do you think we are trying to learn from this study?

Experiment 2

1. Please describe what happened and what you did during experimental sessions.

2. Please describe any strategies that you may have used to earn points. Did any of your strategies change across the experiment?

3. There were times at which no points were delivered. Did you keep clicking during these times? If so, why?

4. Did hearing the sound change your strategy? If so, how did it change and why?

5. What do you think we are trying to learn from this study?
Appendix I

Debriefing Form
Appendix I. Debriefing Form

The purpose of this study was to investigate how the timing of positive reinforcement influences behavior. You could earn points based on clicking the circles. At times, the program switched which circle produced points. At other times, there were no points available.

Please do not discuss what you did and what happened in this study with others until we have finished collecting data for this project. If you discuss the study with others it may influence their behavior and invalidate the results. All data that we have collected from you will remain de-identified. The results of this study will contribute to our understanding of how reinforcement affects behavior.

We will randomly select 1 of every 5 students to receive the $25 bonus; all participants have an equal chance to earn to bonus regardless of which group they were assigned to. You will receive an email to inform you whether or not you have been selected for this bonus.

If you have any other questions about the study, please ask. We thank you for your participation.
Appendix J

Single Subject Graphs for Participants in the RI 5-s Group for Experiment 1
Appendix J. Single subject graphs for participants in the RI 5-s group for Experiment 1.

The top panel displays data for $B_1$ only and the bottom panel displays data for both $B_1$ and $B_2$. 

![Graph showing single subject responses for participants in the RI 5-s group for Experiment 1.](image)
Appendix K

Single Subject Graphs for Participants in the RI 30-s Group for Experiment 1
Appendix K. Single subject graphs for participants in the RI 30-s group for Experiment 1. The top panel displays data for $B_1$ only and the bottom panel displays data for both $B_1$ and $B_2$. 
Appendix L

Single Subject Graphs for Participants in the RI 60-s Group for Experiment 1
Appendix L. Single subject graphs for participants in the RI 60-s group for Experiment 1. The top panel displays data for B₁ only and the bottom panel displays data for both B₁ and B₂.
Appendix M

Mean and Standard Error of the Mean for Responding on B₁ During Each Minute of the First Exposure to Phase 2
Appendix M.

Mean and standard error of the mean for responding on B₁ during each minute of the first exposure to Phase 2

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Mean and standard error of the mean for responding on B₁ during each minute of the second exposure to Phase 2

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Appendix N

B₁ Responses for Participants in the RI 5-S Group During the First Exposure and Second Exposure of Phase 2
Appendix N.

B₁ responses for participants in the RI 5-s group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
$B_1$ responses for participants in the RI 30-s group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
$B_1$ responses for participants in the RI 60-s group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
Appendix O

Mean and Standard Error of the Mean for Responding on B$_2$
During Each Minute of the First Exposure to Phase 2
Appendix O.

Mean and standard error of the mean for responding on B2 during each minute of the first exposure to Phase 2

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Mean and standard error of the mean for responding on B2 during each minute of the second exposure to Phase 2

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Appendix P

B₂ Responses for Participants in the RI 5-s Group During the
First Exposure and Second Exposure of Phase 2
Appendix P.

B₂ responses for participants in the RI 5-s group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
B₂ responses for participants in the RI 30-s group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
B₂ responses for participants in the RI 60-s group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
Appendix Q

Single Subject Graphs for Participants in the RI 5-s Group for Experiment 2
Appendix Q. Single subject graphs for participants in the RI 5-s group for Experiment 2.

The top panel displays data for $B_1$ only and the bottom panel displays data for both $B_1$ and $B_2$. 
Appendix R

Single Subject Graphs for Participants in the RI 30-s Group for Experiment 1
Appendix R. Single subject graphs for participants in the RI 30-s group for Experiment 1. The top panel displays data for $B_1$ only and the bottom panel displays data for both $B_1$ and $B_2$. 
Appendix S

Mean and Standard Error of the Mean for Responding on B1 during Each Minute of the First Exposure to Phase 2
Appendix S.

Mean and standard error of the mean for responding on B\textsubscript{1} during each minute of the first exposure to Phase 2

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Mean and standard error of the mean for responding on B₁ during each minute of the second exposure to Phase 2

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143
Appendix T

B1 Responses for Participants in the RI 5 s + Sound Group During the First Exposure and Second Exposure of Phase 2
Appendix T.

$B_1$ responses for participants in the RI 5 s + Sound group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
B₁ responses for participants in the RI 60 s + Sound group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
Appendix U

Mean and Standard Error of the Mean for Responding on B2
During Each Minute of the First Exposure to Phase 2

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Appendix U.

Mean and standard error of the mean for responding on B\textsubscript{2} during each minute of the first exposure to Phase 2

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<td>2.92</td>
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<td>8.03</td>
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Mean and standard error of the mean for responding on B$_2$ during each minute of the second exposure to Phase 2

<table>
<thead>
<tr>
<th>RI 30 s + Sound Group</th>
<th>RI 60 s + Sound Group</th>
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<tr>
<td>Mean</td>
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<tr>
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<td>49.4</td>
<td>18.87</td>
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Mean 28.30  Standard Error 24.13
Value     20.90
Mean 24.90  Standard Error 23.19
Value     17.92
Mean 15.10  Standard Error 13.28
Value     13.90
Mean 15.16  Standard Error 22.34
Value     20.44
Mean 24.43  Standard Error 17.18
Value     11.83
Mean 13.91  Standard Error 8.78
Value     11.91
Mean 21.60  Standard Error 13.56
Value     7.17
Mean 8.56  Standard Error 17.39
Value     23.15
Mean 27.12  Standard Error 17.05
Value     17.05

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Appendix V

B₂ Responses for Participants in the RI 5 s + Sound Group During the First Exposure and Second Exposure of Phase 2
Appendix V.

