12-2019

The Effects of Lag Reinforcement Schedules and Differential Reinforcement of Alternative Responding on Reinforced Variability and Resurgence

Weizhi Wu

The Effects of Lag Reinforcement Schedules and Differential Reinforcement of Alternative Responding on Reinforced Variability and Resurgence

by

Weizhi Wu

A thesis submitted to the College of Psychology and Liberal Arts of
Florida Institute of Technology
in partial fulfillment of the requirements
for the degree of

Master of Science
in
Applied Behavior Analysis and Organizational Behavior Management

Melbourne, Florida
December, 2019

We the undersigned committee hereby approve the attached thesis, “The Effects of Lag Reinforcement Schedules and Differential Reinforcement of Alternative Responding on Reinforced Variability and Resurgence” by Weizhi Wu.

David Wilder, Ph.D., BCBA-D
Professor
School of Behavior Analysis

Kimberly Sloman, Ph.D., BCBA-D
Associate Professor
School of Behavior Analysis

Anthony LoGalbo, Ph.D.
Associate Professor
School of Psychology

Lisa Steelman, Ph.D.
Professor and Dean
College of Psychology and Liberal Arts

Abstract

Title: The Effects of Lag Reinforcement Schedules and Differential Reinforcement of Alternative Responding on Reinforced Variability and Resurgence

Author: Weizhi Wu

Advisor: David Wilder, BCBA-D, Ph. D.

Differential reinforcement of an alternative responding (DRA) is a commonly used procedure to teach children with ASD more functionally and socially appropriate skills and decrease problem behavior. However, resurgence of problem behavior could occur when treatment integrity errors appearing while implementing DRA procedure. In research, one approach to mitigating resurgence is to reinforce varied alternative responses using a lag schedule. A lag schedule of reinforcement is a method to increase variability in which a reinforcer will be delivered contingently if the response differs from a certain number of previous responses. The present laboratory study evaluated whether reinforced behavioral variability could be increased and resurgence mitigated when implementing a DRA procedure with a Lag schedule versus a Yoked-DRA with no variability requirement. This study included three phases. In Phase 1, a target response was reinforced. In phase 2, the alternative responses in the Lag component and Yoked-DRA component were introduced while the target response was on extinction. In Phase 3, all responses were placed on extinction and resurgence and behavioral variability were evaluated. For all three participants, resurgence was similar in both components, inconsistent with previous studies. During Phase 2, greater variability was observed in the Lag component than in the Yoked-DRA component for all three participants. In Phase 3, the level of behavioral variability was similar in both components. The present study suggests that using a Lag schedule could not mitigate resurgence. This study demonstrates a translational approach that may be used to increase behavioral variability and find potential methods for mitigating resurgence when multiple appropriate responses are available.

Keywords: behavioral variability; relapse; resurgence; DRA; Lag schedule; translational research; college students

Table of Contents

List of Figures

List of Tables

Acknowledgement

I would like to thank my supervisor, Dr. Christopher A. Podlesnik for all your guidance and support during my graduate school. Chris, thank you for allowing and helping me to design and conduct a research study I was interested in. You taught me how to think critically while designing and conducting research. You showed me the fun of doing research and studying experimental behavior analysis in general. You have given me great support to be a better writer, student, researcher, and behavior analyst. Thank you so much for your quick replies and were always there to help throughout my time at Florida Tech.

I would also like to thank my committee members, Dr. Sloman, and Dr. LoGalbo for your time, support, and feedback on my project.

Thank you, Dr. Corina Jimenez-Gomez for always being available for support and willing to help me to work more professionally as a researcher.

A special thanks to Jialing Sun for your time and effort you put into developing and programming for my thesis. I could not have done this project without you. Thank you very much!

Dedication

I dedicate my thesis to my parents who always support me, love me, and push me to be a better me.

Introduction

Individuals diagnosed with Autism Spectrum Disorder (ASD) often have communication difficulties, social impairment, and stereotypic behaviors (Wing & Gould, 1979). Two core features of symptomology are included within the DSM-V, including (1) impairment in social communication and (2) presence of rigidity, restricted interests, and/or repetitive behavior. The restricted and repetitive behavior can be manifest in different forms, such as limited interests, rigid adherence to playing, and motor stereotypy (APA, 2013). Given that restricted and repetitive behavior may result in negative outcomes (Mercier, Mottron, & Belleville, 2000; Wolfe, Slocum, & Kunnavatana, 2014), improving appropriate behavioral variability may result in meaningful outcomes for individuals with ASD.

