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A TRANSLATIONAL EXAMINATION OF ALTERNATIVE-RESPONSE
DISCRIMINATION TRAINING AND RESURGENCE

by

Kaitlyn O. Browning

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Psychology

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ABSTRACT

A Translational Evaluation of Alternative-Response
Discrimination Training and Resurgence

By

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Utah State University, 2020

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Resurgence refers to the increase of a previously reinforced target behavior following a worsening of conditions for a more recently reinforced alternative behavior. Resurgence is of particular clinical relevance because it may account for instances of relapse following differential-reinforcement-based treatments for problem behavior in clinical populations. For example, resurgence of severe problem behavior may occur during and after functional communication training when treatment integrity failures result in the worsening of conditions for the recently acquired alternative response. Given the clinical significance of resurgence, a considerable amount of research has focused on mitigating this effect. For example, previous applied research has reported reduced resurgence of severe destructive behavior in the presence of a stimulus that signaled the unavailability of alternative reinforcement. Importantly, the generality of this finding is unknown given the limited conditions under which resurgence was evaluated. In a reverse-translational evaluation using rats as subjects, the purpose of Experiments 1 and 2

was to extend this finding. In both experiments, the target response was first reinforced in baseline, and then target responding was placed on extinction in the following discrimination training phase. In this phase, discrimination of the alternative response was trained using a two-component multiple schedule in which an S^D stimulus signaled reinforcement for the alternative response and an S^A stimulus signaled alternative-response extinction. The goal of Experiment 1 was to determine whether a the S^A stimulus would mitigate resurgence of target responding if the alternative response also contacts extinction under conditions in which it was previously reinforced. During testing, the alternative response was placed on extinction in the S^D component during testing and resurgence of target responding was assessed in both components. Contrary to previous findings, the S^A stimulus did not prevent resurgence. The goal of Experiment 2 was to determine whether the particular testing conditions of Experiment 1 contributed to these discrepant results by comparing resurgence under multiple- and single-stimulus testing conditions. Resurgence was not affected by the particular testing procedures and rates of target responding during testing were comparable under S^D alone, S^A alone, or no discriminative stimulus conditions. Thus, the discrepancy between the current findings and those previously reported are not likely due to testing conditions. Instead, it is possible that particular aspects of the discrimination training procedures are related to the resurgence mitigating effect of S^A stimuli.

PUBLIC ABSTRACT

A Translational Evaluation of Alternative-Response

Discrimination Training and Resurgence

Kaitlyn O. Browning

Individuals with neurodevelopmental disorders such as autism spectrum disorders often engage in severe forms of problem behavior. Reward-based behavioral interventions are highly effective at reducing levels of problem behavior and teaching more appropriate and adaptive alternative behaviors. Despite successful reduction in problem behavior during treatment, problem behaviors are susceptible to reoccurrence or relapse. Resurgence is a type of behavioral relapse that is particularly relevant to the treatment of problem behavior and may occur following the worsening of conditions of a more recently learned alternative behavior. That is, if the rewards that were used to teach the alternative behavior are removed or lessened, problem behavior may increase as a result. Importantly, resurgence of problem behavior poses a major obstacle for these individuals and their families. Recent clinical research has suggested that resurgence of severe destructive behavior may be prevented using a specific signal to indicate that a particular behavior will not be rewarded. While this may be a promising method for preventing resurgence, the generality of this finding is unknown. Laboratory research with animal subjects is a useful way to study resurgence under highly controlled settings and can provide important information for the development of behavioral interventions in clinical settings. The general procedures of behavioral interventions used in the clinic were approximated in Experiments 1 and 2 with rats as subjects to expand on this

previous clinical finding. The goal of Experiment 1 was to determine whether resurgence would still be prevented by the signal that indicates reward unavailability when the reward is removed under conditions in which it was previously available. Contrary to previous findings, the signal for reward unavailability did not prevent resurgence; however, the conditions under which resurgence was tested were different between Experiment 1 and the previous clinical research. The goal of Experiment 2 was to determine whether this difference contributed to the discrepant findings. Resurgence was compared under conditions identical to Experiment 1 as well as conditions that more closely resembled those in the clinic. Resurgence was not differentially impacted by the testing procedures and, importantly, was not reduced under conditions similar to those used in the clinic. These results suggest that the conditions under which this signal may mitigate resurgence are limited and suggest avenues for future research to determine the necessary and sufficient conditions for this effect.

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Kaitlyn O. Browning

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CHAPTER I

INTRODUCTION

Resurgence refers to an increase of a previously reinforced behavior following the worsening of conditions for a more recently reinforced alternative response (Epstein, 1985; Lattal & Wacker, 2015; Shahan & Craig, 2017). Resurgence is of particular clinical significance because it may account for instances of relapse of problem behavior following otherwise successful interventions (Greer & Shahan, 2019). For example, functional communication training (FCT) is the most effective and commonly used treatment for severe problem behavior in individuals with neurodevelopmental disorders (Greer et al., 2018; Tiger et al., 2008). During FCT, the problem behavior is placed on extinction, and instead the client is taught an alternative functional communicative response (FCR) to request access to the reinforcer that previously maintained the problem behavior. As a result, instances of the problem behavior decrease and rates of the FCR increase. Despite these positive treatment effects, resurgence of severe problem behavior may occur during or following FCT (e.g., Briggs et al., 2018; Volkert et al., 2009). Given that resurgence poses a serious concern for maintaining positive treatment effects, research on resurgence is critical to the development of more effective treatment approaches for problem behaviors in clinical populations.

Along with applied research in clinical settings, resurgence may also be studied in highly controlled laboratory settings with nonhuman animals. This type of research is translational given that it has direct implications for the development of effective clinical treatments (St. Peter, 2015). In a three-phase procedure, a target response is first reinforced in the baseline phase. In the second phase, that target response is placed on

extinction while reinforcement is made available for an alternative response. Finally, resurgence of target responding is assessed in the third phase by placing the alternative response on extinction. Resurgence is evident if rates of the target response increase in the final phase relative to response rates at the end of the second phase (e.g., Craig & Shahan, 2016; Winterbauer & Bouton, 2010).

An important focus of resurgence research is to identify variables relevant to its mitigation or prevention (Wathen & Podlesnik, 2018). For example, several basic researchers have shown that treatment with periods of alternative-response reinforcement that alternate with periods of extinction reduces resurgence compared to treatment with constant alternative reinforcement (Schepers & Bouton, 2015; Thrailkill et al., 2019; Trask et al., 2018). Such treatment may reduce resurgence through increased discrimination of the presence and absence of reinforcers for the target and alternative response (Shahan et al., 2020).

Relatedly, discrimination training is often incorporated into FCT such that alternating periods of FCR reinforcement and extinction are differentially signaled by S^D or S^Δ discriminative stimuli, respectively (Saini et al., 2016). Such discrimination training may increase the feasibility of treatment implementation and reduce the risk of failures in treatment adherence. That is, one limitation of FCT is that the FCR is often reinforced according to a dense schedule of reinforcement to facilitate response acquisition. As a result, the FCR may occur at rates too high to maintain treatment adherence, which may result in resurgence. Discrimination training is used to reduce the overall levels of FCR and to teach the individual when reinforcement is and is not available (Greer et al., 2018; Tiger et al., 2008).

Additionally, there is evidence to suggest that discriminative stimuli that signal FCR extinction may be used to mitigate resurgence of problem behavior. Fuhrman et al. (2016) and Fisher et al. (2020) showed that resurgence of severe destructive behavior was substantially reduced in the presence of the S^{Δ} stimulus compared to resurgence under standard test conditions in which discriminative stimuli were absent. These studies provide preliminary evidence that a stimulus that signals alternative-response extinction can prevent resurgence; however, given that resurgence was only assessed with and without the S^{Δ} stimulus, the generality of this conclusion remains unknown.

In two reverse-translational experiments, the basic procedures of Fuhrman et al. (2016) and Fisher et al. (2020) were replicated using rats as subjects to further investigate the relation between alternative-response discrimination training and resurgence. The purpose of Experiment 1 was to determine whether a stimulus that signaled alternative-response extinction would mitigate resurgence of target responding if the alternative response also contacts extinction under conditions in which it was previously reinforced. Resurgence was tested under stimulus conditions identical to the previous discrimination-training phase in which the S^D and S^{Δ} stimuli alternated in a two-component multiple schedule, but the alternative response was also placed on extinction in the S^D component. Contrary to the findings previously reported, resurgence of target responding was not migrated under S^{Δ} stimulus conditions.

The purpose of Experiment 2 was to investigate whether the particular testing conditions of Experiment 1 contributed to the discrepant findings and to determine the independent effects of alternative-response discriminative stimuli on resurgence of target responding. Following discrimination training, resurgence was tested in the presence of

the S^D or S^A stimulus alone, in the absence of all discriminative stimuli, or under the same multiple-schedule conditions as in Experiment 1. Target responding during resurgence testing was not differentially affected by testing conditions or alternative-response discriminative stimuli. These results suggest that the conditions under which a stimulus that signals alternative-response extinction mitigate resurgence are limited.

CHAPTER II

LITERATURE REVIEW

Treatment of Problem Behavior

Individuals with neurodevelopmental disorders such as autism spectrum disorders or intellectual disabilities often engage in challenging behavior (Emerson et al., 2001; Harvey et al., 2009). Estimates of the prevalence of challenging behavior in this population have reported rates as high as 94% of individuals having engaged in at least one form of challenging behavior (Matson et al., 2008; Jang et al., 2011). Such problem behavior includes, but is not limited to, overactivity, stereotypy (e.g., Heyvaert et al., 2010), inappropriate sexual behaviors (e.g., Fyffe et al., 2004), inappropriate communicative behaviors (e.g., Frea & Hughes, 1997), inappropriate mealtime behaviors (e.g., Piazza et al., 2003), and non-compliance (e.g., Russo et al., 1981). Some more dangerous forms of problem behavior, such as self-injury, aggression, or property destruction are particularly worrisome because instances of these behaviors may threaten the safety and well-being of the individual and their caregivers (e.g., Iwata et al., 1994).

Additionally, the occurrence of challenging behavior in this population is a serious concern and poses a major obstacle for these individuals and their families (Crocker et al., 2006). That is, instances of challenging behavior are related to elevated caregiver and teacher stress (Lecavalier & Wiltz, 2006) and are one of the biggest challenges to improving participation and inclusion of individuals with neurodevelopmental disorders in the community (Bigby, 2012). Thus, development and implementation of effective treatments that reduce problematic behaviors is critical.

Behavioral interventions may include the use of extinction (e.g., Lerman & Iwata, 1996a), punishment (e.g., Foxx, 2003), noncontingent reinforcement (e.g., Carr et al., 2009), or response blocking (e.g., Lerman & Iwata, 1996b). While these procedures have been shown to be effective in reducing instances of challenging behavior, it is also important to teach appropriate replacement behaviors (Carr & Durand, 1985). Treatments that accomplish both goals may substantially improve the quality of life for these individuals and their families. The most commonly used and effective treatment for problem behavior in individuals with neurodevelopmental disorders is functional communication training (FCT; Durand & Moskowitz, 2015; Greer et al., 2018; Tiger et al., 2008). Such individuals often engage in problem behavior to seek attention from others or to escape nonpreferred activities (Beavers et al., 2013). As a result, the individual may learn that engaging in these particular behaviors is a reliable way to earn these desired consequences. The purpose of FCT is to reduce problem behavior *and* teach a more adaptive and appropriate communicative response that effectively expresses one's needs.

Prior to the start of FCT, a functional analysis (FA) is first conducted to identify a consequence that maintains the problem behavior (Iwata et al., 1994). Then during FCT, the problem behavior is placed on extinction and the client is taught an appropriate alternative response to gain access to the functional reinforcer that previously maintained the problem behavior. For example, the FA may indicate that the client is engaging in aggression as a means to avoid schoolwork. The problem behavior would then be placed on extinction such that instances of aggression do not prevent the request to complete schoolwork. Instead, the therapist may teach the client say "break please" to earn time

away from this nonpreferred activity. As a result, instances of aggression following academic requests decrease and the client learns to request a break when desired.

Functional communication training has been used to successfully reduce many topographies of problem behavior including self-injury, stereotypy, pica, destructive behaviors, aggression, among others (Kurtz et al., 2011) and is effective over a range of disorders and disabilities (Gerow, Davis, et al., 2018). Additionally, FCT has been validated for use in many settings, including inpatient (Hagopian et al., 1998) and outpatient (Kurtz et al., 2003) facilities; in school (Mancil & Boman, 2010; Rivera, et al., 2019) or home (Gerow, Hagan-Burke, et al., 2018; Harding et al., 2009) settings; and even adapted for remote delivery via telehealth (Lindgren et al., 2020).

Resurgence

Despite the efficacy of FCT in reducing problem behavior, long-term behavior change is difficult to sustain (Bouton, 2014) and problem behavior is susceptible to reoccurrence or *relapse*. Specifically, resurgence refers to an increase in a previously reinforced behavior following the worsening of conditions for a more recently reinforced alternative response (Epstein, 1985; Lattal & Wacker, 2015; Shahan & Craig, 2017). Resurgence is of particular clinical significance because it may contribute to instances of relapse during or following treatment. That is, resurgence of problem behavior may occur if the conditions of reinforcement for the FCR are worsened in some way. For example, Volkert et al. (2009) assessed the effects of extinction of the FCR on rates of aggression in three children diagnosed with a neurodevelopmental disorder. Following a baseline in which aggression was reinforced, aggression was placed on extinction during FCT and the participants could instead earn reinforcers for engaging in an FCR. As a result,

aggression was reduced to near-zero levels; however, resurgence of aggression was observed when the FCR was subsequently placed on extinction, and in some cases, aggression increased to levels above that of baseline.

