Summer 8-9-2019

Resurgence Following Interdependent and Traditional Differential Reinforcement of Alternative Behavior

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RESURGENCE FOLLOWING TRADITIONAL AND INTERDEPENDENT DIFFERENTIAL REINFORCEMENT OF ALTERNATIVE BEHAVIOR

by

Ashley M. Fuhrman

A DISSERTATION

Presented to the Faculty of

the University of Nebraska Graduate College

in Partial Fulfillment of the Requirements

for the Degree of Doctor of Philosophy

Medical Sciences Interdepartmental Area
Graduate Program

(Applied Behavior Analysis)

Under the Supervision of Professor Wayne W. Fisher

University of Nebraska Medical Center
Omaha, NE

June, 2019

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ACKNOWLEDGEMENTS

I would not have come this far if it was not for the extraordinary people in my life who have supported me. I am grateful for my dad, who taught me to work hard to achieve my goals. For my mom, who always supported me through everything, I know she would be proud. For my sister, who also moved to Omaha, I am thankful for her support and the extra time we were able to spend together while living in the same city. I am extremely grateful for my husband, Shea, and his family for their never-ending support and encouragement. Without Shea’s patience, understanding, love, and willingness to pick up my slack at home to make up for my hours spent on schoolwork, I would not have been able to complete this program. To my son, Strider, who was an extraordinary gift while I was in the program, I am thankful for the motivation he provided me to succeed and the joy he brings me on a daily basis. To my undergraduate mentors, Kevin Klatt and Renee Norman, who are responsible for introducing me to behavior analysis and setting me up for success in graduate school. I was fortunate to have received mentorship from a number of outstanding professors throughout my graduate career, especially from all members of my dissertation committee. I am especially thankful to my direct mentors, Wayne Fisher and Brian Greer, for everything they have taught me throughout the last six years. Their support and mentorship have provided me with countless opportunities to grow as a student, clinician, and researcher. To the students and coworkers who helped me tremendously with data collection and running sessions, Kendra Smallwood, Natasha Chamberlain, Alexandra Hardee, and Jamie Jones, I am thankful for the countless early mornings you spent helping me with research.
Clinicians frequently prescribe functional communication training (FCT) as a treatment for severe destructive behavior. Recent research has shown that FCT treatments are susceptible to treatment relapse in the form of resurgence of destructive behavior when individuals contact periods in which reinforcers are unavailable (e.g., Fisher, Greer, Fuhrman, Saini, & Simmons, 2018). Behavioral Momentum Theory (BMT) is a quantitative model of behavior researchers have employed to predict treatment relapse when the reinforcement component of FCT is suspended, which may occur when a caregiver is unable to implement treatment. Although many studies support the accuracy of BMT (e.g., Fisher et al., 2018), it does not provide predictions for training multiple alternative responses during FCT, which recent research suggests can decrease resurgence (e.g., Lambert, Bloom, Samaha, & Dayton, 2017). A novel theory of resurgence, Resurgence as Choice (RaC; Shahan & Craig, 2017), allows researchers to test predictions of programming multiple alternative responses. The current study used a translational arrangement to evaluate the effects of training one alternative response versus multiple alternative responses on the resurgence of target behavior. Findings showed that multiple-response training did not decrease resurgence of target responding consistently, however, it increased the total amount of responding observed during the resurgence phase and decreased the overall probability of the target response.

Keywords: resurgence, destructive behavior, translational, quantitative models
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<tr>
<td>DRA</td>
<td>Differential reinforcement of alternative behavior</td>
</tr>
<tr>
<td>FCT</td>
<td>Functional communication training</td>
</tr>
<tr>
<td>FCR</td>
<td>Functional communication response</td>
</tr>
<tr>
<td>BMT</td>
<td>Behavioral momentum theory</td>
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<tr>
<td>RaC</td>
<td>Resurgence as choice</td>
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<td>Trad DRA</td>
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INTRODUCTION

Severe Destructive Behavior

Many individuals with autism or intellectual disability display severe destructive behavior (e.g., aggression, self-injurious behavior) that pose significant health risks to the individual and others and represent overwhelming barriers to community integration (Crocker et al., 2006). As such, it is critical that researchers develop and validate treatments for severe destructive behavior that remain effective under both optimal (e.g., in the clinic) and natural conditions (e.g., in the home or at school). A common treatment for destructive behavior is differential reinforcement of alternative behavior (DRA) prescribed based on the results of a functional analysis. During DRA, a clinician teaches an appropriate alternative response to replace destructive behavior. The DRA treatment with the most empirical support for severe destructive behavior is functional communication training (FCT), which typically involves (a) suspending the contingency between destructive behavior and its functional reinforcer (i.e., extinction) and (b) delivering the functional reinforcer contingent on an appropriate request (i.e., the functional communication response [FCR]; Carr & Durand, 1985).

Despite its effectiveness, recent research suggests that destructive behavior may be susceptible to treatment relapse in the form of resurgence following successful treatment with FCT if the communication response does not produce reinforcement (e.g., Briggs, Fisher, Greer, & Kimball, 2018; Fisher, Greer, Fuhrman, Saini, & Simmons, 2018; Fuhrman, Fisher, & Greer, 2016; Volkert, Lerman, Call, & Trosclear-Lasserre, 2009). Resurgence occurs when a previously reinforced response (e.g., destructive behavior) reemerges when an alternative response (e.g., FCR) is challenged (e.g., extinction).
Individuals treated with FCT often contact periods without reinforcement when caregivers make treatment-integrity errors when implementing the treatment outside of the clinic, where they experience many distractions and competing responsibilities. For example, when a caregiver must change the diaper for an infant sibling or take an important phone call, it is likely that the caregiver will be unable to provide their child with the functional reinforcer each time the child engages in an FCR. It is imperative that the treatments we develop and prescribe remain durable and effective even in the absence of implementation (Greer & Shahan, 2019). Thus, to improve the effectiveness and generality of FCT, it is crucial to evaluate techniques to mitigate the resurgence of destructive behavior in the face of treatment-integrity errors.