Studies in basic (e.g., Page & Neuringer, 1985), translational (e.g., Galizio, Frye, Haynes, Friedel, Smith, & Odum, 2018), and applied (e.g., Lee, McComas, & Jawor, 2002) literature have concluded that behavioral variability can be an operant dimension of behavior and controlled by its antecedents and consequences (de Souza Barba, 2012). Behavioral variability can be maintained via reinforcement, depending on the reinforcement contingency (Page & Neuringer, 1985). A lag schedule of reinforcement is a recency-based method in which a reinforcer will be delivered contingently if the response differs from a certain number of previous responses (Page & Neuringer, 1985; Neuringer & Jensen, 2013). For example, under a lag 1 schedule, a reinforcer will be delivered contingently if the response is different from the previous response. Reinforced behavioral variability has been observed across different species, for example, pigeons (e.g., Doughty & Lattal, 2001; Doughty, Giorno, & Miller, 2013; Doughty & Galizo, 2015; Galizio et al., 2018), rats (e.g., Neuringer, 1991; Cherot, Jones, & Neuringer, 1996; Stahlman, Roberts, & Blaisdell, 2010), and humans (e.g., Schwartz, 1982; Lee, McComas, & Jawor, 2002; Adami, Falcomata, Muething, & Hoffman, 2017; Silbaugh & Falcomata, 2016).

Operant behavior can be manipulated by antecedents and consequences. Behavioral variability shows sensitivity to operant contingencies. For example, response variation can be greater when it is required for reinforcement than in its absence. For example, Page and Neuringer (1985) reinforced eight-peck response sequences in pigeons only if they meet lag 50 requirement. In other words, reinforcers were only delivered when the sequence was different from the previous 50 sequences. They observed 70% of trials resulted in reinforcer delivery. To test whether variability was directly reinforced, they added a control procedure in which variability was not required for reinforcement. In this yoked control, trials were followed by same consequences at the same rates as during Variability condition where lag 50 was in place. They observed low levels of variability in the yoked condition and increased variation in the Variability condition. These findings suggest that direct reinforcement of variability determines response variation.

Page and Neuringer's (1985) findings also suggest the degree of variation is sensitive to the variability contingencies. For example, a lag 50 schedule could produce higher levels of behavioral variability than a lag 1 schedule. An increasing number of applied and translational studies use lag schedules to increase variability in manding (i.e., requests) exhibited by individuals with ASD (Lee, McComas, & Jawor, 2002; Adami, Falcomata, Muething, & Hoffman, 2017; Falcomata, Muething, Silbaugh, Adami, Hoffman, Shpall, & Ringdahl 2018). Lee, McComas, and Jawor (2002) evaluate the effects of a Lag 1 schedule on variability to social questions in children with ASD. During baseline, they implemented differential reinforcement of alternative behavior (DRA; Carr & Durand, 1985; Vollmer, Roane, Ringdahl, & Marcus, 1999) that all appropriate responses were reinforced, regardless of variability. Next, the Lag 1/DRA condition was implemented where reinforcement was delivered contingently on socially appropriate responses that differed from the previous response. For two out of three participants, the Lag 1/DRA procedure produced higher level of appropriate variable manding than a DRA procedure which with no lag contingency. Lag schedules have also been shown to increase variability in tacts (i.e., labelling) (Heldt & Schlinger, 2012), vocal responses (Esch, Esch, & Love, 2009; Koehler-Platten, Grow, Schulze, &

Bertone, 2013), play skills (Baruni, Rapp, Lipe, & Novotny, 2014), and feeding (Silbaugh & Falcomata, 2016). Moreover, studies show that discriminative stimuli can guide organisms to produce repetitive behaviors in the presence of one stimulus or context and produce variable behaviors in the presence of the other stimulus or context (Page & Neuringer, 1985; Denney & Neuringer, 1998; Doughty & Lattal, 2001; Ward, Kynaston, Bailey, & Odum, 2008). These findings from basic, translational, and applied research all support the idea of behavioral variability as an operant dimension of behavior (Neuringer & Jensen, 2013).