As stated above, resurgence of challenging behavior may occur as the result of the worsening of conditions for the FCR, which includes manipulations other than complete FCR extinction. For example, Volkert et al. (2009) also observed resurgence of aggression in all three participants when the schedule of reinforcement for the FCR was changed from a fixed-ratio (FR) 1 to an FR-12, substantially reducing the rate of reinforcement. Further, Briggs et al. (2018) conducted a reanalysis of clinical data and found that resurgence occurred in 76% of the cases evaluated when the rate of FCT reinforcement was decreased. Resurgence has also been observed when treatment fidelity is challenged by errors of omission. Marsteller and St. Peter (2012) observed resurgence of aggression following treatment in which reinforcers for the alternative response was delivered with only 70% treatment fidelity in a child diagnosed with autism spectrum disorder (see also St. Peter Pipkin et al., 2010). Thus, findings from the applied literature suggest that resurgence poses a serious concern for maintaining positive treatment effects. Importantly, studying resurgence and identifying procedures that may be used to mitigate the effect could suggest more effective treatment approaches for problem behaviors in clinical populations (Greer & Shahan, 2019; St. Peter, 2015).

In addition to evaluating resurgence during FCT in clinical settings, resurgence may be examined in the basic laboratory with nonhuman subjects such as rats or pigeons. Given the procedural similarities between those used in treatment and those used in the laboratory, such research has direct implications for the development of effective clinical

treatments. In the laboratory, resurgence may be studied using a three-phase procedure. First, a target response is reinforced in baseline (e.g., pressing the right lever). Then, the target response is placed on extinction while reinforcement is made available for an alternative behavior (e.g., pressing the left lever) in the treatment phase. Finally, resurgence of target responding may be assessed by placing the alternative response on extinction. Resurgence is said to occur if target responding subsequently increases relative to the treatment phase (e.g., Craig & Shahan, 2016; Winterbauer & Bouton, 2010).

Given the clinical significance of resurgence, a considerable amount of research using both human participants and nonhuman subjects has been conducted to identify variables that impact resurgence and may be used to mitigate this effect (Wathen & Podlesnik, 2018). Specifically, several researchers have investigated the relation between the schedule of reinforcement for the alternative response and subsequent resurgence. For example, there is evidence in children (Marsteller & St. Peter, 2014), rats (Bouton & Trask, 2016; Trask et al., 2018), and pigeons (Lieving & Lattal, 2003) that shifting from response-dependent alternative reinforcement to response-independent reinforcement at the same rate does not produce resurgence.

Additionally, several researchers have demonstrated that placing an alternative response previously maintained with a relatively lower rate of alternative reinforcement on extinction produces less resurgence of target responding than extinction of an alternative response that was previously maintained with a relatively higher rate of reinforcement; however, lower rates of alternative reinforcement often result in more elevated target responding during treatment (Bouton & Trask, 2016; Craig & Shahan,

2016; Craig et al., 2016; Sweeney & Shahan, 2013a; Cançado et al., 2015). Additionally, this overall effect has been replicated when reinforcement rate is held constant and the magnitude of alternative reinforcement is manipulated (Craig, Browning, Nall, et al., 2017). Similarly, completely removing alternative reinforcement following gradual thinning of the rate of reinforcement may produce less resurgence than removing a consistently high rate of alternative reinforcement (Sweeney & Shahan, 2013a; Schepers & Bouton, 2015; Winterbauer & Bouton, 2012), but resurgence may still occur during schedule thinning (Briggs et al., 2018). These data suggest that conditions of alternative reinforcement that result in greater reductions in target behavior during treatment may also produce larger resurgence effects following treatment challenges.

Several researchers have also assessed whether longer treatment durations reduce resurgence compared to shorter durations. Leitenberg et al. (1975) observed less resurgence of target key pecking in pigeons following 27 daily sessions of treatment compared to 3 or 9 sessions; however, Winterbauer et al. (2013) found comparable levels of resurgence of lever pressing in rats following 4, 12, and 36 daily sessions; although, resurgence was numerically (but not statistically) higher in the 4-session group. Nall et al. (2018) also did not find statistically different levels of resurgence of target responding that was previously maintained by alcohol or cocaine self-administration following 5 or 20 daily sessions of treatment, but resurgence of alcohol seeking was numerically higher following 5 treatment sessions. Thus, data from the basic laboratory have produced mixed findings but generally suggest that treatment duration does not impact resurgence.

In the clinic, Greer et al. (2020) evaluated the effect of treatment duration on resurgence in six children who engaged in severe problem behavior. Resurgence of

problem behavior was comparable between the long and short treatment conditions even though the long treatment was three times as many sessions as the short treatment. Alternatively, Wacker et al. (2011) reported significant reductions in resurgence of problem behavior in eight children at the end of an extended treatment in which FCT was administered over an average of 14 months. Importantly, Wacker et al. (2011) conducted periodic extinction challenges across the course of treatment resulting in repeated resurgence tests. Problem behavior resurged during each extinction challenge, but the magnitude of resurgence decreased across successive tests, resulting in less resurgence in the final extinction challenge. Thus, it is unclear whether resurgence was reduced as the result of repeated exposure to alternative-response extinction or the duration of treatment.

In fact, several researchers in the basic laboratory have shown that repeated exposure to alternative-response extinction does reduce resurgence (Schepers & Bouton, 2015; Thraikill et al., 2019; Trask et al., 2018; but see Sweeney & Shahan, 2013b). As a means to clarify the relation between treatment duration and repeated alternative-response extinction and their effects on resurgence, Shahan et al. (2020) conducted a parametric assessment of treatment duration and resurgence in which rats were exposed to either 3, 7, 15, 23, or 31 daily sessions of treatment across groups. A sixth group was included in which rats were exposed to alternative reinforcement or extinction across alternating sessions during treatment. Their findings suggest that increasing the length of treatment does systematically reduce resurgence, but that the reductions are so small they are unlikely to be clinically significant; however, resurgence systematically decreased across successive alternative-response extinction sessions and was significantly smaller compared to resurgence following treatment with constant alternative reinforcement.

To explain this effect, Shahan et al. (2020) expanded on previous arguments (i.e., Trask et al., 2018) that on/off alternative-reinforcement treatment results in weaker resurgence through improved discrimination of the current response-reinforcer contingencies signaled by the presence and absence of alternative reinforcers. This conclusion suggests that improved discrimination of the prevailing contingencies of reinforcement may be a promising variable in mitigating resurgence.

Discrimination Training

The discrimination of response-reinforcer contingencies has traditionally been established through discrimination training. In discrimination training, a particular response is only reinforced in the presence of a specific stimulus, referred to as the S^D , and that response is extinguished in the presence of a second stimulus, referred to as the S^A (e.g., Rilling, 1977). That is, the S^D signals that reinforcement *is* available for a particular response while the S^A signals that reinforcement *is not* available. Effective discrimination is evident by differential responding in the presence of these different stimuli (e.g., Balsam, 1988), such that the response may occur more frequently in the presence of the S^D and less frequently in the presence of the S^A . More broadly, discrimination is related to the concept of stimulus control, which refers to the relation between changes in stimuli and resulting changes in behavior (Terrace, 1966).

Importantly, there is evidence that stimuli paired with reinforcement or extinction may mitigate resurgence and other forms of behavioral relapse. For example, Craig, Browning, and Shahan (2017) observed reduced resurgence of lever pressing in rats when a discrete visual stimulus previously paired with target and alternative reinforcement (i.e., the light in the food aperture) was presented response-dependently when the alternative

response was placed on extinction during testing. Similarly, Trask (2019) found that presentation of a tone (both response-dependently and -independently) previously paired with both target-response extinction and alternative reinforcement mitigated resurgence of target responding in rats. Additionally, presentation of discrete stimuli associated with response-extinction has also been shown to reduce other forms of relapse in rats including reinstatement, spontaneous recovery (Bernal-Gamboa et al., 2017), and renewal (Nieto et al., 2017; Willcocks & McNally, 2014).

Discrimination training has also been used in clinical settings during FCT to establish stimulus control of the FCR. Such stimulus control may be necessary to control the rate of the behavior as a means of avoiding inadvertent extinction (Tiger et al., 2008). That is, the FCR is typically reinforced according to a dense schedule of reinforcement (e.g., FR 1) to facilitate response acquisition early in treatment, but this may result in unmanageably high rates of responding. If the FCR occurs at a rate too high for the caregivers or therapists to maintain treatment adherence, the FCR may contact extinction resulting in resurgence. To reduce this possibility, the FCR may be placed under stimulus control such that discriminative stimuli are used during treatment to differentially signal when reinforcement for the FCR is available (S^D) or unavailable (S^A).

Discrimination training is typically incorporated into FCT by the use of a two-component multiple schedule in which periods of FCR reinforcement signaled by the S^D alternates in time with periods of FCR extinction signaled by the S^A (Saini et al., 2016). The duration of the S^A component may also be increased to reduce the overall rate of FCR reinforcement to further control the rate of the FCR (e.g., Betz et al., 2013; Hanley et al., 2001). In addition to increasing the practicality of FCT implementation,

discrimination training can also be used to promote rapid transfer of treatment effects. For example, Fisher et al. (2015) observed successful transfer of FCR discrimination across novel therapists and contexts, as well as transfer of both FCR discrimination and reduction in problem behavior across contexts when the discriminative stimuli from discrimination training were present in these novel settings. Greer et al. (2019) expanded on these findings by demonstrating successful transfer of both FCR discrimination and problem behavior reduction from the therapist to the caregiver.

There is also evidence to suggest that discrimination training in FCT may be used to reduce resurgence. For example, there are two studies that have demonstrated significant reductions in resurgence of destructive behavior in the presence of the FCR S^{Δ} stimulus following FCR discrimination training. The first study, by Fuhrman et al. (2016), assessed resurgence of destructive behavior in two children following FCT with and without FCR discrimination training. During discrimination training, FCT was conducted in a two-component multiple schedule in which the FCR was reinforced only in the component signaled by the S^D (i.e., green index card) and not in the component signaled by the S^{Δ} (i.e., red index card). Problem behavior was placed on extinction in both components. Following this treatment, resurgence was tested during extended exposure to the S^{Δ} in which reinforcement for the FCR was never available. In the control condition, traditional FCT treatment was conducted without discrimination training in which problem behavior was placed on extinction while the FCR was reinforced. Following traditional FCT, resurgence was tested by placing the FCR on extinction and no discriminative stimuli were presented. Instances of destructive behavior was substantially reduced under the extended S^{Δ} condition following FCT with discrimination

training compared to resurgence of destructive behavior following traditional FCT. These findings suggest that presentation of a stimulus that signals extinction of the alternative response will reduce or prevent resurgence of the target behavior.

However, it is important to note that one limitation of this study makes interpretation of their findings difficult. That is, the obtained rate of reinforcement for the FCR was much lower in the discrimination FCT treatment condition compared to the traditional FCT condition. While Fuhrman et al., (2016) intentionally thinned the rate of reinforcement for the FCR by increasing the duration of the S^{Δ} component relative to the S^D component during discrimination training, previous research described above has shown that the change in target behavior is much smaller following removal of lean or thinned rates of alternative reinforcement compared to removal of relatively richer rates. Thus, it is unclear whether the observed reduction in resurgence was the result of the S^{Δ} stimulus present during testing or the history of a lower rate of FCR reinforcement during treatment.

In the follow-up study, Fisher et al. (2020) extended the findings of the original experiment and addressed this limitation. In this study, resurgence of severe destructive behavior was assessed in the presence and absence of an alternative-response S^{Δ} stimulus in four children with neurodevelopmental disorders. Prior to treatment, the FCR was first brought under stimulus control using the multiple-schedule FCT procedure from the previous study. That is, the FCR was reinforced in the S^D component but not in the S^{Δ} component, and the rate of FCR reinforcement was thinned by increasing the duration of the S^{Δ} component. Following discrimination training, FCT was evaluated in two separate contexts using a multielement design. The general FCT procedures were identical across

contexts such that problem behavior was reinforced during baseline, problem behavior was extinguished while the FCR was reinforced during treatment, and resurgence was tested by placing the FCR on extinction. The contexts differed by the presence or absence of the discriminative stimuli previously established during pretraining. In the first context, the S^D was presented alone throughout the treatment phase, and the S^A was presented alone during resurgence testing. In the second context, the discriminative stimuli were not present during treatment or testing. Importantly, the researchers controlled for the rate of FCR reinforcement across contexts.

Consistent with the findings of from the initial study, resurgence of destructive behavior was substantially reduced in the presence of the S^A stimulus compared to in its absence. Importantly, because Fisher et al. (2020) controlled for the rate of alternative reinforcement across conditions, this experiment provides more compelling evidence that resurgence may be prevented by a stimulus that signals extinction of the alternative response; however, given that resurgence was only evaluated in the presence and absence of the S^A stimulus and not under S^D conditions, the generality of this conclusion is unknown.

CHAPTER III

EXPERIMENT 1

Purpose

Concepts from discrimination training, in which specific stimuli come to signal the availability (S^D) or unavailability (S^A) of reinforcement for a particular response, have been incorporated into FCT to increase the feasibility of treatment implementation. Importantly, previous applied research has shown that following discrimination training, resurgence of problem behavior may be prevented when the alternative response remains on extinction under extended S^A conditions compared to when the alternative response contacts extinction under conditions in which discriminative stimuli are absent.

However, the findings from this research are limited because resurgence was only assessed with and without the S^A stimulus. It comes as no surprise that resurgence may not occur under conditions in which the alternative response was never reinforced (S^A), but due to a failure in treatment adherence, it is very possible that the alternative response may contact extinction under conditions in which it was previously reinforced (S^D). Thus, it remains unclear whether resurgence would be mitigated in the presence of the S^A stimulus if the alternative response is also placed on extinction in the presence of the S^D stimulus that previously signaled reinforcement availability. The purpose of Experiment 1 was to address this question.

The general procedures reported by Fuhrman et al., (2016) and Fisher et al. (2020) were approximated in a reverse-translational experiment with rats as subjects. Following baseline in which target lever pressing was reinforced, rats received discrimination training in which alternative lever pressing was reinforced in one component of a

multiple schedule signaled by an S^D stimulus and extinguished in the second component signaled by the S^A stimulus, while target lever pressing was placed on extinction in both. In the final phase, resurgence of target responding was tested in both components in which the alternative-response extinction continued in the S^A component, and the alternative response was also placed on extinction in the S^D component.