**Quantitative Models of Behavior**

One way that researchers can conceptualize and study resurgence is to use quantitative models of behavior. Quantitative models of behavior make precise and testable predictions about the processes and variables that affect resurgence. Importantly, these models can guide clinical and translational researchers in developing novel modifications to improve commonly prescribed treatments for destructive behavior (e.g., FCT). As stated by Critchfield and Reed (2009), anyone who has a desire to translate basic science into everyday concerns should learn to apply quantitative principles.

Behavioral Momentum Theory (BMT) is one quantitative model that researchers have used to predict the resurgence of destructive following successful FCT treatment (Nevin & Shahan, 2011). The predictions of BMT align with the metaphor of the momentum of moving objects, where the strength of a response is equivalent to the mass of a moving object and the baseline rate of a response is equivalent to the velocity of a moving object. The model predicts that the more strength a behavior has, the more
likely it is to persist in the face of challenges (e.g., when the functional reinforcer is unavailable). Furthermore, BMT predicts that higher reinforcer rates increase the strength of a response and thereby increase its persistence and the likelihood that it will resurge when alternative reinforcement becomes unavailable. Regarding FCT, BMT predicts that the more frequently destructive behavior contacts reinforcers in a given context, the more likely it is to resurge when treatment is disrupted in that context (e.g., when a caregiver is unable to reinforce the FCR). Multiple studies support the accuracy of BMT’s predictions under various experimental and clinical arrangements (e.g., Fisher et al., 2018; Fuhrman, Fisher, Greer, 2016; Mace, et al., 2010; Marsteller & St. Peter, 2014; Nevin, Tota, Torquato, & Shull, 1990; Pritchard, Hoerger, & Mace, 2014; Wacker et al., 2011; Wacker et al., 2013). For example, Fisher et al. (2018) found that programming a leaner schedule of reinforcement during baseline and FCT and increasing the number of treatment sessions decreased resurgence of destructive behavior, results predicted by BMT.

Although some research findings support the predictions of BMT, recent research demonstrates concerning errors in the predictions of BMT (e.g., counter to the predictions of BMT, target responding sometimes increases during extinction with differential reinforcement relative to extinction without differential reinforcement; Craig & Shahan, 2016; Shahan & Craig, 2017). Another limitation of BMT is that it does not allow for predictions regarding some treatment variables that are common in the applied setting (Greer & Shahan, 2019). For example, BMT makes no predictions about the effects of manipulating potentially important treatment variables, such as (a) increasing the quality of alternative reinforcers, (b) decreasing the amount of effort required for the alternative response, or (c) increasing the number of available alternative responses programmed during treatment. Unfortunately, because BMT cannot account for some
variables that are common components of prescribed treatments, it is difficult to translate the fundamental underpinnings of the theory to improve current applied practices.

To address the limitations of BMT, Shahan and Craig (2017) proposed a novel theory of treatment relapse called Resurgence as Choice (RaC). The RaC theory is based on a strong scientific premise that is an extension of the generalized matching law, which states that organisms allocate proportionally more time to responses that produce proportionally more reinforcement (Baum & Rachlin, 1969). Thus, the theory suggests that the probability of a behavior (e.g., destructive behavior or FCR) is a function of the relative value of consequences that an organism historically obtained following the behavior (Shahan & Craig, 2017). Research has shown that RaC provides accurate predictions in many situations where BMT failed, and RaC also accounts for variables that BMT does not (e.g., effects of qualitatively different reinforcers for the target and alternative responses). These features of RaC allow researchers to model and test important predictions that BMT cannot address (Shahan & Craig, 2017). As such, RaC appears to be well suited for developing and refining FCT treatments for destructive behavior.

**Training Multiple Response Alternatives**

Results of preliminary research suggest that teaching multiple alternative responses can mitigate the resurgence of target behavior (e.g., Bloom & Lambert, 2015; Hoffman & Falcomata, 2014; Lambert, Bloom, Samaha, & Dayton, 2017; Lambert, Bloom, Samaha, Dayton, & Rodewald, 2015), findings predicted by RaC but not BMT. That is, instead of teaching individuals only one alternative response, clinicians may be able to mitigate the resurgence of destructive behavior following treatment by teaching multiple alternative responses. If these preliminary results prove to be general and
robust, they have clear and significant clinical implications for enhancing current treatment procedures.

One way to teach multiple alternative responses during DRA is to use serial training procedures (i.e., serial DRA). During the first phase of serial DRA, clinicians provide reinforcement for destructive behavior and in the second phase, they place destructive behavior on extinction and sequentially train, reinforce, and extinguish multiple alternative responses. For example, after training the first alternative response, the clinician places that response on extinction and begins providing reinforcement for a second alternative response. After training the second response, the clinician places both the first and second alternative responses on extinction and begins providing reinforcement for a third response. The results of a recent translational study by Lambert et al. (2015) showed that serial DRA decreased the magnitude of target-response recovery during extinction relative to traditional DRA for three participants. In 2017, Lambert et al. extended their translational research by using serial training procedures during FCT (i.e., serial FCT) with two children referred for problem behavior. Lambert et al. (2017) found that less problem behavior occurred during extinction following serial DRA relative to traditional DRA. Although some studies evaluating serial DRA have produced promising results, recent studies have been unable to replicate the results (Purcell, 2018) or have demonstrated that the reductions in resurgence are a result of the number of available alternative responses rather than the serial training procedure itself (Diaz-Salvat, St. Peter, & Shuler, in preparation). Also, the predictions of the RaC theory suggest that sequentially placing the alternative responses on extinction during serial FCT may actually counteract the potential beneficial effects of training multiple alternative communication responses.
An additional method that clinicians can use to teach multiple alternative responses during DRA is to employ a lag schedule of reinforcement. A lag schedule induces behavioral variability because it programs reinforcement for a response that is different than a predetermined number of previous responses (Page & Neuringer, 1985). For example, on a Lag-1 schedule, a clinician may only provide reinforcement for a child’s mand (e.g., “toy please”) if that mand differed from the mand that produced the preceding reinforcer (e.g., “I want toy.”). Adami, Falcomata, Muething, and Hoffman (2017) compared the use of Lag-0 (i.e., no lag contingency) and Lag-1 schedules of reinforcement for mands during FCT and found that problem behavior remained low in both conditions, but that the Lag-1 schedule increased the variability of mands relative to the Lag-0 schedule. Falcomata et al. extended Adami et al. by increasing the lag schedule during FCT from a Lag 0 to a Lag 5 and observed maintenance of treatment effects (i.e., low levels of problem behavior). The authors of both studies pointed out that no resurgence of problem behavior occurred even though they placed some mands on extinction during the conditions in which they used lag schedules greater than 1.