B₂ responses for participants in the RI 5 s + Sound group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
B₂ responses for participants in the RI 60 s + Sound group during the first exposure (top panel) and second exposure (bottom panel) of Phase 2.
Appendix W

A Review of Resurgence Literature with Human Participants
Appendix W.

A Review of Resurgence Literature with Human Participants

Resurgence is reemergence of a previously reinforced behavior when an alternative source of reinforcement is terminated or decreased (Lattal & St. Peter Pipkin, 2009). Resurgence is often studied in a three-phase sequence (Lieving & Lattal, 2003). During the first phase, a response is reinforced (Behavior 1, or B₁). During the second phase, B₁ is extinguished and an alternative response (B₂) is reinforced. During the final phase, both behaviors are on programmed extinction schedules. This can be viewed as a “test” context that can be used to evaluate persistence of B₂ and resurgence of B₁. Resurgence is said to have occurred if a reemergence of B₁ is seen during this test. Although the three-phase procedure is common, some researchers use multiple schedule arrangements to study the resurgence of previously extinguished behaviors (cf. Mace et al., 2010, Study 3).

Resurgence has been demonstrated in both human and nonhuman animals with a variety of positive and negative reinforcers, including food (Lieving & Lattel, 2003), alcohol and drugs (Podlesnik, Jimenez-Gomez, & Shahan, 2006), social attention (Mace et al., 2010), escape from demands and other aversive conditions (Bruzek, Thompson, & Peters, 2009; Volkert, Lerman, Call, & Trosclair-Lasserre, 2009), tangible items (Lieving, Hagopian, Long, & O’Conner, 2004), and conditioned reinforcers in the form of computer points (Marsteller & St. Peter, 2012). Resurgence has been considered an important area of research, as this behavioral phenomenon is related to both relapse of problematic behaviors and the development of complex human behavior, including problem solving and creativity.
Many behavioral interventions involve teaching and reinforcing more desirable behaviors to replace problematic ones. Some examples include coping skills to replace depressive behaviors or drug use and healthy eating and exercise regimens to replace behaviors contributing to obesity (Wacker et al., 2011; Bouton, 2014). Resurgence is one mechanism related to treatment relapse in these areas (Lattal & St. Peter Pipkin, 2009).

One area of particular interest has been resurgence related to interventions using differential reinforcement (DRA) for treating severe problem behavior (Doughty & Oken, 2008; Lattal & St. Peter Pipkin, 2009). DRA is a commonly used intervention in which the focus is to extinguish the target behavior and reinforce pro-social behavior (e.g., a communication response) (Petscher, Rey & Bailey, 2009). The first two phases of a resurgence paradigm mirror the arrangement that clients with severe problem behavior may encounter in the natural environment during treatment. Prior to intervention, a target behavior such as aggression (B1) would have a history of reinforcement (e.g., in the form of social attention or access to tangible items). A DRA procedure could be implemented in which aggression is extinguished, and a mand (B2) is reinforced. If there is subsequently a lapse in treatment integrity, this could be conceptualized as the third phase described above, or a “resurgence test” condition. For example, a care provider might ignore the mand, in which case aggression could resurge. Alternatively, some intentional conditions could cause resurgence of problem behavior, such as planned schedule thinning of the DRA schedule (Volkert, Lerman, Call, & Trosclair-Lasserre, 2009). Consequently, understanding the variables that affect resurgence can help inform recommendations for applied interventions to protect against this form of treatment relapse.
A literature review by Lattal and St. Peter Pipkin (2009) outlined the variables affecting resurgence. Lattal and St. Peter Pipkin described how these variables might affect resurgence in applied practice and offered recommendations for avoiding resurgence during treatment. They noted (information in italics inserted):

The research reviewed herein suggests the significance of resurgence as a behavioral process operating in both laboratory and applied environments. Many of the claims with respect to human behavior, including those made here, are extrapolative from laboratory research with nonhuman animals. Of the three studies directly examining applied implications of resurgence (Bruzek, 2007; Lieving et al., 2004; Volkert, 2007), two are recent, yet unpublished, dissertations [the first and third references were subsequently published in peer-reviewed journals in 2009]. This is promising, however, as it suggests that basic research related to resurgence is beginning to be infused into application. The implications of resurgence in terms of understanding the origins of unwanted behavior during treatment regimens, failed treatment effects, and facilitating problem solving (cf. Epstein, 1985, 1991), bode well for its continued investigation in both research and application. (p. 263)