Method

Subjects

Five experimentally naïve male Long-Evans rats served as subjects. Rats were approximately 71-90 days old upon arrival and were individually housed in a temperature- and humidity-controlled colony room with a 12:12/hr light-dark cycle (lights on at 07:00). Throughout the experiment rats had ad libitum access to water in the home cages and were maintained at 80% of their free-feeding weights by supplemental post-session feeding. All experimental procedures described below were conducted in accordance with Utah State University's Institutional Animal Review Committee guidelines.

Apparatus

Five identical Med Associates (St. Albans, VT) operant chambers were used. Chambers measured 30 cm x 24 cm x 21 cm and were housed in sound- and light-attenuating cubicles. Each chamber was constructed of two aluminum side panels, and a clear Plexiglas ceiling, door, and back wall. Two retractable levers on the right-side panel, with stimulus lights above them, were positioned on either side of a food receptacle that was illuminated when 45-mg grain-based food pellets (Bio Serv, Flemington, NJ) were delivered. A house light positioned at the top center of the left-side

panel was used for general chamber illumination. A 2,900 Hz tone generator positioned to the right of the house light was used to emit a 65-db tone. A white noise generator positioned adjacent to the chamber cubicles was used to emit white noise and mask extraneous sound during each experimental session. All experimental events and data collection were controlled by Med-PC software run on a computer in an adjacent control room.

Procedure

Experimental sessions were conducted seven days per week at approximately the same time each day. All sessions were at least 30 min excluding time for reinforcement delivery with the exception that session time during the Discrimination Training and Test phases could exceed 30 min (see below). During reinforcement deliveries, all experimental timers were paused for 4 s, the pellet dispenser dropped a single food pellet into the illuminated food receptacle, the lever stimulus lights darkened, and, when applicable, the discriminative stimuli remained present.

Training. Rats were first trained to consume pellets from the lit food aperture for three 30-min sessions. Food pellets were delivered response independently according to a variable time (VT) 60-s schedule, such that a single food pellet was delivered, on average, every 60 s. The VT schedule and all variable-interval (VI) schedules described below consisted of 10 intervals derived from Flesher and Hoffman's (1962) constant-probability distribution. Levers remained retracted and lever-stimulus and house lights were darkened throughout training.

Phase 1: Baseline. Sessions during Baseline began with insertion of the target lever (right-left, counterbalanced across subjects) and illumination of the target-lever

stimulus light. During the first session, the first target response immediately produced a food pellet, thereafter responses to the target lever produced food according to a VI 30-s schedule, such that a single food pellet was delivered following the target response, on average, every 30 s. This phase lasted 20 sessions.

Phase 2: Discrimination Training. Sessions during Discrimination Training began with insertion of both the target and alternative levers and illumination of both lever stimulus lights. During this phase, a two-component multiple schedule, comprised of an S^D and an S^Δ component, was used to train alternative-response discrimination. Components were signaled by either a constant house light and tone or flashing house light and pulsing tone (on/off every 0.5 s), counterbalanced across subjects. Responses to the alternative lever were reinforced according to a VI 5 s schedule in the S^D component, were placed on extinction in the S^Δ component, and target responding was extinguished in both. The VI timer only counted down during the S^D component, and if the VI timer did not elapse before the end of the S^D component, it was paused until the next S^D presentation, thereafter the timer continued. Additionally, if the VI timer elapsed and the rat did not earn the food pellet before the end of the S^D component, the food could not be earned until the next S^D component began. Each component was presented 15 times in strict alternation for a total of 30 component presentations per session, and component durations ranged from 10 to 110 s, averaging 1 min (see Shahan, 2002). In the first session, the S^D component was presented first, and the first alternative lever press immediately produced a food pellet, after which the VI timer began and components strictly alternated. During all subsequent sessions, the first component was selected randomly, and both components had equal probability of being selected. A 3-s change

over delay (COD) in the S^{Δ} component was arranged such that any alternative response made in the final 3 s of the S^{Δ} component delayed transition to the S^D component until an alternative response was not made for 3 s. The COD was included to avoid adventitious reinforcement of alternative responding in the S^{Δ} component by transition to the S^D component. Thus, time in S^{Δ} could exceed time in S^D , depending on individual subject's performance. This phase lasted 25 sessions.

Phase 3: Test. Sessions during the Test phase were identical to those in the previous phase with the exception that the alternative response was no longer reinforced in the S^D component. Thus, resurgence of target responding was assessed in both the S^D and S^{Δ} components. This phase lasted 5 sessions.

Data Analyses. The primary dependent variables of interest were target and alternative responses per min across sessions and phases and between components. Additionally, a discrimination index (DI) was calculated to evaluate alternative response discrimination in each session of Phases 2 and 3 by dividing alternative responses in the S^D component by total alternative responses in the S^D plus S^{Δ} components. Statistical significance was determined using $\alpha = .05$.

Results

Table 1 provides a summary of response rates, reinforcer rates, and discrimination indices across phases of Experiment 1 for individual subjects.

Phase 1: Baseline. Target response rates increased across sessions of Baseline for all rats and while response rates varied across subjects, obtained reinforcers/min were comparable (see Table 1).

Table 1.
Target and Alternative Response Rates, Discrimination Indices, and Reinforcer Rates for Individual Subjects Across Phases of Experiment 1.

| | Subject | Phase | | | | |
|------------|---------|-------------------|-------------------|----------------|-------------------|----------------|
| | | Ph 1 ^a | Ph 2 ^b | | Ph 3 ^c | |
| | | | S ^D | S ^Δ | S ^D | S ^Δ |
| Target/min | SD6 | 10.01 | 0.00 | 0.62 | 1.47 | 3.47 |
| | SD7 | 20.59 | 1.33 | 2.49 | 3.27 | 2.42 |
| | SD8 | 41.21 | 0.07 | 0.59 | 2.67 | 5.03 |
| | SD9 | 26.28 | 0.07 | 1.74 | 2.00 | 3.32 |
| | SD10 | 22.98 | 0.00 | 0.00 | 0.60 | 1.89 |
| Alt./min | SD6 | - | 51.13 | 34.33 | 32.67 | 19.14 |
| | SD7 | - | 69.53 | 21.69 | 21.80 | 6.93 |
| | SD8 | - | 88.67 | 15.07 | 27.27 | 12.65 |
| | SD9 | - | 62.33 | 18.19 | 29.73 | 9.03 |
| | SD10 | - | 95.00 | 22.96 | 23.27 | 6.38 |
| DI | SD6 | - | 0.58 | | 0.62 | |
| | SD7 | - | 0.76 | | 0.76 | |
| | SD8 | - | 0.85 | | 0.68 | |
| | SD9 | - | 0.77 | | 0.77 | |
| | SD10 | - | 0.80 | | 0.78 | |
| Rein./min | SD6 | 1.59 | 10.07 | - | - | - |
| | SD7 | 1.72 | 8.40 | - | - | - |
| | SD8 | 1.89 | 10.60 | - | - | - |
| | SD9 | 1.81 | 9.40 | - | - | - |
| | SD10 | 1.74 | 10.20 | - | - | - |

^aData from the average last three sessions of Phase 1 are shown, ^bData from the last session of Phase 2 are shown, ^cData from the first session of Phase 3 are shown.

Phase 2: Discrimination Training. Figure 1 displays target response rates in the S^D and S^Δ components across sessions of Phase 2 for individual subjects. Target responding decreased across sessions of Phase 2 in both components but were more elevated in the S^Δ component. A 2 x 25 (Component x Session) repeated measures

ANOVA conducted on these data support this conclusion. The effects of Component, $F(1, 4) = 18.98, p = .012, \eta_p^2 = .83$, and Session, $F(24, 96) = 14.66, p < .001, \eta_p^2 = .79$ were significant, but the Component X Session interaction, $F(24, 96) = 1.33, p = .169, \eta_p^2 = .25$, was not. This pattern was consistent across subjects as each rat showed more target responding in the S^{Δ} than in the S^D component during all sessions of Phase 2 (see Table 1 for Phase-2 terminal target response rates across components for individual subjects).

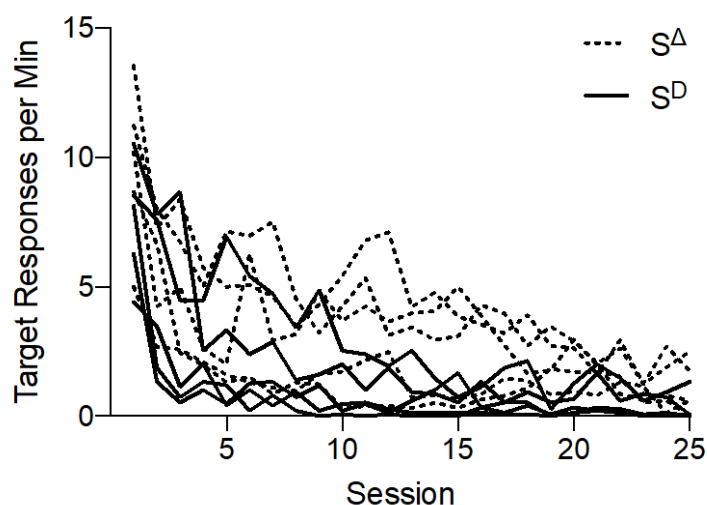


Figure 1. Target responses per min in the S^D and S^{Δ} components across sessions of Phase 2 for individual subjects in Experiment 1.

Figure 2 displays alternative responses rates for individual subjects in the S^D and S^{Δ} components across sessions of Phase 2. Alternative responding increased across sessions in the S^D component but remained low and stable across sessions in the S^{Δ} component. A 2 x 25 (Component x Session) repeated measures ANOVA supported this conclusion. The effects of Component, $F(1, 4) = 18.93, p = .012, \eta_p^2 = .83$, and Session, $F(24, 96) = 8.71, p < .001, \eta_p^2 = .69$, and the Component x Session interaction, $F(24, 96) = 8.06, p < .001, \eta_p^2 = .67$, were all significant.

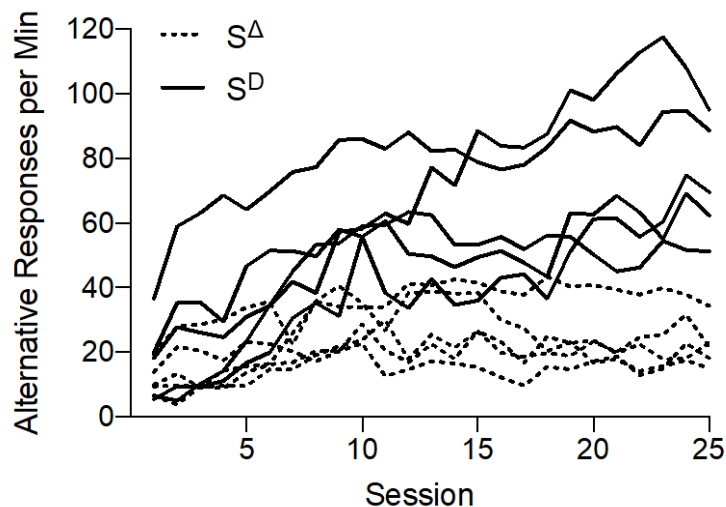


Figure 2. Alternative responses per min in the S^D and S^A components across sessions of Phase 2 for individual subjects in Experiment 1.

Figure 3 displays the alternative-response DI for individual subjects across sessions of Phase 2. A DI greater than 0.50 indicates more responding in the S^D component than in the S^A component. A one-sample t -test conducted on the DI averaged across the last five sessions of Phase 2 suggested that the proportion of responding in the S^D was significantly higher than 0.50, $t(4) = 4.40$, $p = .012$, $d = 1.97$. The individual subject data are consistent with this pattern such that three rats showed greater responding in the S^D component in every session of this phase and the remaining two displayed greater S^D responding by session 7 (see Table 1 for Phase-2 terminal alternative response rates across components and corresponding DI for individual subjects). Taken together, the data in Figures 2 and 3 suggest that rats effectively allocated alternative responding according to the arranged discrimination.

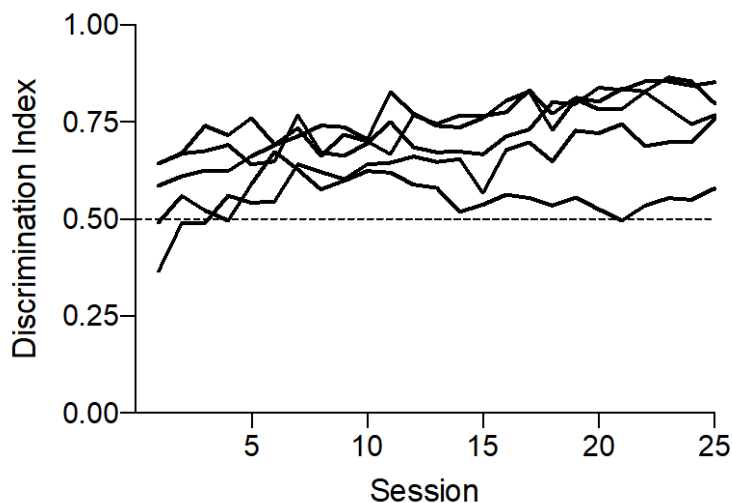


Figure 3. Alternative-response discrimination indices across sessions of Phase 2 for individual subjects in Experiment 1. Dashed line at 0.50 indicates equal responding across components.

Phase 3: Test. Figure 4 displays target responding during the last session of Phase 2 and across all five sessions of Phase 3 for individual subjects. The left panel displays target responding in the S^D component, and the right panel displays target responding in the S^A component. A 2 x 2 (Component x Phase) repeated measures ANOVA conducted on target response rates during the last session of Phase 2 and the first session of Phase 3 revealed a significant effect of Component, $F(1, 4) = 14.76, p = .018, \eta_p^2 = .79$, and Phase, $F(1,4) = 18.09, p = .013, \eta_p^2 = .82$, and a nonsignificant Component X Phase interaction, $F(1,4) = 0.37, p = .577, \eta_p^2 = .08$. The main effects suggest that target responding was generally higher in the S^A component and increased across phases in both components, but the nonsignificant interaction suggests that this increase in target responding was not different between components. The individual subject data are consistent with these conclusions. All rats showed a numerical increase in target behavior in the S^D component and four of five rats showed a numerical increase

in the S^{Δ} component (see Table 1); however, the magnitude of resurgence in each component varied across individuals: three rats showed a larger increase in the S^{Δ} component and the remaining two showed a larger increase in the S^D component. Thus, these data do not provide compelling evidence for reduced resurgence in the presence of the S^{Δ} stimulus.