Although researchers have yet to evaluate the effects of lag schedules during FCT in a traditional resurgence paradigm, the results of these studies suggest that the use of lag schedules during FCT could potentially mitigate relapse of problem behavior when the alternative communication response contacts periods of extinction (i.e., treatment challenges). Despite the potential benefits of the procedure, the feasibility of the implementation of and data collection for lag schedules may be impractical, especially as the size of the lag schedule increases. For example, with a Lag-5 schedule, a clinician would reinforce a response only if it differed from the previous five responses; thus, the clinician would need to collect data on all response topographies and the order in which they occurred which ones produced the last five reinforcers.
Therefore, it may be beneficial to use a different type of schedule to provide reinforcement for multiple alternative responses during FCT.

A schedule that basic researchers use to ensure the equal probability of reinforcer deliveries across response alternatives is an interdependent concurrent schedule (Stubbs & Pliskoff, 1969). During an interdependent concurrent variable-interval (VI) schedule of reinforcement for two response alternatives, an experimenter uses a single VI schedule and provides reinforcement for one of the two responses following the end of each interval according to a randomized and equally distributed list of the two responses. For example, on an interdependent concurrent VI 30-s schedule for two different key pecks by pigeons, an experimenter would deliver a reinforcer approximately every 30 s for one of the two key pecks, depending on which of the two responses was selected for reinforcement (Alessandri, Lattal, & Fantino, 2013). In an applied setting, a clinician might arrange an interdependent schedule such that he or she would randomly but equally deliver reinforcement for different topographies of responses. An interdependent schedule may be one way in which clinicians could effectively and feasibly provide reinforcement for multiple alternative responses during FCT because the clinician can determine the order of reinforcer deliveries for the multiple alternative responses ahead of time and then simply follow the schedule during the treatment session. Also, it may be much less susceptible to integrity errors when carried out by caregivers because they would not need to keep track of the child's responses and the order in which they occurred.

In the current study, we extended previous research and evaluated the effects of training multiple alternative responses on the resurgence of target behavior in an analog context. This study served as a translational evaluation of the resurgence of target
behavior following an analog arrangement of DRA with an interdependent, concurrent reinforcement schedule (iDRA) compared to traditional DRA (trad DRA).

CHAPTER 1: METHODS

Participants, Setting, and Materials

We enrolled 14 typically developing adults, 13 females and one male, in the study. Participants ranged in age between 22 and 42 ($M = 29$) and spoke English as their first language. We enrolled participants in dyads to facilitate reinforcement-yoking procedures. We assigned the first participant in each dyad to the iDRA group and the second participant to the trad DRA group. We programmed the first participant in each dyad to the iDRA group because we hypothesized participants would be less efficient in obtaining tokens during iDRA relative to trad DRA and therefore wanted to yoke token deliveries from the condition that we expected the least amount of token deliveries in. They completed participation in one research session that lasted approximately 30 to 45 min. We planned to exclude participants if target responding extinguished during baseline, but no participant met that criterion. We also planned to exclude participants if we did not observe suppression of target responding during DRA and excluded a total of two participants who met that criterion. Therefore, we retained a total of six participants per group.

We conducted sessions in a room with a table, chairs that was adjacent to a room with one-way observation. Materials included two to four BigMac buttons, tokens, a clear jar for the tokens, laptop computers, VI schedules, paper, and pens. One experimenter sat in the room with the participant to deliver the session rules and tokens. Data collectors remained behind the one-way observation window during experimental sessions and data collection materials consisted of a laptop computer, VI schedules, paper, and pens.
Response Measurement

Trained observers sat in the observation room and used BDataPro (Bullock, Fisher, & Hagopian, 2017) to collect data on laptop computers. Observers collected data on the frequency of target responses, alternative responses, and token deliveries. We defined target and alternative responses as pressing BigMac buttons with a unique color, purple, orange, blue, or green, associated with each button. We defined button presses as a participant using his or her hand or finger(s) to press a BigMac button such that an observer could hear an audible click. BDataPro calculated the rate of target and alternative response by dividing the number of responses by the session time.

Interobserver Agreement and Procedural Integrity

A second observer collected data simultaneously, but independently on 58% of sessions. BDataPro recorded an agreement for each 10-s interval in which both data collectors scored the same number of a given response (e.g., each recording 3 target responses between Second 0 and Second 9). BDataPro then summed the number of intervals with exact agreements, divided the sum by the total number of intervals, and converted the resulting quotient to a percentage. The second observer was blind to the experimental hypotheses for 29% of the sessions for which a second observer collected data. Mean interobserver-agreement coefficients were 99.27% (range, 96.46% to 100%) for target responses and alternative responses and 94.24% (range, 88.19% to 98.13%) for token deliveries.

An observer independently collected data on the occurrence of correct token delivery, which was our measure of procedural integrity, during 92% of sessions. A correct token delivery occurred if the experimenter delivered the token for the correct response and within 1 s of the response. We calculated integrity by dividing the number of correct token deliveries by the total number of token deliveries and converting the
quotient to a percentage. Mean procedural integrity was 94% across sessions (range, 67.3% to 100%).

**Experimental Procedure**

**Experimental Design**

We used a between-participants group design and the standard three-phase resurgence preparation (Podlesnik & Kelley, 2015) to evaluate the resurgence of target behavior following iDRA (i.e., test condition) and trad DRA (i.e., control condition). That is, each participant’s evaluation consisted of one, three-phase arrangement during which we conducted baseline followed by DRA and extinction. For six of the participants, we conducted DRA in a traditional manner (i.e., one available alternative response) and for the other six participants, we conducted iDRA (i.e., three available alternative responses). The first participant in each dyad experienced iDRA and the second participant experienced trad DRA during which we arranged token deliveries on a VI schedule of reinforcement yoked to the interreinforcement times produced by the participant who experienced iDRA. We programmed the first participant in each dyad to the iDRA group because we hypothesized participants would be less efficient in obtaining tokens during iDRA relative to trad DRA and therefore wanted to yoke token deliveries from the condition that we expected the least amount of token deliveries in.