As should be apparent by this summary, most of their suggestions were derived from studies that involved nonhuman animals. They made several recommendations for extending the resurgence literature to human participants (see Table 1). Since that time, applied researchers have shown more interest in the resurgence phenomenon, because of its potential applied significance, and more research with human participants has been published. The purpose of the current paper is to review the published investigations of resurgence with humans since Lattal and St. Peter Pipkin (2009) and relate their findings to the more recent publications.
Table 1. Recommendations for further research from Lattal & St. Peter Pipkin (2009) provided by phase.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Recommendations</th>
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<tbody>
<tr>
<td>Reinforcement Phase</td>
<td>•Further analysis of resurgence of responses part of response class hierarchies</td>
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<tr>
<td></td>
<td>•Determine variables that affect resurgence following negative reinforcement</td>
</tr>
<tr>
<td></td>
<td>•Further analysis of reinforcement variables in Phase 1 that affect resurgence: reinforcer type, schedule value, delay to reinforcement, and quality of reinforcement</td>
</tr>
<tr>
<td>Alternative Reinforcement Phase</td>
<td>•Assess parameter effects of the alternative reinforcement schedule affect suppression of B₁ in Phase 2 and subsequent resurgence in Phase 3</td>
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<td></td>
<td>•Assess the effects of fully extinguishing B₁ prior to initiating reinforcement for B₂ vs initiating extinction and DRA simultaneously</td>
</tr>
<tr>
<td>Resurgence Phase</td>
<td>•Provide several other measures of resurgence in addition to rate of responding, such as: latency to onset, duration, and magnitude</td>
</tr>
<tr>
<td></td>
<td>•Assess the effects of different methods of extinction (discontinuation of reinforcement deliveries) vs eliminating the response-reinforcer relationship with response-independent delivery of reinforcers</td>
</tr>
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</table>

Methods

A literature search for articles published in the field of psychology was conducted through Scopus using the term “resurgence” and a date range of 2009 or later. One hundred and three studies were identified. The abstracts were reviewed to determine whether the topic was indeed related to behavioral resurgence, whether an independent variable was manipulated, and to identify the subject population. Articles were excluded if they were determined to be a discussion paper (n=8) or a study of resurgence using a nonhuman animal population (n=12). A total of 72 articles were excluded because...
although the word “resurgence” appeared, it did not involve the subject of behavioral resurgence (e.g., the word “resurgence” appeared in the article to describe that there has been an increase in research interest for a particular concept), or the article focused on a different behavioral phenomenon and mentioned the concept of resurgence in the introduction or discussion but did not manipulate or measure variables related to resurgence. One article was excluded because it was not available in English. A total of 12 articles remained. The reference lists of the identified articles were then reviewed to identify additional empirical studies of resurgence that did not appear on the Scopus search and were within the specified date range; two additional articles were identified in this search. Two articles that appeared in the Scopus search and were within the data range are not summarized in this paper because they were already included in the review by Lattal and St. Peter Pipkin (2009). The two excluded articles were Volkert, Lerman, Call, and Trosclair-Lasserre (2009) and Bruzek, Thompson, and Peters (2009). Four additional articles identified in the Scopus search were also excluded from this review, because they involved studies of establishing derived relations and measured resurgence of responses that had not previously been directly trained or reinforced. The four articles excluded for this reason were Doughty, Cash, Finch, Holloway, and Wallington (2010), Doughty, Kastner, and Bismark (2011), Doughty, Leake, and Stoudemire, (2014), and Hernandez, Medina, and Aleen (2009). These papers appeared to be beyond the scope of interest for purposes of this literature review, as the author’s aim was to study resurgence as it related to treatment of problem behavior.

The remaining articles were then separated into two broad categories based on methodology of the study: human operant and clinically relevant studies. Articles were
assigned to the human operant category when resurgence was studied in the context of an arbitrary task (e.g., such as computer-clicks) as opposed to a socially-relevant response. Articles were assigned to the clinically relevant category if the dependent variable(s) included behavior(s) that were clinically important themselves (e.g., pro-social communication, problem behavior, etc.). If an article included more than one experiment and utilized different dependent variables across experiments, the article was included in both categories, and the experiments are discussed individually in the relevant section (Marsteller & St. Peter, 2012). Three studies were considered human operant and 8 studies involved clinically relevant responding. A brief summary of these studies and is provided below, followed by a synopsis of broad conclusions that can be drawn related to resurgence in human participants and the applied implications derived from this line of research. Finally, a summary of suggestions for additional research is presented to further a comprehensive view of resurgence related to human behavior in the future.

**Human Operant Investigations of Resurgence**

Human operant preparations are a useful tool for conducting translational research (Mendres & Borrero, 2010). These procedures can be used to extend findings from the nonhuman literature to highly controlled studies with human participants or to learn more about a phenomenon demonstrated in an applied study. Human operant methods involve experimental tasks that employ the use of simple and arbitrary dependent variables (e.g., button-pressing, clicking shapes on a computer screen, or operating a microswitch). Since the purpose of human operant studies is usually to study a basic behavioral mechanism in humans, recruitment of participants often does not require drawing a sample from a
specialized population or selecting individuals who have a particular clinical need. Arbitrary responses that are non-harmful, easy to measure, and for which a specific history of reinforcement can be established are selected to serve as an analog to clinically relevant behavior. Three studies of resurgence were found to have been published since 2009.