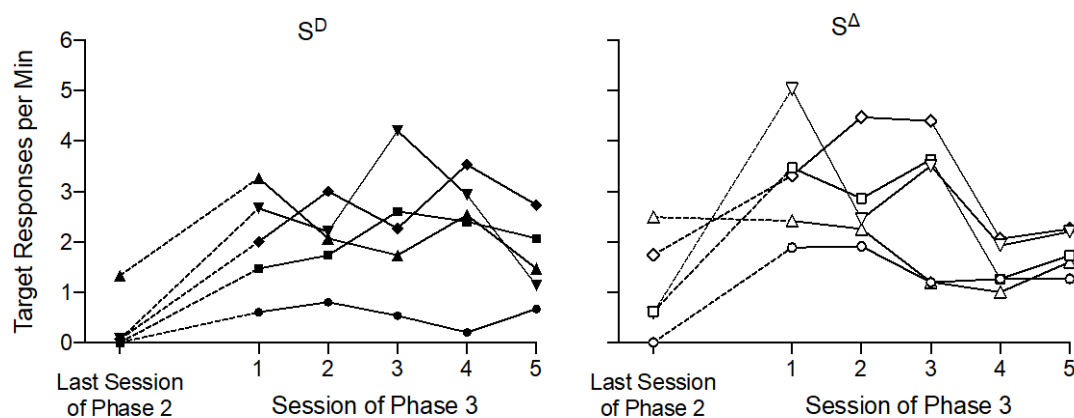


Figure 4. Target responses per min in the last session of Phase 2 and all five sessions of Phase 3 in the S^D (left panel) and S^{Δ} (right panel) components for individual subjects in Experiment 1. Dashed line represents the change across phases and symbols are consistent for each subject.

The remaining data in Figure 4 show that, on average, target responding was initially higher in Phase 3 in the S^{Δ} component and decreased across sessions and target responding remained relatively steady in the S^D component. In support of this conclusion, a 2×5 (Component \times Session) repeated measures ANOVA conducted on target response rates across sessions of Phase 3 revealed a significant Component \times Session interaction, $F(4, 16) = 3.63, p = .028, \eta_p^2 = .48$, and nonsignificant effects of Component, $F(1, 4) = 2.58, p = .184, \eta_p^2 = .39$, and Session, $F(4, 16) = 2.83, p = .060, \eta_p^2 = .41$.

Finally, Figure 5 displays alternative response rates across sessions of Phase 3 for individual subjects. A 2 x 5 (Component x Session) repeated measures ANOVA conducted on these data revealed significant effects of Component, $F(1, 4) = 49.64, p = .002, \eta_p^2 = .93$, and Session, $F(4, 16) = 32.23, p < .001, \eta_p^2 = .89$, and a significant Component X Session interaction, $F(4, 16) = 15.06, p < .001, \eta_p^2 = .79$. Thus, alternative responding was initially higher and subsequently decreased more across sessions in the S^D component than in the S^Δ component. Additionally, the DI averaged across these sessions ($M = .71, SEM = .04$) was statistically greater than 0.50, $t(4) = 4.98, p = .008, d = 2.23$, suggesting that differential alternative responding across the two components continued during Phase 3 (see Table 1 for alternative response rates and corresponding DI in the first session of Phase 3 for individual subjects).

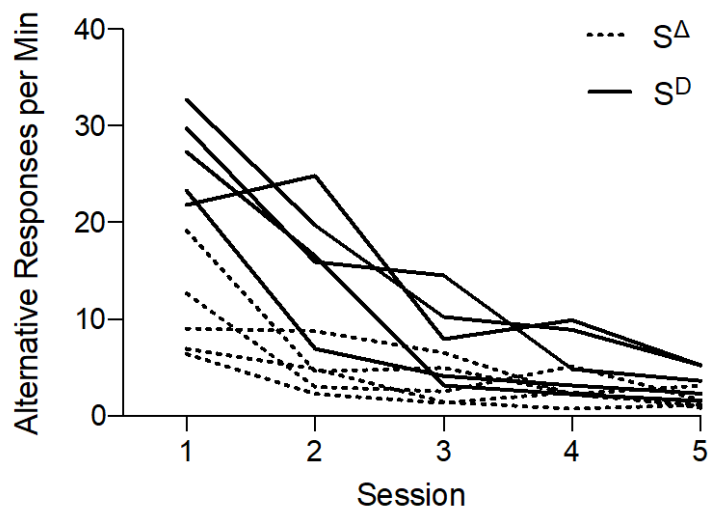


Figure 5. Alternative responses per min in the S^D and S^Δ components across sessions of Phase 3 for individual subjects in Experiment 1.

Discussion

Previous research with individuals with neurodevelopmental disorders has shown that resurgence of severe problem behavior was substantially reduced in the presence of an S^A stimulus that signaled alternative-response extinction (Fisher et al., 2020; Fuhrman et al., 2016); however, the generality of these findings is unknown given that resurgence was only assessed in the presence or absence of the S^A stimulus and not under conditions that explicitly signaled availability of alternative reinforcement. The purpose of Experiment 1 was to extend these findings by determining whether an S^A would mitigate resurgence if the alternative response is also placed on extinction in the presence of an S^D stimulus that signaled alternative reinforcement availability.

Following Baseline in which target responding was reinforced, rats were exposed to alternative-response discrimination training in a two-component multiple schedule in Phase 2. In this phase, alternative responding was reinforced in the S^D component and extinguished in the S^A component, while target responding was extinguished in both. Resurgence of target responding was then assessed in both components by placing the alternative response on extinction in the S^D component.

Resurgence was observed in both components, and importantly, resurgence was not reduced in the S^A compared to in the S^D . While it is not surprising that resurgence occurred following alternative-response extinction in the S^D component, it is unclear why resurgence occurred in the S^A component in which alternative reinforcement was never available. Further, it is unlikely that resurgence occurred in the S^A component as a result of failure to effectively discriminate the stimuli arranged in Phase 2 because alternative responding was differentially allocated across components during discrimination training,

as measured by the DI. While it is possible that rats allocated behavior according to the signaling effects of the presence and absence of alternative reinforcement, the fact that the DI remained above indifference when alternative reinforcers were removed in Phase 3 suggests that the discriminative stimuli were contributing to response allocation to some extent.

Instead, it is possible that resurgence occurred in the S^{Δ} component as a result of the specific testing conditions. That is, while the purpose of this experiment was to compare resurgence in the presence of both the S^D and S^{Δ} stimuli, differences in testing conditions between experiments may have contributed to the discrepancy between our findings and those previously reported. For example, removing alternative reinforcement in one component during Phase 3 may have resulted in behavioral contrast. That is, manipulating the rate of reinforcement in one component of a multiple schedule may impact the rate of responding in the other component (e.g., Williams, 1983). Specifically, behavioral contrast is when behavior in an unaltered component changes in the direction opposite from the rate of reinforcement in the altered component (e.g., Bloomfield, 1967). Positive contrast refers to when behavior increases in the unchanged component following a decrease in the rate of reinforcement in the altered component, and negative contrast refers to when behavior decreases in the unchanged component following an increase in the rate of reinforcement in the other (Reynolds, 1961a; 1961b).

While the majority of studies on behavioral contrast involve measurement of a single response within a multiple schedule (Williams, 2002), there is evidence that contrast effects may occur under concurrent schedules with multiple responses as well, which may be relevant to the findings of Experiment 1. For example, Catania (1961)

evaluated contrast effects in concurrent multiple schedules using pigeons. Following a baseline in which pigeons earned food for pecking concurrently available red and green keys, a multiple schedule was introduced in which pecking the green key was placed on extinction in the first component and reinforced in the second component, while pecking the red key was reinforced in both components. When extinction of green-key pecking was introduced in the first component, pecking the green key subsequently increased in the other, unchanged component. Additionally, pecking the red key in the unchanged component also increased despite no changes in the contingencies for that response. These findings suggest that contrast effects may not be isolated to only the response in which the contingency was altered but may have a more general impact on behavior allocation within multiple schedules.

Based on these data, it may be the case that the increase in target responding in the S^A component following extinction of the alternative response in the S^D component in Phase 3 was the result of positive contrast. That is, target responding increased in the unchanged S^A component following a decrease in the rate of reinforcement for the alternative response (i.e., VI 5 s to extinction) in the altered S^D component. In fact, there is evidence that resurgence and behavioral contrast may be related. For example, Pyszczynski and Shahan (2013) observed resurgence of alcohol seeking in one component of a multiple schedule following extinction of food-maintained responding in the second component using rats. Following a baseline in which lever pressing produced alcohol in one component and chain pulling produced food in the second component, lever pressing was placed on extinction in the alcohol component in Phase 2. In the final phase, chain pulling was also placed on extinction in the food component and lever

pressing in the alcohol component subsequently increased. The authors suggest that the resurgence effect observed in the alcohol component may be related to positive contrast.

Whether or not behavioral contrast contributed to our results, these data suggest that an S^{Δ} may not mitigate resurgence if alternative-response extinction also occurs in the presence of the S^D under multiple-schedule conditions. Given that the previous applied research found reduced resurgence when tested under S^{Δ} conditions alone, these findings together with those obtained in Experiment 1 pose the question of what the independent effects of discriminative stimuli presentation on resurgence are.

CHAPTER IV

EXPERIMENT 2

Purpose

Previous applied research has demonstrated that resurgence of severe destructive behavior is substantially reduced in the presence of the FCR S^A stimulus. While the results of these examinations suggest that S^A stimuli may be an effective way to mitigate resurgence, the generality of these findings remain unknown. Specifically, the results of Experiment 1 suggest that resurgence may not be mitigated in the presence of the S^A stimulus if alternative-response extinction also occurs during intervening S^D components in a multiple schedule. It may be the case that the different procedures used during testing across experiments may have contributed to the discrepant findings.

The purpose of Experiment 2 was to compare resurgence under the conditions of Experiment 1 in which presentation of the S^D and S^A stimulus alternate in a multiple schedule and resurgence under conditions that better approximate those in Fuhrman et al. (2016) and Fisher et al. (2020) in which the discriminative stimulus is presented alone. As in Experiment 1, target responding was reinforced in the first phase, and alternative response discrimination training and target-response extinction occurred in the second phase. Resurgence of target responding was assessed in the third phase across four groups of rats: three single-stimulus test groups and one multiple-stimulus test group. For the three single-stimulus tests, testing occurred in the presence of only the S^A stimulus in the S^A Alone group, in the presence of only the S^D stimulus in the S^D Alone group, or in the absence of discriminative stimuli altogether in the No Stim group. For the Mult Stim group, testing occurred as in Experiment 1 in which the stimulus conditions present

during the previous discrimination training phase continued and the alternative response was placed on extinction in the S^D component.

Method

Subjects

Twenty-eight experimentally naïve male Long-Evans rats served as subjects. Rats were housed and cared for under the same conditions as Experiment 1.

Apparatus

Five identical Med Associates operant chambers in addition to the five chambers from Experiment 1 were used.

Procedure

Experimental sessions were conducted in the same manner as in Experiment 1.

Training, Phase 1: Baseline, and Phase 2: Discrimination Training. The procedures used in the Training, Baseline, and Alternative-Response Discrimination Training phases were identical to that described in Experiment 1 for all rats. In brief, target lever pressing was reinforced on a VI 30-s schedule in Baseline for 20 sessions and then placed on extinction in the following Discrimination Training phase. During discrimination training, a two-component multiple schedule was introduced in which alternative lever pressing was reinforced on a VI 5-s schedule in the S^D component and extinguished in the S^A component. Components were differentially signaled by either a constant house light and tone or flashing/pulsing house light and tone (on/off every 0.5 s), counterbalanced across subjects. Discrimination training lasted 25 sessions.

Phase 3: Test. Prior to the start of the Test phase, rats were divided into four groups. The S^A Alone, S^D Alone, and No Stim groups were tested under single-stimulus

conditions, and the Mult Stim group was tested under multiple-stimulus conditions. Rats were assigned to groups matched on response rates such that target response rates during the last three sessions of Baseline and the last three sessions of Discrimination Training (within component) were comparable and did not differ statistically between groups. During this phase, the target response remained on extinction and the alternative response was also placed on extinction for all groups, but the particular stimulus conditions present varied by group.

The S^A or S^D stimulus from the previous Discrimination Training phase were presented continuously for the duration of the session for the S^A Alone and S^D Alone groups, respectively, and all alternative-response discriminative stimuli from the previous phase were absent for the No Stim group. For example, the flashing house light and pulsing tone stimuli may have served as the S^A stimulus and the constant house light/tone stimuli may have served as the S^D stimulus for a particular rat. If this rat was assigned to the S^A Alone group, the house light and tone would flash/pulse for the duration of the session but if this rat was assigned to the S^D Alone group, the house light and tone would remain on for the duration of the session. The house light and tone remained off for the duration of the session in the No Stim Test group regardless of previous discriminative stimulus assignment. This phase lasted 5 session.

Data Analyses. The primary dependent variables of interest were target and alternative responses per min across sessions and between groups and components. Additionally, a discrimination index (DI) was calculated as in Experiment 1 to evaluate differential alternative-response allocation across discriminative stimuli during Phases 2 for all groups and also in Phase 3 for the Mult Stim group. Statistical significance was

determined using with $\alpha = .05$. Greenhouse-Geisser corrections to degrees of freedom were applied when Mauchly's test indicated a violation of sphericity for within-subject factors in analyses of variance (ANOVA). For all analyses, the within-subject factors included session/phase and component, and the between-subject factor was group.

Results

Table 2 provides a summary of response rates, reinforcer rates, and discrimination indices across phases of Experiment 2 for each group.