**Method**

**Informed-Consent Process.** We received approval from our institutional review board to withhold the hypothesis and some procedural details from the participants during the informed-consent process. The experimenter described that the purpose of the study was to evaluate the effectiveness of teaching procedures for children who engage in severe destructive behavior. The experimenter stated the potential risks and
benefits associated with the study, the anticipated duration of the study, and that he or she would provide more information about the study following its end. In addition, the experimenter informed the participant that he or she would receive $20 for each hour of study participation.

**General Procedure**

The experimenter placed BigMac buttons on a table in a semicircle, equidistant from one another before the session began. The participant entered the room and sat at the table such that the BigMac buttons were equidistant from him or her. We assessed participant responding in one 30- to 45-min session that included sequential phases of baseline, trad DRA or iDRA, and extinction. An experimenter sat in the room and signaled the start of each phase by stating a contingency-specifying rule. The experimenter in the room wore an earpiece connected to a walkie-talkie. An experimenter in the observation room communicated the VI schedule through the walkie-talkie. We randomized the location of the target and alternative responses across each dyad of participants. That is, we assigned the same location for the target response for each dyad (e.g., Button 1 was the target response for both participants in Dyad 1) but randomized that location for each new dyad.

**Baseline.** The experimenter placed one button on the table and delivered the following rule before the start of the phase:

“I’m going to have a variety of responses for you to engage in. For each response, sometimes you will get tokens and sometimes you won’t. Please only use one hand at a time and do not move any of the buttons. Try to get as many tokens as you can. This is the response I’m going to have you do first [experimenter modeled the target response]. You can begin when I say ‘go’.”
We observed large variability in the rate of responding across participants in the first two dyads. Therefore, we attempted to reduce the variability in responses rates by adding a statement to the rules for the remaining participants. The experimenter said, “Also try to pay attention to when you are getting tokens and try not to just push the button as fast as you can.”

The experimenter said, “Go,” and delivered the first token for the first instance of the target response. The experimenter then delivered tokens for the target response on an interdependent, concurrent VI 15-s schedule of reinforcement during the iDRA condition. For the remainder of the phase for participants that experienced trad DRA, the experimenter delivered tokens on a VI schedule of reinforcement yoked to the interreinforcement times produced during baseline by the preceding participant in the dyad who experienced iDRA, with one caveat for extreme responses. If the participant assigned to iDRA exhibited any extreme response pauses that exceeded 3 standard deviations from their mean interresponse time, we replaced that extreme values in the yoked schedule with the value that was equal to 3 standard deviations above the mean. For example, if a participant who experienced iDRA exhibited one 90-s response pause, with a mean interresponse time of 12 s and a standard deviation of 16 s, we replaced the 90-s interval with a 48-s interval in the yoked schedule for the corresponding trad DRA participant. We implemented this caveat in the yoking schedule to avoid extinction of responding for the trad DRA participant. The baseline phase was a minimum of 10 min in duration and continued until we achieved a stable or increasing trend in target responding. Immediately after the baseline phase ended, the experimenter moved to the DRA phase (i.e., iDRA or trad DRA).

**iDRA.** Six of the participants experienced iDRA. Before the start of the phase, the experimenter added three additional BigMac buttons to the table and said:
“This response is still available [experimenter modeled the target response], but here are some other responses you can do [experimenter modeled the alternative responses]. Please only use one hand at a time and do not move any of the buttons. Get as many tokens as you can and try to pay attention to which buttons are getting you tokens. You can begin when I say ‘go’.”

Data collectors paused data collection while the experimenter stated the rule. We used the same rule statement that we added in the baseline phase after the first two dyads.

The experimenter delivered the first three tokens on a fixed-ratio (FR) 1 schedule of reinforcement for each of the three alternative responses for the first dyad, (i.e., the first time the participant engaged in each of the three alternative responses, he or she received a token). The experimenter delivered tokens on an FR-1 schedule of reinforcement for the other dyads for the first 2 min of the phase to simulate pretraining for an FCR in a clinical treatment. The two participants that we excluded from the study developed patterns of responding during iDRA that included the target response (e.g., pushing all buttons in the order in which they were arranged on the table). We hypothesized the FR-1 schedule for the first 2 min of the phase would also decrease the likelihood of participants developing a pattern of responding that included the target response.

For the remainder of the phase, the experimenter delivered tokens for the alternative responses on an interdependent concurrent VI 5-s schedule of reinforcement. We used an interdependent concurrent VI schedule to ensure that participants obtained an equal proportion of reinforcement across the available alternative responses (Stubbs & Pliskoff, 1969). The response button for the target response from baseline remained in the same location during iDRA. The experimenter placed target responding on extinction for the entire phase and implemented a 3-s change-over-delay (Herrnstein, 1961) for
any target responses that occurred within 3 s of the alternative response scheduled for token delivery. We conducted iDRA for a minimum of 10 min. We extended the iDRA phase if we a) extended the participant’s baseline phase (i.e., we made baseline and iDRA phases equal within participants) or b) did not observe suppression of target responding, defined as a mean of two responses per min or less in the last 2, 2-min session bins. Immediately after the iDRA phase ended, the experimenter moved to the extinction phase.

**Trad DRA.** Six participants experienced trad DRA. Before the start of the phase, the experimenter added a BigMac button to the table and said:

“This response is still available [experimenter modeled the target response], but here is another response you can do [experimenter modeled the alternative response]. Please only use one hand at a time and do not move any of the buttons. Get as many tokens as you can and try to pay attention to which button is getting you tokens.”

Data collectors paused data collection while the experimenter stated the rule. After the first two dyads, we added the same statement to the rules as we did in the baseline and iDRA phases (i.e., “also, try to pay attention to when you are getting tokens and try not to just push the buttons as fast as you can”) for the remainder of the participants.