Using a human operant preparation, Marsteller and St. Peter (2012) conducted a systematic investigation of “treatment integrity failures” on the effects on resurgence with three participants. Treatment integrity failures have been observed to come in at least two forms: errors of omission and errors of commission (St. Peter Pipkin, Vollmer, & Sloman, 2010). An error of omission is when there is a failure to deliver a programmed consequence (e.g., criteria were met to earn a scheduled reinforcer, but the reinforcer was not delivered). An error of commission is the delivery of a consequence at an unscheduled time (e.g., a reinforcer was not earned and was delivered in error). Previous applied research by St. Peter Pipkin and colleagues had investigated the effects of varying treatment integrity failures by programming omission errors. St. Peter and colleagues found very little resurgence of problem behavior in contrast to what would be expected given the resurgence literature (e.g., Volkert, Lerman, Call, & Trosclair-Lasserre 2009). The Marsteller and St. Peter study consisted of two experiments, the first of which was conducted in a human operant arrangement in order to provide a controlled translational investigation to address this discrepancy. (The second experiment extended these findings in an applied setting and will be summarized in the clinically-relevant section of this paper.) The experimental task consisted of a computer program with two different colored circles moving across the screen. The dependent variable was the
number of clicks on each circle. Consequences (computer points) were delivered contingent on clicks, and the schedule of reinforcement differed depending on the phase. As with most resurgence research, the study consisted of multiple phases. During Phase 1, reinforcement was programmed for responses on B₁ (e.g., clicking on a red circle) on an FR 1 schedule. Phase 2 was a DRA phase in which B₂ (e.g., clicking on a black circle) was reinforced on and FR 1, and there were no programmed consequences for B₁. The first resurgence test phase included programmed omission errors. In this phase, earned reinforcers were not consistently delivered. Reinforcers were delivered for B₂ with a probability of 0.7 (rather than 1.0 probability when an FR 1 schedule was in place). The purpose of this was to simulate lowered treatment integrity, such as when care providers commit errors of omission by failing to deliver the reinforcer now and then. The second resurgence test phase was a typical extinction test in which there were no programmed consequences for either response. All participants experienced both the omission error test condition and the extinction test condition. The omission-error condition produced resurgence of B₁, but to a lesser degree than the resurgence observed during the extinction phase. These results demonstrated that lapses in treatment integrity involving errors of omission are likely to cause resurgence of clinically important behaviors. These results are congruent with the findings presented by Volkert and colleagues, demonstrating that thinning the alternative reinforcement schedule (whether intended or unintended) resulted in resurgence.

It is important to study the phenomenon of resurgence in its own right, in part to understand the frequency with which this phenomenon is observed. However, it is also important to evaluate methods of decreasing the probability of resurgence or avoiding it.
altogether. After treatment for problem behavior has been implemented, the last thing care providers and practitioners wish to see happen is for problem behavior to re-emerge. Some human operant research is aimed at this goal. Human operant work in this arena is important, because the variables affecting resurgence can be studied carefully without putting an individual at risk of harming himself or others, and the schedules and histories of reinforcement can be controlled more easily than in a naturalistic context.

In a translational study aimed at investigating a potential method for decreasing resurgence, McHugh, Procter, Herzog, Schock, and Reed (2012) studied the effects of mindfulness training on an arbitrary computer response. Mindfulness training involves teaching individuals to direct their attention to thoughts, emotions, and other stimuli currently present on a moment-to-moment basis. Participants were assigned to one of two conditions: a guided mindfulness task in which participants were instructed to focus on stimuli currently present in the environment (e.g., their own breath) or an unfocused attention task in which participants were instructed to let their thoughts drift to past and future events. The first experiment in this study did not test for resurgence. It simply evaluated whether participants who were exposed to the 15-minute guided mindfulness exercise were more or less sensitive to subsequent extinction condition than participants assigned to the unfocused attention task. The authors found that, indeed, those participants who received the mindfulness exercise were more sensitive to subsequent extinction conditions, suggesting that mindfulness exercises might then affect resurgence.

The second experiment in the McHugh et al. (2012) study did evaluate resurgence. Thirty participants between the ages of 21 and 60 participated in a human operant task using multiple schedules to assess resurgence. The dependent variable was
pressing the spacebar when a circle appeared on the screen. During Phase 1, responding was reinforced on a multiple VR-20 VI-Yoked schedule. During Phase 2, participants were presented with a multiple FI-15 s FI-15 s schedule. Participants then participated in either a mindfulness or unfocused attention activity for 15 minutes. Finally, during Phase 3 there were no programmed consequences for either response. During the resurgence test, the individuals in the group that received mindfulness training demonstrated a lack of resurgence during Phase 3, while the control group showed higher resurgence of B₁. These results suggest that teaching mindfulness might make individuals more “sensitive” to current contingencies. Because mindfulness tasks are directed at focusing attention on in-the-moment stimuli, they task may decrease participant engagement with verbal rules that might promote resurgence. For example, participants may continue engaging in response patterns based on rules that no longer match the current contingencies, such as responding on B₁ will earn points. Another possibility is that mindfulness tasks might result in focused attention on the current moment and increase the saliency and control of the contingencies in effect and decrease the likelihood participants will continue to respond during periods of extinction. Mindfulness is becoming an increasingly common component of clinical intervention, such as Dialectical Behavior Therapy, which teaches clients mindfulness and a variety of skills to replace target behaviors (Linehan, 2014). The McHugh et al. study provides preliminary evidence that one benefit to mindfulness interventions may be a decrease in potential relapse of undesired behaviors. However, these benefits may be restricted in clinical practice to clients with the verbal repertoires needed to participate in mindfulness activities.
Resurgence of Clinically Relevant Behavior