Operant behaviors can also be affected by disruptors like extinction. For example, while withholding the reinforcement for the recently reinforced behavior, the overall rate of this behavior will decrease. This type of disruption suggests the sensitivity of the operant behaviors to its consequences (Craig, Nevin, & Odum, 2014). Studies suggested that behavioral variation is less disrupted by extinction than repetition (Cohen, Neuringer, & Rhodes, 1990; Neuringer, 1991; Doughty & Lattal, 2001). According to behavioral momentum theory, some research suggests that when facing disruptors, the level of persistence of responding can indicate response strength (Nevin, 1974). Research suggests that behavioral variability is likely to show more persistence than behavioral repetition while maintained by the same reinforcer rates (Doughty & Lattal, 2001).

According to behavioral momentum theory, the more persistent the behavior, the more likely it will be susceptible to relapse (Craig, Nevin, & Odum, 2014; Podlesnik & DeLeon, 2015). Relapse is defined as the reappearance of the previously extinguished behavior. Treatment relapse in clinical settings is defined as the return of the previously eliminated problem behavior (e.g., aggression, self-injury) when the treatment faces some kind of challenge (Wathen & Podlesnik, 2018). It is commonly observed with problem behavior such as aggression or self-injury when fading the use of DRA procedures (Nevin & Wacker, 2013; Wacker, Harding, Morgan, Berg, Schieltz, Lee, & Padilla, 2013).

Resurgence is a laboratory model of relapse defined as the reappearance of the previously extinguished behavior while withholding or reducing the reinforcement for the recently reinforced behavior. In a typical resurgence model, target response will be reinforced in Phase 1. When moving to Phase 2, target response will be placed on extinction while alternative response will be introduced and reinforced, modeling DRA treatment (see Lieving, Hagopian, Long, & Connor, 2004; Podlesnik & Kelley, 2014; Wathen & Podlesnik, 2018). In Phase 3, both responses will be placed on extinction and the resurgence of the target response is likely. Given the importance of behavioral variability theoretically and practically, an important question is whether target behavior is susceptible to relapse when using lag schedules for alternative responding, as is the case with typical DRA procedures.

A further understanding of variable responding could be helpful in developing interventions to prevent or mitigate resurgence. One related approach to mitigating resurgence is to teach multiple alternative responses (Lambert, Bloom, Samaha, Dayton, & Rodewald, 2015). Researchers compared the effect of serial DRA training (i.e. teaching multiple alternative responses) with typical DRA training (i.e. teaching one alternative response) on the magnitude of resurgence of a target behavior. They observed that during a serial DRA condition, while facing challenges like extinction, the more recently reinforced responses (alternative) responses would resurge before the reappearance of the target behavior. Lambert, Bloom, Samaha, and Dayton (2017) then replicated and extended Lambert et al.'s (2015) laboratory study in an applied study with two children who exhibited problem behavior. They compared the effect of traditional functional communication training (FCT; Carr & Durrand, 1985), a type of DRA, to serial-FCT on resurgence of problem behavior using similar methods as Lambert et al. (2015). However, in contrast with the previous study, primacy effects for both subjects were observed. In other words, the magnitude of resurgence of problem behavior was greater than the resurgence of any mands trained later. They nevertheless observed that the total amount of responding allocated to the problem behavior was less in the serial-FCT component than in the traditional-FCT component. These two studies both have significant implications and suggest effective methods of modifying DRA treatment by arranging multiple alternative responses for reducing resurgence.