The response button for the target response from baseline remained in the same location during trad DRA. The experimenter placed target responding on extinction for the entire phase and implemented a 3-s change-over delay for any target responses that occurred within 3 s of the alternative response. The experimenter delivered the first token following the first instance of the alternative response and all subsequent tokens according to a VI schedule of reinforcement yoked to the interreinforcement times produced by the preceding participant in the dyad who experienced iDRA. As in baseline
for participants who experienced iDRA, we replaced any extreme values in the yoked schedule with the value that was equal to three standard deviations above the mean of all the yoked values. We conducted trad DRA for a minimum of 10 min. We extended the phase if we a) extended the participant’s baseline phase (i.e., we made baseline and trad DRA phases equal within participants) or b) we observed a decreasing trend did not observe suppression of target responding, defined as a mean of two responses per min or less in the last 2, 2-min session bins. Immediately after the trad DRA phase ended, the experimenter moved to the extinction phase.

**Extinction.** We implemented identical extinction procedures across both groups. The extinction phase lasted 10 min and began immediately after the DRA phase. The experimenter did not provide any rules. The target and alternative response(s) (i.e., one alternative response for participants in the trad DRA group, three alternative responses for participants in the iDRA group) from the DRA phases remained present during extinction. The experimenter placed target and alternative responses on extinction for the entire phase.

**Debriefing procedure.** Following each participant’s completion of the study, the experimenter asked each participant what behaviors they thought resulted in token delivery during the study and recorded their answers. The experimenter then explained the full procedures and hypothesis of the study and described the reasoning for the blinding procedures. The experimenter also provided the participant with the opportunity to ask questions about the study procedures.

**CHAPTER 2: RESULTS AND DISCUSSION**

**Results**
Figure 1 displays the rate of target and alternative responding for the first three dyads. For the first dyad (top panel), we observed maintenance of target responding in baseline and immediate suppression of target responding during DRA for both participants. We observed a large range in the overall rate of responding across the two participants in the dyad. The participant who experienced iDRA emitted near-zero or zero levels of target responding and high, increasing levels of alternative responding across all three response options during DRA. During trad DRA with the second participant, we did not observe suppression of target responding to zero levels until 16 min into the phase and alternative responding increased as the phase progressed. During the extinction phase, we observed resurgence of target responding following trad DRA but not following iDRA. In addition, we observed high rates of alternative responding during extinction for both participants in this dyad.

The middle panel of Figure 1 displays the results for the second dyad of participants. We obtained similar responding as with the first dyad with the exception that suppression of target responding occurred more rapidly in trad DRA than iDRA and we observed resurgence of target responding in the extinction phase following both sequences. A higher level of resurgence occurred in the extinction phase following trad DRA than in the extinction phase following iDRA. We observed high rates of alternative responding in the extinction phase for both participants. The bottom panel of Figure 1 displays the results for the third dyad of participants. As with the second dyad, trad DRA suppressed target responding more rapidly than iDRA and both participants emitted high, increasing rates of alternative responding during DRA. During the extinction phase, low levels of resurgence occurred with both participants, but we obtained higher rates of alternative responding with the participant who experienced iDRA.

Figure 2 displays the rate of responding for the fourth, fifth, and sixth dyads. With
Figure 1. Results for Dyads 1-3. Responses per minute of target and alternative responding during iDRA (left) and trad DRA (right) sequences for dyads one (top), two (middle), and three (bottom).
Figure 2. Results for Dyads 4-6. Responses per minute of target and alternative responding during iDRA (left) and trad DRA (right) sequences for dyads four (top), five (middle), and six (bottom).
the fourth dyad (top panel of Figure 2), we observed stable or increasing trends of target responding in baseline and suppression of target responding during DRA phases. Target responding decreased more rapidly for the participant who experienced trad DRA.

The participant who experienced iDRA developed a pattern in which she always depressed the first alternative response immediately after depressing the target response. The participant responded for four consecutive minutes without obtaining the token scheduled for an FR-1 delivery for the first alternative response. After four consecutive minutes without delivering a token, the session therapist removed the change-over-delay and delivered a token immediately after the participant engaged in the first alternative response. When we put the change-over-delay back in place, the participant again began depressing the target response immediately before engaging in the first alternative response. Therefore, at minute 10 in iDRA, we eliminated the change-over-delay for the remainder of the phase and then observed suppression of target responding. During the extinction phase, moderate levels of resurgence occurred with the participant who experienced iDRA and low levels of resurgence occurred for the participant who experienced trad DRA. We observed higher rates of alternative responding in the extinction phase following iDRA than in the extinction phase that followed trad DRA.

The middle panel of Figure 2 displays the results for the fifth dyad of participants. With both participants, baseline resulted in stable rates of target responding during baseline and DRA resulted in suppression of target responding and a high rate of alternative responding. During the extinction phase, we observed low rates of target responding and persistence of alternative responding with both participants. The bottom panel of Figure 2 displays the results for the sixth dyad of participants. Again, we observed high rates of target responding during baseline and suppression of target responding.
responding and high, stable levels of alternative responding during DRA for both participants. However, trad DRA suppressed target responding more rapidly than iDRA. During the extinction phase, both participants exhibited low levels of resurgence, however, we observed slightly higher levels of resurgence with the participant who experienced iDRA than with the participant who experienced trad DRA.

Table 1 presents the average rate of token deliveries during baseline and DRA phases for all six dyads. Our yoking procedure resulted in similar rates of token delivery across participants in each dyad with the exception of Dyads 3 and 4, for which token deliveries were higher for the participants who experienced iDRA.

<table>
<thead>
<tr>
<th>Dyad</th>
<th>Baseline (iDRA)</th>
<th>iDRA</th>
<th>Baseline (Trad DRA)</th>
<th>Trad DRA</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2.93</td>
<td>4.92</td>
<td>3.00</td>
<td>5.06</td>
</tr>
<tr>
<td>2</td>
<td>2.80</td>
<td>8.70</td>
<td>3.14</td>
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<td>3.80</td>
<td>7.29</td>
<td>2.63</td>
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<td>3.00</td>
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</tr>
<tr>
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<td>3.70</td>
<td>5.64</td>
<td>3.40</td>
<td>4.86</td>
</tr>
</tbody>
</table>

Table 1. Mean Rates of Token Deliveries.