The studies examined in the previous section examined resurgence using non-clinically relevant behaviors. As stated previously, such studies are helpful for a better understanding of the phenomenon, itself, and for identifying variables that may or may not impact the extent to which resurgence occurs. However, in order to determine how these variables improve actual treatment effectiveness, they need to be studied in the context of socially significant problems. Articles reviewed in this section all involved dependent variables that were clinically important themselves (e.g., pro-social communication behaviors, problem behavior). Researchers selected the participants in these studies based on a direct clinical need (e.g., history of engaging in severe problem behavior) and/or because they represented populations that often receive behavior analytic services (e.g., children diagnosed with autism spectrum disorders). Generally speaking, studies in this category either focused on demonstrating conditions sufficient to produce resurgence of clinical behaviors or on potential variables that could be manipulated to affect the probability, or amount, of resurgence of these behaviors.

Studies Demonstrating Resurgence of Clinically Relevant Behavior

Although laboratory research has reliably produced resurgence in humans, one could ask whether resurgence actually occurs in practice. Recall the Marsteller and St. Peter (2012) study described above. In their first experiment (a human operant experiment), Marsteller and St. Peter demonstrated that omission errors during intervention resulted in resurgence of B1. The purpose of Experiment 2 was to extend this to an individual engaged in clinically relevant behaviors. The participant was a 7-year-old
male who was diagnosed with autism and ADHD. He was being treated for problem behavior including aggression, disruptive behavior, and inappropriate vocalizations. These problem behaviors were maintained by social attention, as shown in a functional analysis conducted prior to the experiment. During Phase 1, responses on B₁ were reinforced on a FR 1. During Phase 2, responses on B₁ were put on extinction and responses on B₂ were reinforced on an FR 1. The experimenters compared resurgence under the condition of omission errors (defined as 70% accuracy delivery of earned reinforcers). Like in their human operant experiment, resurgence was observed during both the extinction and omission phases, though resurgence occurred to a greater degree during extinction. This study demonstrated that resurgence may be observed when treating problem behavior with DRA interventions, and that this may occur when there are errors of treatment fidelity (e.g., when only some reinforcer deliveries are missed) as well as total extinction. Thus, this study replicated findings of Experiment 1 in a clinically relevant situation.

A very common DRA intervention for problem behavior is functional communication training (FCT), in which the alternative response is a mand reinforced by the same stimulus that previously maintained problem behavior (Tiger, Hanley, & Bruzek, 2008). A clinically relevant question might be, what happens if the newly acquired mand is placed on extinction? For example, what might occur when a child requests attention, but the care provider is not able to provide attention each time it is requested? Wacker et al. (2011) investigated the long-term effects of functional communication training and tested resurgence of problem behavior during extinction probes at intermittent points during treatment. Participants were 8 children with
developmental disabilities and limited vocal repertoires. The children were between the ages of 2 and 4 years at the onset of the 2-year project. All participants were referred for treatment because they engaged in problem behavior such as aggression, property destruction, and self injury. Functional analyses indicated problem behavior was maintained by escape from demands. The participants’ mothers served as therapists implementing FCT. Participants were taught to operate a microswitch as a mand for a break. Extinction treatment challenges were introduced to determine whether the problem behavior returned during extinction challenges. In addition to the extinction challenges, other challenges were introduced in the form of extended extinction, introduction of novel tasks, removal of the microswitch, and competing concurrent reinforcement of both the problem behavior and target behavior. Resurgence was seen in the early challenges. The treatment effects eventually persisted during challenges as evidenced by cessation of resurgence over time. These results are promising because they indicate that although treatment effects may be tenuous early in FCT, long-term treatment implementation should decrease the chances of relapse during planned and unplanned challenges. The authors suggest that exposing treatments to challenges is an important way to test durability of interventions and could be used in applied practice as a method for gauging when to decrease treatment support. However, it was unclear what effects the repeated extinction probes had on behavior. Basic research has evaluated the effects of prolonged exposure to DRA with and without the delivery of repeated extinction probes (Sweeny & Shahan, 2013). The results of that research suggest that Wacker and colleagues’ results could be attributed to the duration of time exposed to DRA, rather than the introduction of repeated resurgence tests. More research is needed to understand the effects of long-
term exposure to treatment and repeated exposures to “treatment challenges” on resurgence.

In a related study, Wacker and colleagues (2013) evaluated whether the presence or absence of stimuli correlated with the intervention (e.g., microswitches) affected resurgence. In this study, 3 children diagnosed with developmental disabilities receiving treatment for self-injurious behavior, aggression, and property destruction. Problem behavior was primarily maintained by escape from demands but also showed sensitivity to social attention. Following FCT, during which pressing a microswitch produced reinforcement, resurgence probes were implemented with extinction when the microswitch was present and absent. Resurgence occurred during all challenges regardless of whether the microswitch was present. It was hypothesized that resurgence might be lower when stimuli correlated with reinforcement during intervention were not present. However, they found that resurgence occurred even in the absence of stimuli correlated with reinforcement of the alternative response. When the microswitch was present, resurgence at similar levels was observed, even though participants often continued engaging in the alternative response. In other words, the presence of discriminative stimuli associated with reinforcement of alternative behavior, is not sufficient for maintaining suppression of the problem behavior.