Phase 1: Baseline. Target responses per min increased across sessions of baseline to comparable levels for all groups. A one-way ANOVA conducted on average target response rate across the last three sessions of baseline confirmed that there was no difference between groups, $F(3, 24) = 0.04, p = 0.99, \eta_p^2 < .01$, (see Table 2).

Phase 2: Discrimination Training. Figure 6 displays target response rates in the S^D and S^A components across sessions of Phase 2 for all groups. Target responding decreased more rapidly in the S^D component and remained relatively elevated in the S^A component, and this effect was consistent across groups (see Table 2 for terminal Phase-2 target response rates). A $25 \times 2 \times 4$ (Session \times Component \times Group) repeated measures ANOVA conducted on these data support these conclusions. The effects of Session, $F(3.28, 78.74) = 36.47, p < .001, \eta_p^2 = .60$, Component, $F(1, 24) = 27.80, p < .001, \eta_p^2 = .54$, and the Session \times Component interaction, $F(5.08, 122.03) = 3.18, p = .009, \eta_p^2 = .12$, were all significant. The effect of Group, $F(3, 24) = 0.35, p = .79, \eta_p^2 = .04$, and the Session \times Group, $F(9.84, 78.74) = 0.63, p = .78, \eta_p^2 = .07$, Component \times Group, $F(3, 24) = 0.87, p = .47, \eta_p^2 = .10$, and Session \times Component \times Group, $F(15.25, 122.03) = 1.03, p = .43, \eta_p^2 = .11$, interactions were not significant.

Table 2.

Mean (SEM) Target and Alternative Response Rates, Discrimination Indices, and Reinforcer Rates for Each Group Across Phases of Experiment 2.

| | Group | | | | | | | | | | | | | | | | |
|------------|-----------------|-----------------|----------------|-----------------|----------------|----------------------|-----------------|----------------|-----------------|----------------------|-----------------|----------------|-----------------|-----------------|-----------------|----------------|-----------------|
| | Mult Stim | | | | | S ^D Alone | | | | S ^Δ Alone | | | | No Stim | | | |
| | P1 ^a | P2 ^b | | P3 ^c | | P1 ^a | P2 ^b | | P3 ^c | P1 ^a | P2 ^b | | P3 ^c | P1 ^a | P2 ^b | | P3 ^c |
| | | S ^D | S ^Δ | S ^D | S ^Δ | | S ^D | S ^Δ | | | S ^D | S ^Δ | | | S ^D | S ^Δ | |
| Target/min | 26.26 | 0.27 | 3.04 | 4.10 | 3.48 | 28.64 | 0.77 | 2.06 | 3.26 | 27.70 | 0.70 | 2.84 | 3.84 | 26.74 | 0.73 | 3.26 | 4.92 |
| SEM | 6.29 | 0.06 | 0.93 | 0.95 | 0.56 | 4.36 | 0.28 | 0.59 | 0.97 | 3.70 | 0.40 | 1.33 | 1.43 | 6.95 | 0.30 | 1.25 | 1.83 |
| Alt./min | - | 92.50 | 32.47 | 28.97 | 11.96 | - | 82.62 | 30.40 | 19.60 | - | 83.34 | 30.74 | 22.68 | - | 86.05 | 28.83 | 16.95 |
| SEM | - | 14.75 | 4.48 | 2.23 | 2.52 | - | 8.29 | 5.47 | 3.83 | - | 10.49 | 5.16 | 3.60 | - | 16.50 | 6.95 | 3.71 |
| DI | - | 0.72 | | 0.72 | | - | 0.72 | | - | - | 0.72 | | - | - | 0.74 | | - |
| SEM | - | 0.03 | | 0.05 | | - | 0.05 | | - | - | 0.02 | | - | - | 0.02 | | - |
| Rein./min | 1.77 | 10.21 | - | - | - | 1.81 | 10.06 | - | - | 1.79 | 10.25 | - | - | 1.78 | 9.96 | - | - |
| SEM | 0.05 | 0.29 | - | - | - | 0.02 | 0.24 | - | - | 0.03 | 0.21 | - | - | 0.05 | 0.48 | - | - |

^aData from the average last three sessions of Phase 1 are shown, ^bData from the last session of Phase 2 are shown, ^cData from the first session of Phase 3 are shown.

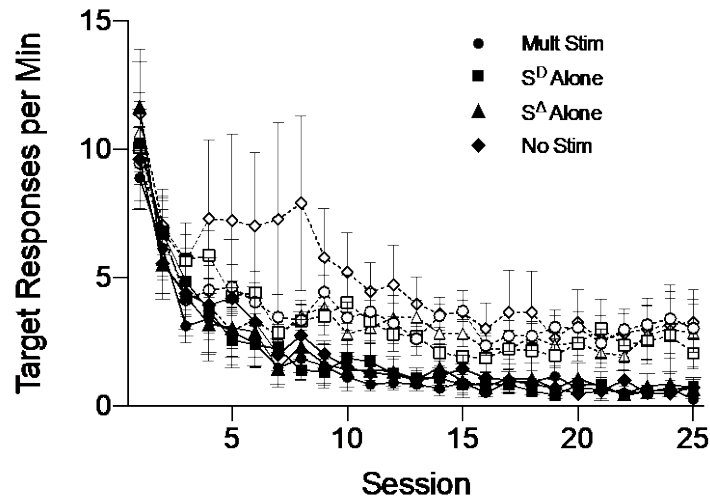


Figure 6. Mean target responses per min in the S^D (closed symbols and solid lines) and S^A (open symbols and dashed lines) components across sessions of Phase 2 for each group in Experiment 2. Error bars represent standard error of the mean.

Figure 7 displays alternative response rates in the S^D and S^A components across sessions of Phase 2 for all groups. Alternative responding increased across sessions in the S^D component but remained relatively low and stable in the S^A component, and this pattern was consistent across groups. A $25 \times 2 \times 4$ (Session \times Component \times Group) repeated measures ANOVA conducted on these data support this conclusion. The effects of Session, $F(2.54, 61.06) = 41.53, p < .001, \eta_p^2 = .63$, Component, $F(1, 24) = 141.36, p < .001, \eta_p^2 = .85$, and the Session \times Component interaction, $F(2.64, 63.36) = 36.39, p < .001, \eta_p^2 = .60$, were all significant. The effect of Group, $F(3, 24) = 0.12, p = .95, \eta_p^2 = .01$, and the Session \times Group, $F(7.63, 61.06) = 0.74, p = .94, \eta_p^2 = .09$, Component \times Group $F(3, 24) = 0.14, p = .93, \eta_p^2 = .018$, and Session \times Component \times Group, $F(7.92, 63.36) = 0.50, p = .99, \eta_p^2 = .06$, interactions were not significant.

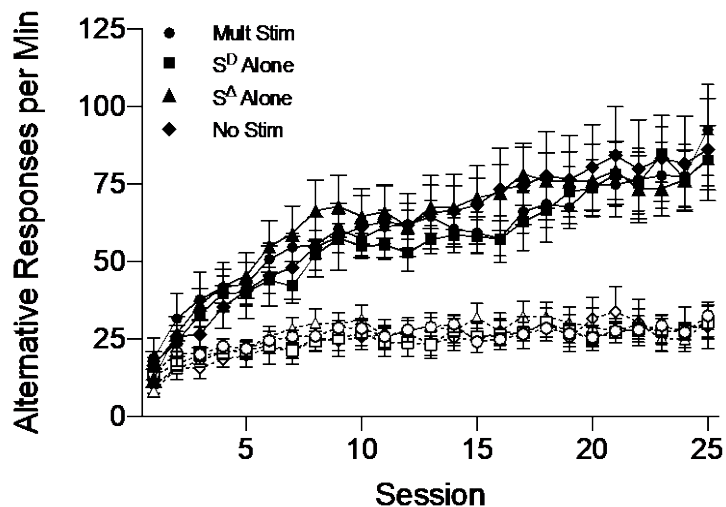


Figure 7. Mean alternative responses per min in the S^D (closed symbols and solid lines) and S^A (open symbols and dashed lines) components across sessions of Phase 2 for each group in Experiment 2. Error bars represent standard error of the mean.

Additionally, Figure 8 displays the alternative-response discrimination index (DI) for each group across sessions of Phase 2. A DI greater than 0.50 indicates that more responding occurred in the S^D component than in the S^A component, and the obtained alternative-response allocation was comparable between groups at the end of discrimination training. A one-way ANOVA conducted the DI from the last session of Phase 2 confirmed no group differences, $F(3, 24) = 0.13, p = .94, \eta_p^2 = .016$, and as a result the following analysis was conducted on DI collapsed across groups. A one-sample *t*-test conducted on DI in the last session of Phase 2 across all subjects suggested that the proportion of responding in the S^D was significantly greater than 0.50, $t(27) = 15.18, p < .001, d = 2.87$. Thus, the data in Figures 6 and 7 suggest that subjects effectively allocated alternative responding according to the arranged discrimination in Phase 2 (see Table 2 for terminal Phase-2 alternative response rates and corresponding DI score).

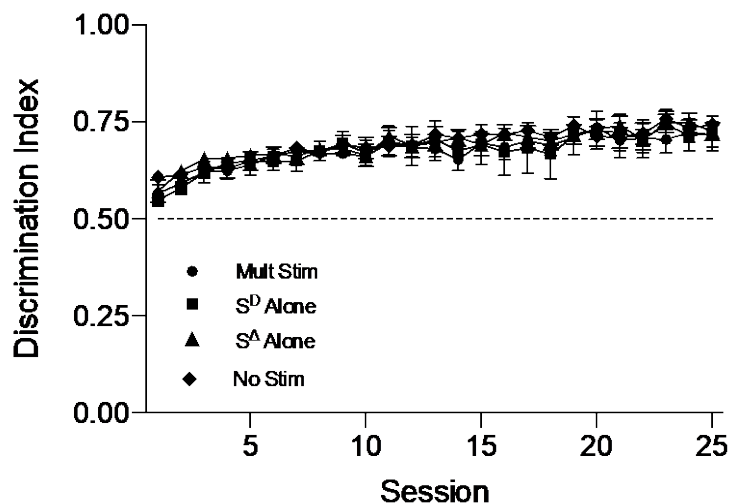


Figure 8. Mean alternative responses per min in the S^D (closed symbols and solid lines) and S^A (open symbols and dashed lines) components across sessions of Phase 2 for each group in Experiment 2. Error bars represent standard error of the mean.

Phase 3: Test. Figure 9 displays target response rates in the last session of Phase 2 and the first session of Phase 3 across stimuli and groups. Given the nonsignificant effect of group on target responding during Phase 2, the left panel displays response rate collapsed across groups in the S^D and S^A components during the last session of Phase 2. The result of a paired-samples *t*-test conducted on these data suggests that target response rates were significantly elevated in the S^A compared to the S^D component at the end of Phase 2, $t(27) = 4.57, p < .001, d = 0.86$. The middle panel of Figure 9 displays response rates in the first session of Phase 3 for the Mult Sim group in the S^D and S^A components. The right panel displays response rates in the first session of Phase 3 for the three single-stimulus groups: S^D Alone, S^A Alone, and No Stim.

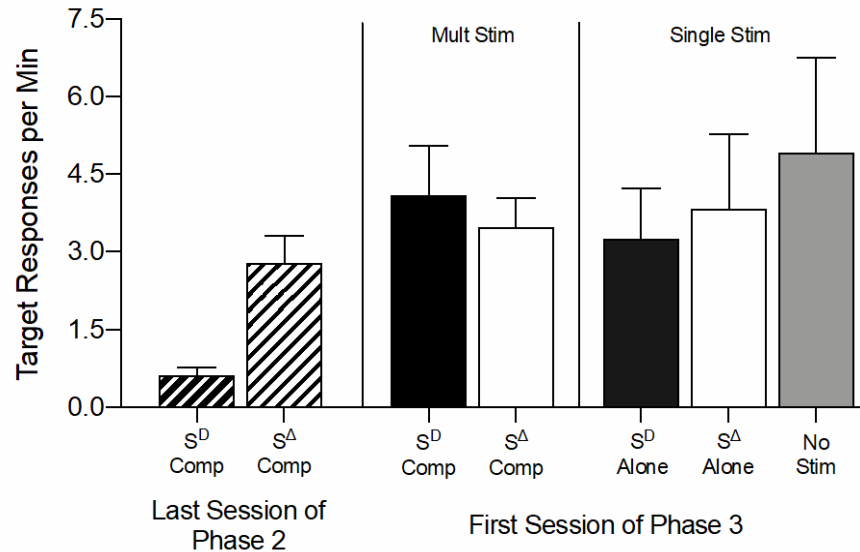


Figure 9. Left panel: Mean target responses per min in the last session of Phase 2 in the S^D and S^A components collapsed across groups. Middle panel: Mean target responses per min in the first session of Phase 3 in the S^D and S^A components for the Mult Stim group. Right panel: Mean target responses per min in the first session of Phase 3 under single stimulus testing for the S^D Alone, S^A Alone, and No Stim groups. Error bars represent standard error of the mean.

For the Mult Stim group specifically, target response rates increased across the last session of Phase 2 and the first session of Phase 3 in the S^D component, but not in the S^A component (see Table 2). A 2 x 2 (Phase x Component) repeated-measures ANOVA conducted on these data for the Mult Stim group supports this conclusion. The effects of Phase, $F(1, 6) = 14.43, p = .008, \eta_p^2 = .71$, and Component, $F(1, 6) = 12.34, p = .01, \eta_p^2 = .67$, were significant, as well as the Phase x Component interaction, $F(1, 6) = 6.87, p = .04, \eta_p^2 = .53$. Follow-up paired-samples *t*-tests conducted on target responding across phases in the S^A and S^D components individually, revealed a significant increase in the S^D component, $t(6) = 4.16, p = .005, d = 1.57$, but not in the S^A component, $t(6) = 0.56, p = .60, d = 0.21$.