Additional data analyses. To account for differences in baseline response rates across sequences, we compared levels of resurgence following iDRA and trad DRA expressed as a proportion of baseline responding. To calculate the proportion of baseline, we averaged the target response rates during the last four baseline sessions for each participant and then divided the target response rates from each extinction
session by the baseline average. Figure 3 shows the resurgence of target behavior expressed as a proportion of baseline responding during extinction following the iDRA and trad DRA conditions for each dyad. For the first dyad, the proportion of baseline target responding was much lower in all five sessions of extinction that followed iDRA relative to those that followed trad DRA. For Dyads 2, 4, and 6, we observed lower proportion of baseline target responding in all five sessions of extinction that followed trad DRA relative to the extinction phase that followed iDRA. With Dyads 3 and 5, we observed similar and low levels of proportion of baseline target responding during the extinction phase for both iDRA and trad DRA.

To evaluate the persistence of target versus alternative responding, we also calculated the average proportion of target responding during extinction sessions following iDRA and trad DRA. To calculate the average proportion of target responding, we divided the rate of target responding by the sum of target responding plus alternative responding during each extinction session for each participant. Next, we averaged that proportional value for each extinction session across all participants in each group. Figure 4 displays the average proportion of target responding during the sessions of extinction following iDRA and trad DRA. Greater proportions of target responding occurred in all five sessions of extinction following trad DRA relative to those following iDRA. That is, following iDRA, participants were more likely to emit an alternative response rather than the target response.

To test for the significance between the proportion of target responding during the extinction phase in each group, we employed a randomization test similar to that described by Craig and Fisher (2018). The randomization test randomly redistributed the obtained data points from Figure 4 to iDRA or trad DRA 100,000 times to determine how often we would get differences in the proportion of target responding due to chance that
Figure 3. Proportion of Baseline Responding. Resurgence of target behavior expressed as a proportion of baseline responding during the extinction following the iDRA and trad DRA conditions for all dyads.
Figure 4. Proportion of Target Responding. The mean proportion of target responding during extinction following iDRA and trad DRA. Asterisks denote sessions in which the difference between the two data points is statistically significant (i.e., $p < .05$).
are as large or larger than those we observed in the study. Randomization analyses revealed that the mean difference between the average proportion of target responding during all sessions of extinction in iDRA and trad DRA was statistically significant, corresponding to a $p$-value of .008. We also conducted five additional randomization analyses to test for significance in the difference between the average proportion of target responding per session of extinction for the two groups. Those randomization analyses revealed the lower proportional rates of target responses during iDRA relative to trad DRA during extinction sessions two and four were statistically significant, corresponding to $p$-values of .03 and .02, respectively. The $p$-values corresponding to the other three sessions were not significant (all $ps > .34$).

We also employed a repeated-measures analysis of variance (ANOVA) using participant’s individual data from each of the five sessions of extinction for each group (i.e., 5 values per participant, 60 total values, 30 values per group). The ANOVA tested the significance of the difference we observed in the proportion of extinction-session target responding between iDRA and trad DRA. The results of the ANOVA revealed a significant difference between the two groups, $F (1, 10) = 6.83$, $p = .026$. This test produced a partial eta$^2$ effect size of 0.406, which is equivalent to a Cohen’s $d$ of 1.65.

To evaluate how well RaC accounts for the differences in responding across both groups, we used least-squares regression to fit the following equation (Equation 13 from Shahan & Craig, 2017) to the average rate of responding obtained during the last five sessions of baseline, the last five sessions of DRA, and all extinction sessions across both groups.

$$B_T = \frac{kV_T}{V_T + V_{Alt} + \frac{1}{A}} \quad (1)$$
According to Equation 1, target responding (B\textsubscript{T}) is a function of multiplying the asymptotic rate of B\textsubscript{T} (i.e., k) by the value of the outcomes produced by the target behavior (i.e., V\textsubscript{T}) and dividing that value by the sum of V\textsubscript{T}, the value of the outcomes produced by the alternative responses (i.e., V\textsubscript{Alt}), and 1 divided by the invigorating effects of reinforcement (i.e., A). We encourage readers to see Shahan and Craig (2017) or Greer and Shahan (2019) for detailed descriptions of the model’s parameters. How Equation 1 applies to trad DRA in the current study is relatively straightforward, however, when applied to iDRA, we have multiple alternative responses and therefore multiple values for those alternative responses, each of which contributes to the relative value of the target response. That is, iDRA may decrease resurgence of a target response because the history of reinforcement for the multiple alternative responses would decrease the relative value of the target response during the resurgence test.

We performed three different sets of model fits to analyze the data. First, we performed model fits using the aggregated mean data for all participants. Next, to eliminate the outlier data we obtained with the first two dyads prior to adding the rule “try not to just push the buttons as fast as you can”, we performed model fits using the aggregated mean data for all participants in dyads 3 through 6. Finally, to determine if using the median response rates would be a better representation of the group data for all participants, we performed model fits with the aggregated median data.

During all model fits, we only used the data from the last five sessions of baseline and last five sessions of DRA because we conducted slightly different phase lengths across dyads during baseline and DRA. We used the data from all sessions of extinction because we conducted exactly five extinction sessions with every participant. For all model fits, we set parameter \( b \) equal to 1 to represent no bias between the target and alternative responses because we programmed identical response topographies and
spaced them equidistant from the participants as well as programmed equal reinforcement rate and quality. We set the initial parameter values of $a = 0.0005$ and $\lambda = 0.006$ based on the results of prior basic research on RaC theory (see Shahan & Craig, 2017 and Greer & Shahan, 2019 for descriptions of $b$, $a$, and $\lambda$). When fitting the equation to the data, we used Microsoft Excel’s Solver to place a constraint on $\lambda$ such that it remained positive. We set parameter $k$ equal to the highest mean or median obtained rate of baseline responding.