**Studies Aimed at Reducing Resurgence of Clinically Relevant Behavior**

If resurgence is a phenomenon that regularly occurs in clinically relevant situations, then a primary question is how can it be avoided or mitigated? Mace and colleagues (2010) conducted one of the first evaluations specifically aimed at decreasing
the occurrence of resurgence. In this 3-part study, the authors first demonstrated resurgence of problem behavior, then investigated a potential method for decreasing resurgence in a nonhuman experiment, and finally tested the efficacy of this method with clinically relevant target behavior. During the first experiment, researchers demonstrated resurgence of escape maintained problem behavior during an extinction phase in 3 children diagnosed with developmental disabilities. Experiment 2 demonstrated that training an alternative response in a context not associated with reinforcement of the initial response resulted in less resurgence in rats. In Experiment 3, a similar evaluation was done with two individuals diagnosed with developmental disabilities. The purpose was to evaluate the effects of teaching the alternative response in different contexts on resurgence of problem behavior. Both participants displayed disruptive behaviors, such as physical aggression and property destruction. Functional analyses of these problem behaviors demonstrated they were maintained by escape from demands. This comparison was done using a multiple schedule arrangement, which differs from the 3-Phase arrangement used in Experiment 1. The arranged components (schedules) will be described. During baseline, the target problem behaviors were reinforced. During Component 2, an alternative behavior was reinforced in the same context as Component 1. During Component 3, the same alternative behavior was reinforced in a separate context (room). An extinction test was conducted in all contexts. The most resurgence was observed when the alternative behavior had been reinforced in the same context that in which the problem behavior had been reinforced. Resurgence was much lower when the alternative behavior had been reinforced in a context different from that in which problem behavior had been reinforced previously. These results suggest that one method
for decreasing resurgence might be to first conduct DRA in a different context from historical reinforcement of the problem behavior. Future research should assess the use of a different training context for DRA in isolation, without also including a component in which the alternative response is reinforced in the original context, to determine if minimal resurgence is still achieved.

Another way to decrease the likelihood of undesired resurgence might be to train and reinforce multiple appropriate mand topographies. This might be effective because perhaps if one mand topography is not reinforced, the individual might engage in other appropriate responses (e.g., other mands) rather than problem behavior. Hoffman and Falcomata (2014) conducted a study with three participants who ranged in age from 7 to 11 years and were diagnosed with autism. All participants had limited communication repertoires and engaged in aggression with a hypothesized tangible function, although no functional analysis was conducted. Mand topographies were a card exchange and activation of a microswitch. During the first part of the study, the first mand topography was reinforced, and then extinguished. Next, a second mand topography was reinforced. The final phase was a resurgence test in which both mand topographies were put on extinction. During this extinction challenge, resurgence of the first mand was observed prior to resurgence of the problem behavior, despite the longer reinforcement history of problem behavior. The results of this study suggested that practitioners should consider teaching more than one mand response in order to avoid future resurgence of problem behavior with the hope that the alternative mand response will resurge rather than problem behavior.
Another possible modification to effectively decrease the probability of resurgence in applied settings could be to make interventions easier to implement. Interventions that are easier to implement may be implemented with greater fidelity. Basic research findings have suggested that fixed-time reinforcement in Phase 3 of a resurgence test prevents resurgence of B1 (Lieving & Lattal, 2003, Experiment 3). Fixed-time (FT) reinforcement schedules are a form of extinction in that they break the response-reinforcement contingency. Marsteller and St. Peter (2012) assessed the use of FT schedules during Phase 3 of an extinction challenge in 4 participants with diagnoses of mental health and/or developmental disabilities who engaged in problem behavior. All participants had a vocal communication repertoire. Each participant experienced two different resurgence tests in a counterbalanced order: (a) a traditional phase of extinction in the form of no programmed consequences for either B1 or B2, and (b) a FT reinforcer delivery phase. Fixed time reinforcement was implemented by yoking time-based delivery of the reinforcer to the mean inter-reinforcement interval during the DRA phase, during which a mand response was taught as a replacement for problem behavior. Resurgence was observed in at least one extinction test for all participants. However, only one participant demonstrated resurgence during one session of the FT reinforcer delivery condition. The results of this study suggested that the use of fixed-time reinforcement may provide a simple intervention option (in that delivery may be easier than DRA for behavior change agents), in situations where treatment integrity of DRA is a concern. One limitation of FT interventions, however, is that they may decrease the motivation to engage in the replacement response (Goh, Iwata, & DeLeon, 2000). In Marsteller and St. Peter, mand engagement was low during the FT test, but was observed
at comparable levels during the DRA phase. Future research should be conducted to
determine to what extent FT schedules might be useful for decreasing the potential for
relapse of problem behaviors.

There may also be a variety of ways the DRA phase can be implemented to affect
resurgence. Previous nonhuman research has suggested there are a variety of variables
related to the schedule of reinforcement implemented during the DRA phase that could
More recently, researchers have begun to extend these questions to human participants.
For example, Reed and Clark (2011) conducted a study to explore how density and
duration of alternative reinforcement affected resurgence of appropriate behavior.