To evaluate the impact of the testing conditions (i.e., multiple- or single-stimulus presentation) on resurgence, target responding across the last session of Phase 2 and the first session of Phase 3 was compared between groups under comparable stimulus conditions. A 2 x 2 (Phase x Group) mixed-model ANOVA was conducted on target response rates across the last session of Phase 2 and the first session of Phase 3 in the S^D component of the Mult Stim group and in the S^D component for the S^D Alone group. The effect of Phase $F(1, 12) = 22.25, p < .001, \eta_p^2 = .65$ was significant, but the effect of Group, $F(1, 12) = 0.05, p = .82, \eta_p^2 < .01$, and the Group x Phase interaction, $F(1, 12) = 0.99, p = .34, \eta_p^2 = .08$, were not significant. These results suggest that resurgence of target responding occurred in the presence of the S^D stimulus and that resurgence was comparable between multiple- and single-stimulus testing conditions (see Table 2).

Additionally, a 2 x 2 (Phase x Group) mixed-model ANOVA was conducted on target response rates across the last session of Phase 2 and the first session of Phase 3 in the S^Δ component of the Mult Stim group and in the S^Δ component for the S^Δ Alone group. The effects of Phase and Group, and the Phase x Group interaction were not significant (all $ps \geq .13$). These results suggest that resurgence did not reliably occur in the presence of the S^Δ stimulus in either test condition (see Table 2). To further evaluate target responding under S^Δ conditions, Figure 10 displays these data for individual subjects. For the S^Δ Alone group, one rat showed a numerical decrease in target response rates and the remaining six showed an increase. Of those six, four showed an increase of at least one response per min. For the Mult stim group, three rats showed a numerical decrease and the remaining four showed an increase. Of those four, three showed an increase of at least one response per min.

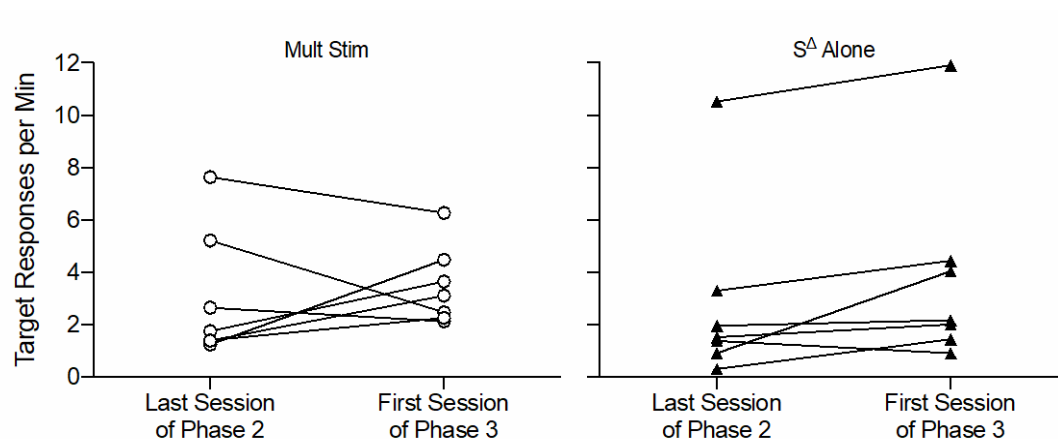


Figure 10. Target responses per in the last session of Phase 2 and the first session of Phase 3 in the S^Δ component for individual rats in the Mult Stim group (left panel) and in the S^Δ Alone group (right panel) in Experiment 2.

Target response rates in the first session of Phase 3 were compared between the S^D Alone, S^Δ Alone, and No Stim groups to evaluate target responding in the presence and absence of alternative-response discriminative stimuli. A one-way ANOVA conducted on these data revealed a nonsignificant effect of group, $F(2, 18) = 0.34, p = .72, \eta_p^2 = .04$, suggesting that target response rates in the first session of resurgence testing were comparable between the three single-stimulus groups (see Table 2).

In summary of the above resurgence analyses, target responding within component did not differ by group but was higher in the S^Δ component than in the S^D component at the end of Phase 2. Subsequently, resurgence occurred in the presence of the S^D stimulus but target responding remained elevated across phases in the presence of the S^Δ stimulus, regardless of test condition. Additionally, levels of target responding in the first session of resurgence testing were comparable between stimulus conditions.

Figure 11 displays target response rates across sessions of Phase 3, separated by testing condition. The left panel shows target responding in the S^D and S^A components for the Mult Stim group, and the right panel shows target responding for the S^D Alone, S^A Alone, and No Stim single-stimulus test groups.

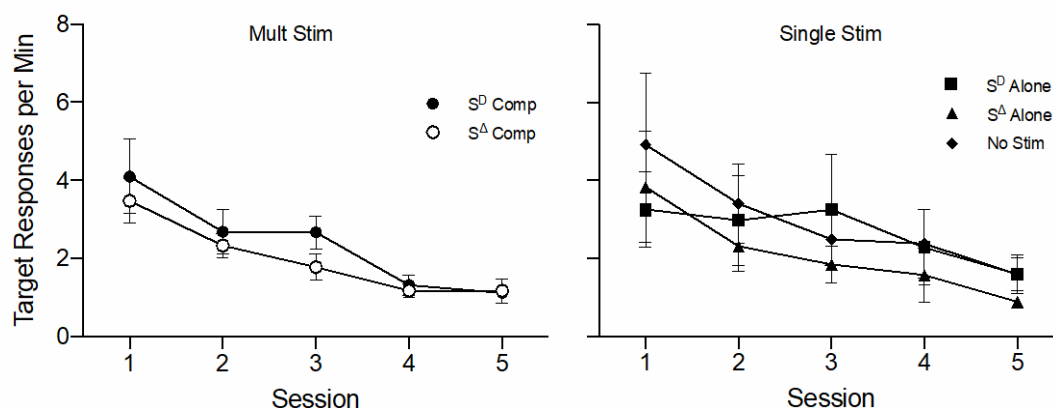


Figure 11. Left panel: Mean target responses per min across sessions of Phase 3 in the S^D and S^A components for the Mult Stim group. Right panel: Mean target responses per min across sessions of Phase 3 for the S^D Alone, S^A Alone, and No Stim single-stimulus test groups. Error bars represent standard error of the mean.

Target responding decreased across sessions of Phase 3 at similar rates between components for the Mult Stim group. The results of a 2 x 5 (Component x Session) repeated-measures ANOVA conducted on these data for the Mult Stim group support this conclusion. Only the effect of Session, $F(1.53, 9.18) = 8.40, p = .01, \eta_p^2 = .58$, was significant and the effect of Component, $F(1, 6) = 2.57, p = .16, \eta_p^2 = .30$, and the Component x Session interaction, $F(4, 24) = 1.29, p = .30, \eta_p^2 = .18$, were not significant. Target responding also decreased across sessions at comparable rates for the three single stimulus test groups. A 3 x 5 (Group x Session) mixed-model ANOVA conducted on

these data revealed a significant effect of Session, $F(1.65, 29.67) = 11.44, p < .001, \eta_p^2 = .39$, and a nonsignificant effect of Group, $F(2, 18) = 0.26, p = .78, \eta_p^2 = .03$, and Group x Session interaction, $F(3.30, 29.67) = 0.88, p = .47, \eta_p^2 = .09$.

To evaluate target responding across sessions of Phase 3 between the multiple- and single-stimulus testing conditions, target response rates were collapsed across components for the Mult Stim group and across groups for the three single-stimulus groups. These data were collapsed in this manner given the nonsignificant effects of Component and Group reported above. A 2 x 5 (Test Condition x Session) mixed-model ANOVA conducted on these data revealed a significant effect of Session, $F(1.72, 44.70) = 13.97, p < .001, \eta_p^2 = .35$, and a nonsignificant effect of Test Condition, $F(1, 26) = 0.21, p = .65, \eta_p^2 < .01$, and Test Condition x Session interaction, $F(1.72, 44.70) = 0.22, p = .77, \eta_p^2 < .01$. Thus, the decrease in target responding across sessions of Phase 3 was not different between multiple- and single-stimulus testing conditions.

Figure 12 displays alternative response rates across sessions of Phase 3, separated by testing condition. The left panel shows alternative responding in the S^D and S^Δ components for the Mult Stim group, and the right panel shows alternative responding for the S^D Alone, S^Δ Alone, and No Stim single-stimulus test groups.

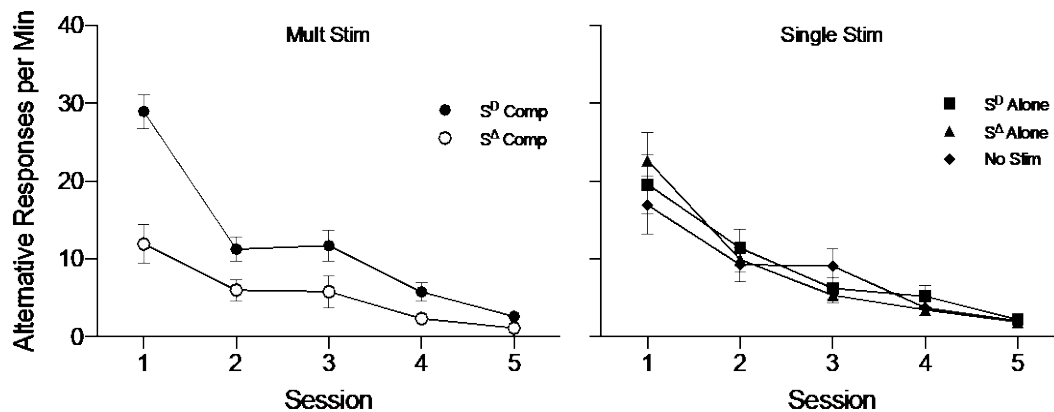


Figure 12. Left panel: Mean alternative responses per min across sessions of Phase 3 in the S^D and S^A components for the Mult Stim group. Right panel: Mean alternative responses per min across sessions of Phase 3 for the S^D Alone, S^A Alone, and No Stim single-stimulus test groups. Error bars represent standard error of the mean.

Alternative responding was elevated and decreased more steeply across sessions of Phase 3 in the S^D component than in the S^A component in the Mult Stim group. A 2 x 5 (Component x Session) repeated-measures ANOVA conducted on these data in the Mult Stim group confirmed this conclusion. The effects of Component, $F(1, 6) = 30.14, p = .002, \eta_p^2 = .83$, and Session, $F(4, 24) = 40.87, p < .001, \eta_p^2 = .87$, and the Component x Session interaction, $F(4, 24) = 11.40, p < .001, \eta_p^2 = .66$, were all significant. Additionally, the DI averaged across these sessions ($M = .70, SEM = .04$) was statistically greater than 0.50, $t(6) = 5.28, p < .001, d = 1.99$, suggesting that differential alternative responding between the two components continued during Phase 3 for the Mult Stim group.

The data in the right panel show that Alternative responding decreased at comparable rates for the S^D Alone, S^A Alone, and No Stim groups. A 3 x 5 (Group x Session) mixed-model ANOVA conducted on these data revealed a significant effect of

Session, $F(1.61, 28.93) = 54.19, p < .001, \eta_p^2 = .75$, and a nonsignificant effect of Group, $F(2, 18) = 0.06, p = .94, \eta_p^2 < .01$, and Group x Session interaction, $F(3.21, 28.93) = 1.27, p = .31, \eta_p^2 = .12$. Taken together, these results suggest that alternative responding was more persistent in the S^D component relative to the S^Δ component under multiple-stimulus testing but the particular stimulus present during single-stimulus testing did not differentially impact alternative-response extinction.

To evaluate the impact of testing condition on alternative responding during extinction, alternative response rates across sessions of Phase 3 were compared between groups under comparable stimulus conditions. A 2 x 5 (Test Condition x Session) mixed-model ANOVA was conducted on alternative responding across sessions of Phase 3 in the S^D component of the Mult Stim group and across sessions in the S^D Alone group. The effect of Session, $F(4, 48) = 63.30, p < .001, \eta_p^2 = .84$, and the Session x Group interaction, $F(4,48) = 3.87, p = .008, \eta_p^2 = .24$, were significant, and the effect of Group, $F(1, 12) = 2.52, p = .14, \eta_p^2 = .17$, was not significant. These results suggest that alternative responding in the presence of the S^D stimulus was more persistent in the multiple-stimulus test than in the single-stimulus test.

Additionally, a 2 x 5 (Test Condition x Session) mixed-model ANOVA was conducted on alternative responding across sessions of Phase 3 in the S^Δ component of the Mult Stim group and across sessions in the S^Δ Alone group. Similarly as in S^D conditions, the effect of Session, $F(1.69, 20.23) = 37.46, p < .001, \eta_p^2 = .76$, and the Session x Group interaction, $F(1.69, 20.23) = 4.84, p = .02, \eta_p^2 = .29$, were significant, and the effect of Group, $F(1, 12) = 3.96, p = .07, \eta_p^2 = .25$, was not significant under S^Δ conditions. These results suggest that alternative responding in the presence of the S^Δ

stimulus was less persistent in the multiple-stimulus test than in the single-stimulus test. Thus, differential alternative-response extinction in the presence of the S^D and S^A stimulus was only evident in the multiple-stimulus test condition (see Table 2 for alternative response rates across stimuli conditions in the first session of Phase 3).

Discussion

The results of Experiment 1 suggest that an S^A for an alternative response may not reduce resurgence if the alternative response also contacts extinction under S^D conditions. These results conflict with those reported in previous applied research in which resurgence of severe destructive behavior was significantly reduced in the presence of the S^A (Fisher et al., 2020; Fuhrman et al., 2016). It is possible that the difference in the testing conditions across studies contributed to the discrepant findings. That is, resurgence of target responding was tested under a multiple schedule in which the S^D and S^A stimuli alternated in time as in the previous discrimination training phase in Experiment 1, and the S^A stimulus was presented in isolation during resurgence testing in the clinical studies.

The purpose of Experiment 2 was to determine the independent effects of alternative-response discriminative stimuli on resurgence of target responding in which a single stimulus is presented in isolation during testing as in the applied experiments and to evaluate these effects against multiple-stimulus testing under a multiple schedule. Baseline and alternative-response discrimination training occurred as in Experiment 1, and resurgence of target responding was assessed in the multiple-schedule arrangement from Experiment 1 in one group of rats and, for the remaining three groups, resurgence was

tested in presence of either the S^{Δ} stimulus alone, the S^D stimulus alone, or no discriminative stimuli.