Another approach to mitigating resurgence is to reinforce varied alternative responding, as has been conducted with requests, or mands (e.g., Adami, Falcomata, Muething, & Hoffman, 2017; Falcomata et al., 2018). Adami, Falcomata, Muething, and Hoffman (2017) embedded a lag schedule with FCT in the treatment of problem behavior on participants diagnosed with ASD. Experimenters evaluated the effect of FCT with Lag 0 schedule (no variation required) with FCT with Lag 1 schedule on the level of problem behavior, variable target mands, and total mands. In the FCT/Lag 1 condition, higher rates of varied mands were observed than the FCT/Lag 0 condition. Additionally, the rate of problem behavior maintained at similar but low level in both conditions relative to baseline. Falcomata et al. (2018) extended Adami, Falcomata, Muething, & Hoffman (2017) by increasing lag schedule values beyond 1 and up to a lag 5. Low rates of problem behavior and high rates of variable and total mands were observed across two participants while thinning the lag schedule from zero to five. For one of the two participants, variable mands persisted while the lag schedule requirement went back to lag 0. These two studies suggested that training multiple mands (alternative behavior) might be another approach to mitigate clinical relapse of problem behavior relative to traditional DRA procedures.

Despite the use of DRA or Lag procedures, few studies have examined the effects of different reinforcement schedules on behavioral variability and resurgence, the purpose of the present study. This laboratory study used a translational approach arranging reinforcement and extinction of arbitrary responses to simulate target and alternative responses with university students. The study included three phases. In Phase 1, target responses were reinforced in the presence of two alternating stimuli in what were both Lag and DRA components in Phase 2. In Phase 2, Lag and DRA components introduced alternative responses that were reinforced while the target response was placed on extinction. In the Lag component, reinforcement was contingent when one alternative response differed from the previous response. In DRA component, only one alternative response was reinforced throughout. In Phase 3, all the alternative responses and the target responses were placed on extinction in both components to assess resurgence of target responding. The laboratory approach enables experimental control to minimize external variables while assessing variables contributing to treating problem behavior in applied research, such as reinforcer contingencies. The present study examined how contingencies affect behavior variability and the persistence of target and alternative behaviors. The results of the current study could contribute to further understanding of behavioral variability and leads to more effective behavioral treatments to mitigate resurgence of problem behavior.

Method

Participants

Three graduate students (pseudonyms used in this study) Daniel, 24, Ana, 23, and John, 34, from Florida Institute of Technology participated in the study. Participants were recruited using University emails. Participants followed simple instructions and engaged in motor response of touching the touchscreen devices. Participants varied by race, gender, or other demographic characteristics. During the pre-experimental survey, participants were asked to report if they had a history of color-blindness and the courses they took. Participants were excluded if they reported colorblindness, majored in behavior analysis, or took advanced psychology courses or any advanced learning courses in the past. The participant was informed in the consent meeting that each person would earn a $10 gift card for completing the study and the person whom earned the highest number of coins would receive an extra $25 gift card.

Settings and Materials

All sessions were conducted in a separate conference room at the Florida Institute of Technology. A table, two chairs, and the touchscreen laptop were present during all sessions. All sessions were conducted by the same experimenter for each participant. Participants finished all experimental sessions on an average of 1.73 hours.

All participants used a touchscreen laptop computer with a Utility 2018 Program in C sharp language. The program arranged a two-component multiple schedule by presenting alternating background themes of an ocean versus a desert within all phases. On the touchscreen, the colors of the target and alternative boxes and target and alternative squares were defined by RGB color codes. Target colored box, light gray (R150G150B150) or dark gray (R82G82B82), was located on the middle of the screen (see Figure 1). Alternative colored boxes, blue (R126G190B236) and orange (R248G174B93), were located around the target boxes. The blue boxes corresponded with the ocean background and the orange boxes corresponded with the desert background. Those backgrounds and colored boxes were counterbalanced across participants to assess the DRA versus Lag schedules. Within all boxes, the small squares randomly moved at a rate of 0.35 cm per second as the target and alternative responses. Touching the square within the boxes in some phases resulted in reinforcer delivery, according to the reinforcement schedules described below (see Kuroda, Cançado, & Podlesnik, 2016, for related procedures).

Once the reinforcement criterion has been met, a coin with sound would appear in the middle of the screen for a minimum of 0.5 seconds, according to the reinforcement schedule described below. After the presentation of the coin, the relevant target and alternative responses were available again, depending on the phase, as described below. The colored boxes and the themes were predetermined for each participant and counterbalanced across participants. The coin-presentation (i.e., reinforcement) time was subtracted from all other timing of events.