To determine parameter estimates to use in the model fits, we first solved for parameters $k$, $a$, and $\lambda$, using the data from all participants. That is, we used the session-by-session rate of target responding for all participants across both groups to calculate the mean and median rate of target responding per session. For example, to determine the mean value to use for target responding during the first session of extinction, we took the rate of target responding during the first session of extinction for each of the 12 participants in the study (i.e., participants from both groups). We used a similar procedure to calculate the reinforcers delivered per hour. That is, we used the session-by-session token deliveries per min for all participants across both groups to calculate the average and median values and then multiplied each of those values by sixty to calculate the average and median reinforcers delivered per hour for each session. After solving for $k$, $a$, and $\lambda$, using the data from all participants, we then used those parameter values to fit Equation 1 to the rate of target responding for each of the two groups separately. That is, for each of the three sets of model fits, we calculated the mean or median session-by-session target responding per min and token deliveries per hour for iDRA and trad DRA separately and used those values to perform two separate model fits to evaluate how well RaC predicted responding for each of the groups. When we conducted the two separate model fits, we set parameters $a$ and $\lambda$ equal to the
values we obtained during the model fit with the aggregated data, however, we solved for parameter $k$ separately for the two groups given the large obtained difference in the rate of baseline responding across the two groups.

As mentioned above, we first performed a model fit using the aggregated mean data. We started this model fit with the initial parameter values of $k = 34$, $a = 0.0005$, and $\lambda = .006$ (based on prior research) and obtained resulting parameter estimates of $k = 30.90$, $a = 72.15$, and $\lambda = 0$ using Microsoft Excel’s Solver. When we performed the two separate model fits, one for each group, we used the parameter values of $a = 72.15$ and $\lambda = 0$, and we obtained a $k$ value of 17.50 for the iDRA group and 44.27 for the trad DRA group. The top panel of Figure 5 displays the results of the model fits for the mean rate of responding across groups for all twelve participants. As can be seen, we obtained higher mean rates of responding for the trad DRA group during all three phases relative to the mean responding of the iDRA group. Specifically, the data for the extinction phase portray responding in the direction we originally hypothesized. That is, it appears iDRA suppressed resurgence when compared to trad DRA. Equation 1 predicted baseline rates of responding similar to those that we obtained. During DRA, Equation 1 predicted slightly lower rates of responding for the iDRA group, which aligns with the obtained mean response rates. Equation 1 accounted for the lower rates of resurgence obtained with iDRA, however, the mean response rates for trad DRA well exceeded those the equation predicted.

Next, to eliminate the outlier data we obtained with the first two dyads, we conducted a model fit with the aggregated mean data from dyads 3 through 6 only. We started this model fit with the initial parameter values of $k = 14.94$, $a = 0.0005$, and $\lambda = .006$ and obtained resulting parameter estimates of $k = 12.39$, $a = 1.30$, and $\lambda = .004$. When we performed the two separate model fits, one for each group, we used the
Figure 5. Model Fits of Equation 1. Model fits of Equation 1 to the mean data from all dyads (top panel), mean data from dyads 3-6 (middle panel), and median data from all dyads (bottom panel).
parameter values of $a = 1.30$ and $\lambda = .004$, and we obtained a $k$ value of 18.71 for the iDRA group and 6.01 for the trad DRA group. The middle panel of Figure 5 shows the results of these model fits. Overall, the mean data without the first two dyads show the opposite results as the graph in the top panel of Figure 5. That is, the data show higher response rates for the iDRA group during all three phases relative to the trad DRA group. During the extinction phase, the data show minimal levels of target responding for the trad DRA group and high levels of resurgence for the iDRA group. Equation 1 predicted baseline rates of responding similar to those that we obtained. During DRA, Equation 1 predicted slightly lower rates of responding for the trad DRA group, which is consistent with what we obtained. However, we obtained response rates slightly higher than what the equation predicted during iDRA. Equation 1 accounted well for the obtained response rates for the trad DRA group during extinction. However, the resurgence we observed with the iDRA group exceeded that of what the equation predicted.

Finally, to determine if using the median response rates would be a better representation of the group data, we conducted a model fit with the median data. We set initial parameter values of $k = 14.75$, $a = 0.0005$, and $\lambda = .006$ and obtained resulting parameter estimates of $k = 13.21$, $a = .0005$, and $\lambda = .008$. When we performed the two separate model fits, one for each group, we used the parameter values of $a = .0005$ and $\lambda = .008$, and we obtained a $k$ value of 14.74 for the iDRA group and 10.47 for the trad DRA group. The bottom panel of Figure 5 displays the results of the model fits with the median data. Overall, the median data show slightly higher response rates for the iDRA group during all three phases relative to the trad DRA group. During the extinction phase, the data show low levels of resurgence for the trad DRA group and slightly higher levels for the iDRA group. Equation 1 accounted fairly well for the median baseline rate
of responding for both groups. During DRA, Equation 1 predicted almost equal response rates for the two groups, however, we obtained lower than predicted rates with the trad DRA group and higher than predicted rates with the iDRA group. Equation 1 accounted well for the level of resurgence we obtained during the extinction phase with the trad DRA group, however, it underestimated the level of resurgence for the iDRA group.

Discussion

The purpose of the current study was to evaluate the effects of programming multiple alternative responses on the resurgence of target behavior in a translational arrangement. Although previous research has evaluated the effects of multiple-response training on resurgence (e.g., Hoffman & Falcomata, 2014; Lambert et al., 2015; Lambert et al., 2017), the current study was the first to employ an interdependent schedule of reinforcement to teach the alternative responses in accordance with the predictions with RaC theory. To our knowledge, this is also the first study to conduct a priori modeling of data using the RaC equations to make predictions about the effects of a translational intervention on resurgence with human participants. In addition, it is the first to conduct posthoc modeling of the data to evaluate the accuracy of the RaC predictions.

We hypothesized that iDRA would result in the mitigation of the resurgence of target behavior during a phase of extinction. The findings showed that iDRA did not result in decreased levels of resurgence relative to trad DRA. However, iDRA significantly increased the proportion of alternative responding that occurred relative to target responding during extinction sessions.

The finding that training multiple alternative responses did not consistently decrease resurgence is inconsistent with previous studies published in the literature (e.g., Bloom & Lambert, 2015; Hoffman & Falcomata, 2014; Lambert et al. 2017; Lambert et al., 2015). However, an increasing number of more recent studies have been
unable to replicate the initial results on the effects of training multiple alternative responses on resurgence (e.g., Purcell, 2018; Nall & Shahan, 2019; Wu et al., 2019). Thus, it is important for future research to evaluate what specific procedures may be responsible for reductions in resurgence in the studies that have demonstrated positive effects of multiple-response training. Additionally, future research should further investigate a) how many additional alternative responses result in significant reductions in resurgence, b) the amount of time it would take to teach individuals those additional alternative responses, and c) if observed reductions in resurgence are of sufficient social significance to warrant the additional teaching time.