The results of Experiment 2 suggest that target behavior was not differentially impacted by testing condition. That is, regardless of testing under a multiple-schedule or in the presence of a single discriminative stimulus, resurgence of target responding was evident in the presence of the S^D stimulus but target responding did not significantly increase across phases in the presence of the S^{Δ} stimulus at the group level. While this may suggest that resurgence did not occur in under S^{Δ} conditions, it is important to note that target responding was significantly elevated in the S^{Δ} component relative to the S^D component at the end of discrimination training (see Figures 6 and 9). Additionally, target response rates across sessions of resurgence testing were not different between stimuli (see Figure 11). Thus, while target responding did not significantly *increase* across phases, target responding remained elevated in the presence of the S^{Δ} stimulus and the increase in target responding in the presence of the S^D stimulus resulted in comparable levels of behavior in Phase 3.

This pattern of target responding resembles those reported in which parameters of alternative reinforcement, such as rate and magnitude, are manipulated (Bouton & Trask, 2016; Craig & Shahan, 2016; Craig et al., 2016; Sweeney & Shahan, 2013a; Cançado et al., 2015). For example, Craig and Shahan (2016) reported elevated target response rates during Phase 2 in rats that received a relatively lean rate of alternative reinforcement compared to rats that received a relatively rich rate. Further, the groups that had received rich alternative reinforcement showed resurgence while the groups that had received lean reinforcement did not, and rates of target responding did not differ between groups in

Phase 3. Thus, parameters of alternative reinforcement as well as stimuli that differentially signal alternative reinforcement both contribute to levels of target responding across Phases 2 and 3. Additionally, the extent to which target responding is elevated during treatment is related to whether or not target responding necessarily increases (Shahan & Craig, 2017).

However, considering the individual subject data displayed in Figure 10, the exact relation between target-response suppression and resurgence is not entirely clear. For the Mult Stim group, the rats that did show an increase had relatively suppressed response rates at the end of Phase 2 compared to the rats that showed a decrease. For the S^Δ Alone group, some rats who showed an increase had relatively elevated response rates while others that also showed an increase had relatively suppressed response rates at the end of Phase 2. Thus, elevated response rates and increases in target response rates was not mutually exclusive, especially in the S^Δ Alone group. Regardless, it is clear that the S^Δ stimulus failed to reliably suppress target responding.

Additionally, target response rates in Phase 3 for the No Stim group were also comparable to those in the S^D and S^Δ stimuli conditions, suggesting that overall levels of target responding during testing was not differentially affected by the presence or absence of alternative-response discriminative stimuli. From an applied perspective, this may suggest that a treatment adherence failure in which the FCR discriminative stimuli are completely absent may not necessarily result in greater resurgence when the FCR contacts extinction. This finding is somewhat surprising given that there is evidence to suggest that removing both alternative reinforcers and discriminative stimuli produces greater relapse. For example, Podlesnik and Kelley (2014) observed greater resurgence of

key pecking in pigeons following removal of alternative reinforcement when the alternative-response discriminative stimulus (i.e., an illuminated key) was absent (i.e., key was darkened) compared to when it remained present during resurgence testing. More broadly, the findings of Podlesnik and Kelley (2014) may be related to the larger relapse effects observed when resurgence and ABA renewal procedures are combined (Kincaid et al., 2015; Trask & Bouton, 2016). That is, renewal refers to the increase in behavior following a change in the context in which that behavior was previously extinguished (Bouton et al., 2011). In ABA renewal, a response is reinforced during baseline in a particular context (i.e., context A), that response is placed on extinction in a separate context (i.e., context B), and relapse is tested in the original baseline context.

Accordingly, the absence of the alternative-response discriminative stimuli in baseline and testing (i.e., house light and tone off) for the No Stim group be characterized as Context A and the presence of discriminative stimuli during discrimination training as Context B. Based on the findings described above, resurgence should be largest in this group in the final phase. While the average target response rate in the first session of Phase 3 was numerically highest in this group (see Table 2), this effect was not significant. Whether or not this is inconsistent with the resurgence + renewal literature is unclear given that this larger relapse effect is not very robust and reliable (see Sweeney & Shahan, 2015; Nighbor et al., 2018).

While testing condition did not have an effect on target response rates in Phase 3, persistence of alternative responding during extinction was differentially impacted by multiple- and single-stimulus test conditions. Specifically, alternative response rates across sessions of Phase 3 were more elevated in the S^D component than in the S^A

component in the Mult Stim group, but alternative-response extinction was comparable between the S^D Alone, S^A Alone, and No Stim groups. Furthermore, alternative response rates were higher in the S^D component and lower in the S^A component for the Mult Stim group compared to the single-stimulus groups. Thus, the discriminative stimuli contributed to differential alternative-response allocation during extinction in the multiple-schedule, but this differentiation was not evident between groups in the single-stimulus conditions.

These results may be related to the differential resistance to extinction often observed in multiple schedules but not in single schedules. Cohen (1998) reported that a response will be more resistant to extinction in a stimulus context associated with a richer rate of reinforcement than in a stimulus context associated with a leaner rate if these stimuli alternate within a multiple schedule and not if presented in isolation in a single schedule. These findings suggest that the comparison of discriminative stimuli inherent in a multiple schedule may be important for differential response allocation under extinction. Thus, it is possible that comparison of S^D and S^A stimuli within the multiple schedule contributed to differential alternative-response persistence in Phase 3 in the Mult Stim group compared to the single stimulus presentation (or absence) in the other groups.

Given that one of the goals of discrimination training in the clinic is to control the overall rates of the FCR and prevent resurgence of challenging behavior (Saini et al., 2016), it would be ideal that the FCR persists during extended periods of extinction under S^D but not S^A conditions. Fisher et al. (2020) observed lower rates of the FCR during the extinction challenge when the S^A stimulus was present compared to when it was absent

for three participants and found no difference for the fourth participant, and Furhman et al. (2016) observed differential rates of the FCR between conditions in one participant but not the other. Thus, there is generally more evidence that following FCT, the FCR is less persistent when the S^A stimulus is presented alone compared to when it is absent, but S^D tests were never included. Additionally, the nondifferential alternative-response extinction obtained in the single-stimulus tests of the current experiment is not entirely consistent with these findings. As a result, it is unclear whether to expect greater FCR persistence in the face of extinction under S^D conditions.

In summary, the results of Experiment 2 suggest that target behavior was not significantly reduced in the presence of a stimulus that signaled alternative-response extinction regardless if that stimulus was presented in isolation or alternating with a stimulus that signals alternative reinforcement. This conclusion is consistent with the results from Experiment 1 but are inconsistent with those reported in the applied literature. Thus, this discrepancy is not likely due to the difference in the testing condition between studies but perhaps due to differences in the discrimination training procedures.

CHAPTER V

GENERAL DISCUSSION

Summary

Previous applied research has reported significant reductions in resurgence of severe destructive behavior in the presence of a discriminative stimulus that signals alternative-response extinction compared to in its absence. The purpose of Experiment 1 was to test the generality of this finding by determining whether an alternative-response S^{Δ} stimulus would mitigate resurgence of target responding when the alternative response also contacts extinction under S^D conditions that had previously signaled alternative-response reinforcement. Resurgence of target responding was comparable in both S^D and S^{Δ} stimulus conditions. These results conflict with those previously reported and suggest that the conditions under which an S^{Δ} stimulus may prevent or mitigate resurgence are limited; however, given the testing conditions used in the applied research, it is possible that an S^{Δ} stimulus may only prevent resurgence when presented in isolation and not when presented in close temporal proximity to the S^D stimulus within a multiple schedule.

The purpose of Experiment 2 was to determine the independent effects of alternative-response discriminative stimuli on resurgence of target responding, and to compare these effects to those produced by discriminative-stimuli presented within a multiple schedule. As in Experiment 1, the S^{Δ} stimulus failed to significantly reduce rates of target responding, and this effect did not differ by testing condition. Additionally, rates of target responding during resurgence testing were not differentially affected by the S^D stimulus, S^{Δ} stimulus, or the absence of discriminative stimuli altogether.

The overall pattern of target and alternative response rates during discrimination training were consistent between Experiments 1 and 2. That is, target responding remained relatively elevated in the S^{Δ} component compared to the S^D component, and alternative responding was allocated according to the arranged discrimination as measured by the discrimination index (DI). Additionally, resurgence occurred under S^D conditions in both experiments; however, resurgence of target responding under S^{Δ} stimulus conditions was only evident in Experiment 1. As mentioned in the discussion of Experiment 2, the failure to observe an increase in target responding across phases in the presence of the S^{Δ} stimulus was not likely the result of any mitigating effect of the S^{Δ} stimulus but rather the generally elevated levels of target responding across phases in the S^{Δ} stimulus. Given that the discrimination training procedures were identical, it is unclear why target response rates in the S^{Δ} component were generally more elevated at the end of Phase 2 in Experiment 2 compared to Experiment 1. Nevertheless, it is clear that the S^{Δ} stimulus did not significantly reduce target response rates during resurgence testing across experiments and testing procedures. Importantly, it is not likely that this was due to a failure to effectively discriminate the stimuli given that alternative responding was differentially allocated during extinction in Phase 3 according to the discriminative stimuli (i.e., $DI > .50$) in Experiment 1 and in the Mult Stim group of Experiment 2. Thus, the question remains what the necessary and sufficient conditions under which an S^{Δ} will mitigate resurgence following discrimination training are.

Discrimination and S^{Δ} Duration

Discrimination training is incorporated into FCT as a means to reduce the overall rate of the FCR by teaching the client to discriminate when reinforcement is available or

unavailable, thereby making implementation of FCT by caregivers more feasible (Tiger et al., 2008). Additionally, it may also be necessary to thin the schedule of reinforcement for the FCR from a relatively dense rate to a relatively lean rate, and discrimination training is an effective way to accomplish this. For example, Hanley et al. (2001) thinned the rate of FCR reinforcement during discrimination training by gradually increasing the duration of the S^{Δ} component across sessions. They concluded that this approach, compared to other thinning procedures, was highly effective because it maintained moderate rates of the FCR and did not produce increases in problem behavior. Betz et al. (2013) expanded on this work by demonstrating that gradual thinning across several sessions is not necessary and that more abrupt and rapid shifts in reinforcement rates would be similarly as effective as long as the FCR was under discriminative control prior to reinforcement thinning. Additionally, it is recommended that clinicians incorporate both FCR discrimination training and schedule thinning in this manner during FCT (Greer et al., 2018).

Consistent with the procedure reported by Betz et al. (2013), the duration of the S^{Δ} component was increased in a single step during FCR discrimination training in both Fuhrman et al. (2016) and Fisher et al. (2020). Initially the duration of the components were 60 s and 30 s and were increased to 60 s and 240 s for the S^D and S^{Δ} components respectively. As a result, participants in both studies experienced an S^{Δ} component that was relatively longer than the S^D component by the time resurgence was tested in the final phase.

Importantly, there is evidence to suggest that the duration of exposure to the S^{Δ} stimulus contributes to effective discrimination. For example, Andrzejewski et al. (2007)

evaluated the impact of the length of exposure to the S^{Δ} stimulus on the acquisition of a discriminated operant in rats. In a two-component multiple schedule, the duration of the S^D component was held constant at 2 min and the duration of the S^{Δ} component was either 1 or 4 min. Regardless of the rate of reinforcement in the S^D component, the speed of acquisition of the discrimination (as evident by proportion of responding in S^D) was substantially faster when the duration of the S^{Δ} component was 4 min compared to 1 min. This was evident both between groups (Experiment 1) and within subjects (Experiment 2). Additionally, Kalmbach et al. (2019) evaluated the effect of S^{Δ} duration on response suppression in the presence of the S^{Δ} relative to its absence in mice. The duration of the S^{Δ} component was either 20, 40 or 80 s across groups, and the duration of the absence of the S^{Δ} was held at an average of 40 s. Similarly, to the findings reported by Andrzejewski et al. (2007), response suppression was a direct function of the S^{Δ} duration such that longer durations produced greater suppression and better discrimination. The authors further conclude that S^{Δ} duration is linearly related to the informativeness of the S^{Δ} stimulus in a manner consistent with the informativeness of stimuli predictive of reinforcement (e.g., Balsam et al., 2010; Shahan & Cunningham, 2015).

In light of these findings, it is possible that increasing the duration of the S^{Δ} component during FCT as a means of thinning rate of FCR reinforcement contributed to the reduced resurgence observed by Fuhrman et al. (2016) and Fisher et al. (2020). Importantly, the duration of the S^{Δ} component was the same as the S^D component and was not increased at any point during discrimination training in Experiments 1 and 2. Thus, this variable may have contributed to the discrepancy between the present experiment and the applied studies.

That is, increasing the duration of the S^Δ component during FCT may have contributed to the depth of FCR discrimination and this increased discrimination was necessary for the S^Δ stimulus to successfully mitigate resurgence. While it is not possible to evaluate FCR discrimination by quantitative measures (e.g., discrimination index) because response rates were collapsed across components, there is some evidence for increased discrimination in the applied studies compared to the present experiments. For example, rates of the FCR decreased in all but one participant across studies when the duration of the S^Δ component increased during discrimination training, suggesting further response suppression, whereas alternative response rates in the S^Δ component remained constant across discrimination training in Experiments 1 and 2. Additionally, rates of the FCR were lower during extinction in the presence of the S^Δ stimulus compared to in its absence in the applied studies while alternative responding during extinction in the present studies was not differentially affected by the S^D or S^Δ stimulus when presented alone or by the absence of discriminative stimuli altogether.

However, these comparisons only provide tentative evidence to suggest the increased S^Δ duration is a critical variable and there is currently no empirical evidence for a *casual* relation between S^Δ duration, alternative-response discrimination, and subsequent resurgence migration. Future research may be directed toward systematically evaluating the effects of increasing the duration of alternative-response S^Δ stimulus presentation.

Theoretical Development

Resurgence as Choice (RaC) is a quantitative model of resurgence that suggests resurgence is governed by the same general processes thought to govern choice.