Experimental Design

Resurgence typically is assessed across three phases (see Wathen & Podlesnik, 2018). The blue and orange components alternated within all phases, except first Training phase, according an ABABABABAB design to evaluate the effects of DRA versus a Lag schedule on behavioral variability and resurgence. Specifically, in Phase 1, only the target response was available within the two components and the reinforcer was delivered contingently on the target response. In Phase 2, the alternative responses were introduced and reinforced while the target responses were placed on extinction. In Phase 3, extinction was arranged for both the alternative target responses in both components.

Procedure

All sessions were programmed to last for 60 trials or the maximum of 8 minutes, whichever came first, except for training phases, as described below. Each session comprised five Lag components and five DRA components with each component alternating (see Figure 2). The Lag component always preceded the DRA component in all phases (i.e., ABABABAB design). Each component consisted of 6 trials and each trial consisted of two touching responses over the squares (Figure 3). In the Lag component, a single trial produced either a 1-s coin presentation or 1-s whiteout, as the intertrial interval (ITI). Whiteout presentations were the same as reinforcement presentations, except no coin or sounds were presented. In the Yoked-DRA component, a single trial produced either a coin presentation or whiteout, as the ITI. In this component, the number of trials to one preselected alternative square was yoked to a list with the number of trials required to produce reinforcement from the preceding Lag component. Therefore, if three trials were required to fulfill the Lag requirement for the first reinforcer in the preceding Lag component, then three consecutive trials to the specified alternative response would be required to produce the first reinforcer in the Yoked-DRA component.

The ITI also varied depending on the amount of time participants spent in the certain preceding Lag trial to ensure the next Lag trial and DRA trial start at the same time, except during training. In the absence of a response, trials automatically proceeded the next one after 3 seconds, followed by the ITI. When a participant completed all 6 trials in the component, followed by the ITI, there was a 5-s blackout with a rotating pie animation (Figure 4) presented on the screen, as the inter-component interval (ICI) between components.

Training. In this session, the background color was green (R165G223B163) and the grey (R115G115B115) box was in the middle in terms of darkness between what were arranged during the multiple schedule (see Figure 5). There was one square in the box moving. The color of the square was either pink (R255G150B197) or white (R255G255B255), with the assignments of the white and pink squares counterbalanced across participants. The target response was defined as touching the square in the middle grey box. Before the initial session, the experimenter provided the instruction, "You can touch the square. You can do as much or as little as you want. I am not going to answer your questions. Start." There was a coin presentation for completion of a target trial including two target responses according to a fixed-ratio (FR) 1 schedule of reinforcement (delivery for correct responding during a trial). The participants mastered the training and moved to Phase 1 while independently performing the target responses three consecutive times.

Phase 1: Target-response reinforcement. In this phase, only the target box presented in the middle of the touchscreen in both components (see Figure 6). The target response was defined as touching the same colored-square as shown in the previous Training phase. The other colored square functioned as the control response that provides participants with the option to touch the other square but in the absence of reinforcement.

The experimenter provided the instruction, “You can touch the squares. You can do as much or as little as you want. I am not going to answer your questions. Start.” The blue and orange components were presented in an ABABABABAB sequence with Lag component preceding the Yoked-DRA component. In Lag component, the coin presentation was arranged contingently upon the target trial according to a variable-ratio (VR2) schedule. In other words, the coin was presented following every two target trials, on average. However, in the Yoked-DRA component, participants earned the reinforcer only after touching the same number of trials required from the preceding Lag component. For example, if two trials were required to fulfill the Lag requirement for the first reinforcer in the preceding Lag component, then two consecutive trials to the specified target response would be required to produce the reinforcer in the Yoked-DRA component. The experimenters used an intermittent, VR schedule to increase resistance to extinction and likelihood of observing resurgence during transitions from conditions of reinforcement to extinction (see Nevin, 2012; Kimball et al., 2018).