Participants were 24 children between the ages of 7 and 15 years diagnosed with an
autism spectrum disorder. Target behaviors were 2- to 3-second play sequences with a
toy (e.g., play dough). First, a play sequence was taught and reinforced with an edible
item on a VR 3 reinforcement schedule. Then extinction, in which no responses were
reinforced was implemented. Next, a second play sequence with a different toy was
taught and reinforced; the toy used in the first sequence was not present during this phase.

There were three groups of participants, and the reinforcement schedule varied across
groups during this second play sequence. The behaviors in the play sequence were
reinforced on either a VR 4 for 30 minutes, VR 2 for 30 minutes, or VR 4 for 60 minutes.
Finally, a resurgence test, in which neither behavior was reinforced, was implemented.
The results indicated the more reinforcers for the target behavior, the less resurgence
observed. This finding is not congruent with findings from previous nonhuman research
(Lieving & Lattal, 2003). Previous studies have demonstrated that the more reinforcers
associated with experimental context, the more resurgence (persistence) is observed during a challenge. Future research is warranted to explore this discrepancy between human and nonhuman studies to determine whether the difference can be attributed to differences in methodology, which may reveal other important variables related to resurgence.

In another study investigating effects of reinforcement parameters, Pritchard, Hoerger, Mace, Penney, & Harris (2014) evaluated the effects of alternative reinforcer density for B2 (the replacement response taught during DRA). The experimental arrangement utilized a 2-component multiple schedule, rather than the sequential 3-phase resurgence preparation utilized in the previously described studies. This study assessed the effects of reinforcer density on both reinstatement and resurgence. Reinstatement is another relapse phenomenon in which the response reemerges following response-independent delivery of the reinforcer. The participant was a 16-year-old male who engaged in aggression and disruptive behavior maintained by attention. First, a functional analysis was conducted to determine the function of the problem behaviors. Next, two different therapists administered different reinforcement schedules: B2 (a communication response) was reinforced on a VI VT 30-s (Therapist 1) or VI VT 120-s (Therapist 2). Then, the therapists discontinued reinforcement for communication, and problem behavior was reinforced on a VI 60-s schedule. Finally, an extinction test was administered to test for resurgence (one therapist implemented a 74-minute extinction condition and a few hours later the other therapist implemented an extinction condition for the same duration). Both reinstatement and resurgence were higher with the therapist who had the higher reinforcement schedule. In contrast to Reed and Clark (2011), the
results of this study were congruent with the predicted effects of reinforcer density based on previous nonhuman studies. Thus, it is unclear what effect various reinforcement schedules during DRA have on resurgence in clinically-relevant situations. More research is needed on the effects of alternative reinforcement schedules on subsequent resurgence.

Discussion

Resurgence is a behavioral phenomenon first identified in nonhuman animals (Leitenberg, Rawson, & Mulick, 1975). Resurgence has since been demonstrated in humans engaged in both arbitrary responses and clinically relevant behaviors. Behavioral relapse in the form of resurgence can occur both due to planned (e.g., schedule thinning) or unplanned extinction (e.g., errors involved in lowered treatment integrity) (Marsteller & St. Peter, 2012; Volkert, Lerman, Call, & Trosclair-Lasserre, 2009). Studying resurgence provides researchers with a translational base for extending findings from the basic literature and determining methods for protecting against relapse of problematic behaviors and increasing the persistence of desired alternative behaviors. The studies reviewed in this paper are indicative of a growing interest in studying resurgence of human behavior since Lattal and St. Peter Pipkin published their review in 2009. At the time, their suggestions related to clinically relevant behavior were primarily based on findings in the nonhuman literature. The work described here extends their recommendations, as there has been more human research on the topic.

A primary area of concern related to resurgence is that treatment integrity failures can lead to resurgence of undesired behaviors. Treatment integrity failures due to
caregiver distraction, staff turnover, training difficulties, and stress are common across settings in which individuals engage in problem behavior (Hasting, 2005). Investigations aimed at identifying effective interventions for training and motivating behavior change agents to deliver interventions with high fidelity are worthwhile ventures. However, it is also worth studying intervention components to discourage relapse of problem behaviors, even when errors in treatment integrity occur.

Wacker and colleagues (2011) demonstrated that the risk of resurgence eventually faded, suggesting that the effects of DRA persist when implemented for a long period of time. These results are promising because they suggest that resurgence may become less of a concern over time with DRA interventions. The duration of time needed to decrease persistence of problem behavior is likely variable between individuals. Future research should determine the relation of different variables and the amount exposure needed to achieve sustainable results. On a practical level, Wacker and colleagues suggest that extinction probes could be incorporated into the intervention process to gauge progress toward sustainable maintenance of behavior change or to identify when it would be appropriate to fade intervention components. Additionally, future research may use repeated probes over a long period as an additional metric by which to compare different modifications aimed at decreasing resurgence. The utility of resurgence challenges as a measure of intervention efficacy should be investigated further. Maintenance of behavior change has been suggested to be an important measure of the utility of a behavioral intervention. However, maintenance is often defined in the treatment of problem behavior as suppression of the problem behavior being maintained with steady and low rates of responding for a period of time with the intervention in place or demonstration that an
intervention is effective in more than one setting (e.g., an intervention effective at home is then shown to be effective at school). Wacker et al. (2011) argued in addition to promoting maintenance by planning for generalization (Stokes & Baer, 1977; Pritchard, Mace, & Penney, 2014), an emphasis should also be placed on the absence of relapse in the event intervention components break down.