Although iDRA did not consistently decrease resurgence of target responding, the current results may have clinical implications for enhancing current treatment procedures for individuals who engage in severe destructive behavior. Specifically, iDRA may result in individuals learning a larger repertoire of alternative responses that they could engage in under periods of extinction. For example, if an individual requests a reinforcer when the caregiver is changing an infant sibling, the caregiver would likely be unable to provide the reinforcer following the first request. If the individual has only one topography of requesting the reinforcer, he or she may revert to destructive behavior shortly after contacting extinction for the appropriate request. On the other hand, if an individual has a larger repertoire of alternative responses, he or she may be less likely to engage in destructive behavior during a treatment challenge. More importantly, the caregiver may then be less likely to make an integrity error in the form of providing reinforcement for destructive behavior. This is particularly important given the findings of recent research that demonstrates caregivers are likely to engage in errors of commission during treatment-adherence challenges (e.g., Mitteer, Greer, Fisher, Briggs, & Wacker, 2018). The findings of Mitteer et al. (2018) also suggest that research
evaluating the efficacy of possible mitigation procedures such as multiple-response training should evaluate the efficacy of those procedures under multiple different challenges to treatment (e.g., reinstatement, renewal).

Another possible benefit of increasing the probability of alternative responses relative to destructive behavior during periods of extinction is that if a caregiver does not hear (i.e., vocal FCR) or see (e.g., card-touch FCR) the individual engage in an alternative response, they could have other topographies of appropriate responses to engage in before reverting to destructive behavior. Additionally, having a larger repertoire of alternative responses may make it more likely that someone in the individual’s environment would understand and provide reinforcement for at least one of those responses. Future research should evaluate the possible benefits of training topographically dissimilar alternative responses during DRA in decreasing the resurgence of or probability of destructive behavior during treatment-adherence challenges.

Utilizing an interdependent schedule during FCT may be superior to other treatment arrangements that program multiple alternative responses (e.g., lag schedules, serial FCT). Relative to serial FCT, an interdependent schedule may more quickly establish each alternative response in an individual’s repertoire because the responses are all programmed to contact reinforcement in the first session rather than sequentially across phases. In addition, an interdependent schedule does not include programmed extinction for any form of functional communication, which may be clinically contraindicated. In comparison to lag schedules, an interdependent schedule may be substantially easier for caregivers to implement in the natural environment. That is, caregivers would not have to keep data on the historical sequences of FCRs that their children emit. Future research should evaluate the effectiveness of, and caregiver’s
preference for interdependent schedules compared to serial or lag schedules of reinforcement.

The results of the model fits demonstrate the importance of selecting the appropriate method to summarize group data. When we analyzed the mean rate of responding for all participants, the results showed a positive effect of iDRA reducing resurgence of target behavior relative to trad DRA. However, when we removed the outlier data sets or used the median rate of responding, the group data findings did not support a conclusion that iDRA reduced resurgence. The results of the model fits also demonstrate that RaC underestimated the level of resurgence that we obtained during the extinction phase for one of the two groups in each of the three model fits. The parameter estimates for each of the three model fits differed from one another and from those obtained with non-human data (Shahan & Craig, 2017) with the parameter estimates from the model fit with the median rate of responding aligning most closely with those obtained with non-humans. Taken together, these results suggest that we need additional data to better understand what parameter values we should use when applying RaC to resurgence with humans.

The current study has a number of limitations that future research should address. First, we recruited typically developing adults as participants, whose well-developed verbal repertoires may have affected the way they responded to the study procedures (Catania, Shimoff, & Matthews, 1989). Thus, the responding we observed may not be representative of how individuals with different verbal repertoires (e.g., children with intellectual disabilities) would respond under the same procedures. Future research should evaluate the effects of the procedures with individuals referred for the treatment of destructive behavior. Additionally, all responses we programmed were topographically identical. By programming topographically identical responses, we may
have been more likely to see reemergence of target responding because the alternative responses were not as discriminable from the target response as if we had programmed topographically dissimilar responses. That is, the participants may not have discriminated that pressing one button was different than pressing a different button, either topographically or functionally. Programming topographically dissimilar responses may also have important applied relevance. That is, having topographically dissimilar alternative responses could make it more likely a) that a caregiver would notice and honor at least one of those responses if they were busy with another task and b) that someone in the individual’s environment would understand and provide reinforcement for at least one of those responses. Future research should evaluate programming alternative responses with different response topographies from one other and from the target response. In addition, manipulating response effort (i.e., decreasing the effort of the alternative responses relative to the target response) may make it less likely to observe resurgence by increasing participants’ bias for the alternative responses.

A few other procedural limitations of the current study exist. First, we obtained a large range in the response rates across participants. Although that range decreased when we added the rule asking participants to not just push the buttons as fast as they could, we still observed a large range across participants. Future studies might consider selecting a response operandum that cannot result in such large disparities in response rate across individuals (e.g., object-permanence box). Additionally, although we yoked token deliveries within each dyad of participants, the rate of token delivery was not equal, especially for Dyads 3 and 4 in which the participants assigned to trad DRA experienced fewer token deliveries relative to the participants assigned to iDRA. Thus, the low levels of resurgence that we observed during the extinction phase for the participants who experienced trad DRA relative to the participants who experienced
iDRA in dyads 3 and 4 could have been due to the lower rate of reinforcement during the DRA phase (Podlesnik & Shahan, 2009). Future research should better control for the rate of reinforcement across groups.

In summary, the results of the current study provide additional information on the possible effects of multiple-response training in mitigating resurgence of a target response. Given the prevalence of resurgence and its negative side effects (e.g., lapses in treatment integrity, use of more intrusive treatments), any procedure that might assist in mitigating the resurgence of destructive behavior is valuable. Overall, the current study expands previous research and provides information that encourages future research to further evaluate the possible benefits of programming multiple alternative responses during DRA treatments to decrease relapse of destructive behavior.
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*Reinforcing multiple alternative responses to mitigate resurgence in children.*

Symposium presentation presented at the 45th Annual Convention of the
Association for Behavior Analysis International.