The basic framework of the model suggests that the probability of a target response is a function of the relative value of the target and alternative options such that:

$$pT = \frac{V_T}{V_T + V_{Alt}}$$

where pT is the conditional probability of the target response and V_T and V_{Alt} are the values of the target and alternative options, respectively. According to RaC, the value of the target and alternative options are functions of the relative recencies of past experiences of reinforcement at those options. Additionally, RaC provides a formal means to calculate predicted target and alternative response rates as a function of these relative values, invigorating effects of reinforcement, and asymptotic baseline response rates (see Shahan & Craig, 2017, for full description of model calculations). From this perspective, allocation of target and alternative responding across sessions of a resurgence procedure are a result of increases or decreases in target and alternative relative values as conditions of reinforcement change. Specifically, the precipitous drop in value for the alternative option when that response is placed on extinction during resurgence testing results in an increase in the relative value for the target option. Subsequently, this increase in relative value drives response allocation to the target option, producing resurgence. Given the importance of mitigating resurgence of problem behavior, RaC is particularly useful to clinicians because it can provide specific and quantitative predictions about the effects of variables relevant to the treatment of problem behavior (Greer & Shahan, 2019).

Alternatively, Context Theory (Bouton et al., 2012; Trask et al., 2015) asserts that resurgence is simply a case of ABC renewal and that the presence and absence of target and alternative reinforcers function as distinct contexts. That is, the presence of target

reinforcers during baseline is characterized as Context A, the presence of alternative reinforcers in Phase 2 as Context B, and the absence of both reinforcers in the final phase as Context C. From this perspective, resurgence results from a failure of the target-response extinction from Context B to generalize to Context C; however, this account is limited due to its qualitative nature and lack of falsifiable predictions (Craig & Shahan, 2016; McConnell & Miller, 2014; Shahan & Craig, 2017).

Despite these limitations, the assertion that behavior is influenced by more local effects of reinforcement is not unfounded (Shahan et al. 2020). In a manner consistent with this, Resurgence as Choice in Context (RaC²) is an extension of RaC that accounts the effects of discriminating the presence and absence of reinforcement on target and alternative response allocation. This discrimination is characterized as a source of bias that impacts behavior allocation above and beyond relative value of the target and alternative options over time (see Shahan et al. 2020 for full model description and calculations).

In its current form, it is unclear how RaC² may be applied to the present data. While RaC² can account for the biasing effect of the discrimination of reinforcer presence or absence, it cannot account for the effects of explicitly arranged discriminative stimuli. Matching-law based models of stimulus control suggest that discriminative stimuli serve as a source of bias that impacts response allocation (Davison & Nevin, 1999; Davison & Tustin, 1978), and the biasing effect of reinforcer discrimination in RaC² was actually inspired by such models. According to these models, discrimination bias impacts response allocation in a manner consistent with bias from the generalized matching law (Baum 1974, 1979); however, discrimination bias is determined by the discriminability of

stimuli and is conceptually different from inherent unaccounted for bias. Further informed by these models of stimulus control, RaC² may be extended to account for the effects of explicitly arranged discriminative stimuli on target and alternative response allocation. Given the emphasis on discrimination training in FCT (Fisher et al., 2015; Greer et al., 2018; 2019), such an extension would increase the utility of RaC² by further capturing the effects of clinically relevant conditions for the treatment of problem behavior. The present experiments provide a foundation for future research on discrimination training and resurgence in the basic animal laboratory, which would provide crucial data for the development of such a quantitative model.

Conclusion

Translational research considers the applicability of fundamental behavioral principles to issues of social significance. Specifically, bidirectional translational research uses clinically significant questions to inform basic research which in turn improves future clinical research and practice (Mace & Critchfield, 2010). The present experiments provide additional support for the utility of translational research, and the obtained findings suggest that the conditions under which an alternative-response S^Δ stimulus will successfully prevent resurgence are limited. While future research is certainly warranted, the present experiments are an initial step toward a more comprehensive understanding of the relation between alternative-response discrimination training and resurgence.

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- long-term treatment of destructive behavior. *Journal of the Experimental Analysis of Behavior*, 96(2), 261-282. <https://doi.org/10.1901/jeab.2011.96-261>
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- Winterbauer, N. E., Lucke, S., & Bouton, M. E. (2013). Some factors modulating the strength of resurgence after extinction of an instrumental behavior. *Learning and Motivation*, 44(1), 60-71. <https://doi.org/10.1016/j.lmot.2012.03.003>

CURRICULUM VITAE

Kaitlyn O. Browning

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EDUCATION

2020 **Ph.D., Psychology** (in progress)
Department of Psychology
Utah State University
Dissertation: A translational examination of alternative-response
discrimination training and resurgence
Dissertation Chair: Timothy Shahan, Ph.D.

2012 **B.A., Psychology**
Department of Psychology
California State University, Long Beach

RESEARCH INTERESTS

Experimental analysis of behavior
Applied behavior analysis
Translational behavior analysis
Quantitative analysis of behavior
Relapse
Stimulus control

MEMBERSHIPS

Association for Behavior Analysis, International
Society for the Quantitative Analysis of Behavior
American Psychological Association, Division 25
Psi Chi Honor Society

AWARDS

2017 Ray Alvord Scholarship
Department of Psychology
Utah State University

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| POSITIONS HELD |
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RESEARCH POSITIONS

- 2015-Present Manager, Shahan Lab
 Department of Psychology
 Utah State University
 Faculty Supervisor: Timothy Shahan, Ph.D.
- 2014-Present Graduate Research Assistant
 Department of Psychology
 Utah State University
 Faculty Supervisor: Timothy Shahan, Ph.D.
 Grant Work:
- 4) 1R01HD093734-01: Basic and Clinical Studies in Reinforcing Positive Behaviors in Intellectual and Developmental Disabilities
 - 3) 1R21AA025604-01A1: Alcohol Seeking and Resurgence Following Escalating Negative Consequences
 - 2) R21DA038950: Resurgence of Punishment-Suppressed Cocaine Seeking
 - 1) 1R21DA037725-01: Theory of Resurgence of Cocaine Seeking
- 2012-2014 Post-Baccalaureate Research Assistant
 Department of Psychology
 University of California, Los Angeles
 Faculty Supervisor: Aaron Blaisdell, Ph.D.
- 2011-2012 Undergraduate Research Assistant
 Department of Psychology
 Department of Physical Therapy
 California State University, Long Beach
 Faculty Supervisors: Young-Hee Cho, Ph.D. & Olfat Mohamed, Ph.D., P.T.

TEACHING POSITIONS

- 2019-2020 Graduate Student Instructor
 Department of Psychology
 Utah State University
 Course: Analysis of Behavior: Basic Principles and Lab, Lecture & Online
 Faculty Supervisor: Gregory Madden, Ph.D.

- 2017 Graduate Student Instructor
Department of Psychology
Utah State University
Course: Analysis of Behavior: Advanced (Online)
Faculty Supervisor: Amy Odum, Ph.D.
- 2014-2015 Graduate Teaching Assistant
Department of Psychology
Utah State University
Course: Analysis of Behavior: Basic Principles (Online)
Supervisor: Jay Hinnenkamp, M.S.
- 2011-2012 Undergraduate Teaching Assistant
Department of Psychology
California State University, Long Beach
Courses: General Psychology & Abnormal Psychology (In person)
Faculty Supervisor: Chi-Ah Chun, Ph.D.

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| PROFESSIONAL SERVICE |
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Graduate Student Representative
Behavior Analysis PhD Program
Department of Psychology
Utah State University
2017-2019

Ad Hoc Reviewer
Behavioral Development
Journal of Applied Behavior Analysis
Journal of the Experimental Analysis of Behavior
Learning and Motivation
The Psychological Record

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| PUBLICATIONS |
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PEER-REVIEWED PUBLICATIONS

- 6) Shahan, T. A., **Browning, K. O.**, & Nall, R. W. (2020). Resurgence as choice in context: Treatment duration and on/off alternative reinforcement. *Journal of the experimental analysis of behavior*. Early view online.
- 5) Craig, A. R., Sullivan, W. E., **Browning, K. O.**, DeRosa, N. M., & Roane, H. S. (2019). Re-exposure to reinforcement in context A during treatment in context B reduces ABC renewal. *Journal of the experimental analysis of behavior*. Early view online.
- 4) **Browning, K. O.** & Shahan, T.A. (2018) Renewal of extinguished operant behavior following changes in social context. *Journal of the experimental analysis of behavior*, 110(3), 430-439.

- 3) Nall, R. W., Craig, A. R., **Browning, K. O.**, & Shahan, T. A. (2018). Longer treatment with alternative non-drug reinforcement fails to reduce resurgence of cocaine or alcohol seeking in rats. *Behavioural brain research*, 341, 54-62.
- 2) Craig, A. R., **Browning, K. O.**, & Shahan, T. A. (2017) Stimuli previously associated with reinforcement mitigate resurgence. *Journal of the experimental analysis of behavior*, 108(2), 139-150.
- 1) Craig, A. R., **Browning, K. O.**, Nall, R. W., Marshall, C. A., & Shahan, T. A. (2017). Resurgence and alternative-reinforcer magnitude. *Journal of the experimental analysis of behavior*. 107(2), 218-233.

MANUSCRIPTS UNDER REVIEW

- 1) Shahan, T. A., **Browning, K. O.**, Nist, A. N., & Sutton, G. M. Resurgence and downshifts in alternative reinforcement rates. *Journal of the experimental analysis of behavior*.

MANUSCRIPTS IN PREPARATION

- 2) **Browning, K. O.**, Sutton, G. M, Nist, A. N., & Shahan, T. A. Alternative reinforcement magnitude thinning and resurgence.
- 1) Craig, A. R., Cunningham, P. J., **Browning, K. O.**, & Shahan, T. A. Reinforcer-rate effects on resistance to extinction depend more on testing conditions than on training conditions.

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| PRESENTATIONS |
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SYMPOSIUM PRESENTATIONS

- 3) **Browning, K.O.**, Nall, R. W., & Shahan, T. A., (2019, May). Treatment duration and resurgence. In A. Fuhrman (chair), Recent Basic and Translational Research Evaluating the Effects of Baseline and Treatment Duration on Resurgence. Symposium conducted at the 45th annual meeting of the Association for Behavior Analysis, International, Chicago, IL.
- 2) **Browning, K. O.** & Shahan, T. A. (2018, May). Social stimuli and relapse of operant behavior in rats. In T. Hackenberg (chair), Cooperation, Altruism, and Social Reinforcement: Current Trends in the Experimental Analysis of Social Behavior. Symposium conducted at the 44th annual meeting of the Association for Behavior Analysis, International, San Diego, CA.
- 1) **Browning, K. O.**, Craig, A. R., & Shahan, T. A. (2016, May). Alternative-reinforcer magnitude effects on response suppression and resurgence. In C. St. Peter (chair), Resurgence and Relapse: From Bench to Bedside. Symposium conducted at the 42nd annual meeting of the Association for Behavior Analysis, International, Chicago, IL.

POSTERS

- 5) **Browning, K. O.**, & Shahan, T. A. (2017, May). ABA renewal using social contextual stimuli. Poster presented at the 40th annual meeting of the Society for the Quantitative Analysis of Behavior, Denver, CO.

- 4) Craig, A. R., **Browning, K. O.**, & Shahan, T. A. (2017, May). Delivery of Conditioned Reinforcers Suppresses Resurgence. Poster presented at the 40th annual meeting of the Society for the Quantitative Analysis of Behavior, Denver, CO.
- 3) Nall, R. W., Craig, A. R., & **Browning, K. O.**, & Shahan, T. A. (2017, May). Effects of treatment duration on resurgence of cocaine seeking. Poster presented at the 40th annual meeting of the Society for the Quantitative Analysis of Behavior, Denver, CO.
- 2) **House, K. O.**, Craig, A. R., Cunningham, P. J., & Shahan, T. A. (2015, May). Difference in resistance to extinction between single and multiple schedules may be related to testing conditions. Poster presented at the 38th annual meeting of the Society for the Quantitative Analysis of Behavior, San Antonio, TX.
- 1) Cho, Y.-H., White, B., **House, K. O.**, Mohamed, O., & Singh-Carlson, S. (2012). Effect of fall-prevention program on subjective health and life expectancy among older adults. Poster presented at the 65th annual meeting of the Gerontology Society of America, San Diego, CA.

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| GRANT PROPOSALS |
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- 2) **Browning, K. O.** & Shahan, T. A. (June 2017). Examining the role of response-noncontingent reinforcement in mitigating resurgence. \$1000 award from the office of Research and Graduate Studies at Utah State University for the Graduate Research and Creative Opportunities Grant.
- 1) **Browning, K. O.** & Shahan, T. A. (February 2017). Assessing the effects of delay to alternative reinforcement on resurgence of target behavior. Unfunded proposal submitted to the Society for the Advancement of Behavior Analysis for the Innovative Student Research Dissertation Grant.

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| ONGOING RESEARCH |
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LEAD INVESTIGATOR

- 1) Translational evaluation of alternative-response discrimination training and resurgence
Faculty Supervisor: Timothy Shahan, Ph.D.
- 2) Parametric analysis of the effects of alternative reinforcement rate and alternating reinforcement on resurgence
Faculty Supervisor: Timothy Shahan, Ph.D.
Student Collaborators: Anthony Nist, Gabrielle Sutton

COLLABORATIONS

- 1) The effects of within-session alternating alternative reinforcement on resurgence
Faculty Supervisor: Timothy Shahan, Ph.D.
Student Collaborators: Sara Trickett

- 2) Resurgence of alcohol seeking after suppression by escalating negative consequences

Faculty Supervisor: Timothy Shahan, Ph.D.

Student Collaborators: Anthony Nist, Rusty Nall

MENTORSHIP

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| 2018-Present | Sara Trickett Undergraduate Laboratory Technician Utah State University Advised on a funded Undergraduate Research and Creative Opportunities grant proposal, June 2019 |
| 2017-2018 | Tanner Nielsen Undergraduate Laboratory Technician Utah State University |
| 2016-2017 | Alexandra Tebbs Undergraduate Laboratory Technician Utah State University |
| 2015-2016 | James Hoye Undergraduate Laboratory Technician Utah State University |

REFERENCES

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