One goal of resurgence research has been to identify recommendations for decreasing the probability or magnitude of resurgence of undesired behaviors. For example, Marstella and St. Peter (2014) suggest that adding a fixed-time schedule of reinforcement during intervention may be effective for preventing resurgence. FT schedules may be a desirable option, because they require relatively less effort for behavior-change agents and they do not require care providers to attend to occurrences of alternative behaviors. However, the FT schedule employed in their study involved reinforcer deliveries every 1 to 2 seconds, a schedule so dense that it would be very difficult to use in applied settings. Although the results of fading this schedule are unknown (because the authors did not test this), it seems likely that decreasing the amount of reinforcement by thinning the FT schedule would evoke resurgence (Shahan & Sweeney, 2011). Future research should test this directly and further investigate whether there are methods to use workable FT schedules that protect against resurgence.

Altering the reinforcement density for the alternative behavior is another candidate for reducing the likelihood of subsequent resurgence. However, whether this strategy would be effective is unclear at this time, because the two studies that evaluated this question yielded differing results. Reed and Clark (2011) showed a lean reinforcement schedule increased resurgence, whereas Prichard, Mace, and Penney
(2014) found the opposite. The predictions from the formula by Shahan and Sweeney (2011) as well as empirical nonhuman data from Sweeney and Shahan (2013) support that lean reinforcement schedules would be expected to result in less resurgence. There were some methodological nuances in the human studies that could have contributed to these results. One notable difference was that Reed and Clark did not provide access to the operanda for B₁ during the DRA phase. Specifically, the toy needed to perform the first play sequence was not present during the DRA Phase. A procedural variation in Prichard et al. was introduced by a confounding phase to their study, because they also wanted to assess for reinstatement. With only one participant, these phases were not counterbalanced. Thus, sequence effects may have impacted their results. Including an additional extinction and behavior-independent delivery of reinforcement prior to the resurgence test could have affected responding during the resurgence phase. Future research with human participants should further assess density of alternative reinforcement to determine appropriate recommendations for decreasing resurgence. In addition, the effects of procedural variations, such as preventing access to the operanda for B₁ (if possible) or introducing other stimuli on resurgence should be evaluated.

Another possibility for preventing resurgence is to train multiple alternative behaviors as was suggested by Hoffman and Falcomata (2014). In this study, teaching multiple alternative behaviors resulted in resurgence of other appropriate behaviors before reemergence of the problematic behavior. In an applied context, this may increase the probability that an appropriate response will be emitted and reinforced prior to resurgence of the problematic behavior. Future research could evaluate how many alternative responses need to be taught to prevent resurgence in a natural setting and how
different response characteristics, such as response effort for the different response, interact to prevent or contribute to resurgence.

In addition to these practical research questions regarding resurgence, there are other issues needing further attention. First, there is no universal agreement on the definition of resurgence (Marsteller & St. Peter, 2012). Lattal and St. Peter Pipkin (2009) recommended that researchers start to assess a variety of parameters in relation to resurgence in addition to rate of responding, such as latency to onset, duration, and magnitude. It does not seem that this recommendation has been widely incorporated into the current research base thus far. Similarly, Shahan and Sweeney (2011) suggest that resurgence should be considered on a continuum rather than as a singular construct. In other words, researchers should assess resurgence based on many parameters of responding rather than focusing conclusions on whether the behavior resurged or not based on an arbitrary binary definition. Second, further research to determine the role of mindfulness on resurgence is warranted. The study by McHugh, Procter, Herzog, Schock, and Reed (2012) showed promising results of mindfulness preventing resurgence during a human operant experiment. Given the incorporation of mindfulness training into clinical interventions (e.g., Dialectical Behavior Therapy; Linehan, 2014), it may be worthwhile to further investigate the role and mechanism of mindfulness in preventing treatment relapse. Furthermore, assuming mindfulness training does help reduce resurgence, how it might be applied to populations who have developmental disabilities and often limited verbal repertoires could be explored. Third, future research should continue to further investigate the generality of the recommendations based on the studies reviewed here. These studies have provided evidence of a relationship between
parameters of observed resurgence and the selected parameters of the independent variables. Future research should assess variations in the parameters of these independent variables (e.g., different schedule values), across a variety of behaviors, populations, and consequences.

The studies reviewed here support the value of empirically studying behavioral history (Pritchard, Hoerger, & Mace, 2014; St. Peter Pipkin & Vollmer, 2009). An organism’s history plays a large role in current repertoires, and behavior analysis is far from understanding the full score of history effects. Behavior change does not mean unlearning or that the effects of past learning are erased (Bouton, 2014). Resurgence is one phenomenon largely influenced by behavioral history. Understanding these phenomena can lead to practical tools for preventing relapse and building the persistence of desirable behaviors increasing the impact of interventions in meaningful ways.

Although progress has been made in understanding the variables affecting resurgence, and there are some potentially viable leads for implementing interventions in a way that prevents unwanted resurgence, the literature is still far from a standard intervention technology to protect against relapse. Continued efforts toward this goal seem to be a worthy venture for behavioral researchers.
Appendix W References


Mace, C. F., McComas, J. J., Mauro, B. C., Progar, P. R., Taylor, B., Ervin, R., & Zanigrillo, A. N. (2010). Differential reinforcement of alternative behavior increases resistance to extinction: Clinical Demonstration, animal modeling, and