Phase 1 ended when the discrimination index (DI) was above 90 percent for three consecutive sessions and the target response occurred at a high frequency and was stable with no increasing or decreasing trends, as judged by using visual inspection (Sidman, 1960). Participants were excluded from the study if they did not meet the criterion for a maximum of 14 sessions. DI was calculated as the percentage of appropriate trials that satisfy the contingency in each component. In Phase 1, DI was calculated as the number of target trials divided by the total number of trials in each component and multiple by 100. Response frequency was calculated as the number of target responses for each component per session.

Phase 2: Alternative-response reinforcement. In this phase, both the target and alternative boxes were present (see Figure 7), with the target box in the middle and the alternative boxes around the target box. The alternative response was defined as touching the white square in the alternative colored boxes. In this phase, the two components presented different contingencies on completion of alternative trials including two alternative responses - a Lag contingency and a Yoked-DRA contingency.

The experimenter provided the instruction, "You can touch the squares. You can do as much or as little as you want. I am not going to answer your questions. Start." Extinction was arranged for target responding in both components, thereby no coin presentation appeared for target responses. In the Lag component, alternative trials were reinforced according to a Lag 1 schedule. In other words, if the participant performed a novel two-alternative-response sequence that differed from the previous two-alternative-response sequence, the coin will be presented. In the Yoked-DRA component, the number of trials to one preselected alternative square was yoked to a list with the number of trials required to produce reinforcement from the preceding Lag component. Therefore, if three trials were required to fulfill the Lag requirement for the first reinforcer in the preceding Lag component, then three consecutive trials to the specified alternative response would be required to produce the first reinforcer in the Yoked-DRA component.

Phase 2 ended when (1) DI reached above 90%, and (2) target responding stabilized at near-zero rates in both components with alternative responses occurring reliably, as judged by visual inspection, and (3) at least 6 sessions in Phase 2. In the Lag component, DI was calculated as the number of alternative trials that satisfy the Lag 1 contingency divided by the total number of trials in the Lag component and multiplied by 100. In the Yoked-DRA component, DI was calculated as the number of alternative trials satisfying the FR2 contingency divided by the total number of trials in the DRA component and then multiplied by 100. Response frequency was calculated as the number of target and alternative responses for each component per session.

Phase-2 Lag training. A training procedure was used to help facilitate learning the Lag contingency. The experimenter presented the touchscreen with instructions available to the participants, "You will repeatedly experience two backgrounds, the way to get the coin is different between the two backgrounds.” (See Figure 8) The experimenter provided the instruction, “You can touch the squares. You can do as much or as little as you want. Make sure you read the instructions carefully. I am not going to answer your questions. Start.” During training, both the target and alternative boxes were present. In this phase, the two components were present in alternation a Lag contingency and a DRA contingency. Extinction was arranged for target responding in both components, thereby no coin presentation appeared for target trials. In the Lag component, alternative trials were reinforced according to a Lag 1 schedule. In the DRA component, alternative trials were reinforced according to a FR 2 schedule. The yoking started after the participant received three consecutive coins in 2 consecutive components. Once again, the participant mastered training and moved to Phase 2.

Reinforcer frequency was recorded as the number of coin presentation for each component per session. The maximum number of coin presentation in each component was 15 per session. One participant was excluded from the current study when the reinforcer frequency was less than seven for a maximum of 10 consecutive sessions.

Phase 3: Resurgence Test. In this phase, all stimuli were the same in Phase 2. Participants were given the same instruction as in Phase 2. In this phase, both alternative and target responses were placed on extinction in both components.

Phase 3 ended when (1) target responding occurred at least 80% below an average frequency of the last three sessions of Phase 1 with no trends, as judged by visual inspection, and (2) alternative responding occurred at least 80% below the average frequency of the last three sessions of Phase 2 with no trends, as judged by visual inspection, and (3) at least 8 sessions in Phase 3 which enabled the experimenters to calculate U-value for two components. If the above criterion has not been met, experimenters could stop Phase 3 on the maximum of 14 sessions.

Data Analysis

Except DI and response frequency, the other dependent variable in this study will be U-value. U-value measures the level of behavioral variability, or uncertainty, that ranges from 0 to 1 (Page & Neuringer, 1985; Doughty & Lattal, 2001). A U-value of 1 indicates absolute uncertainty or variation, and a U-value of 0 indicates absolute certainty or repetition. U-value was calculated using Equation 1:

$$U = \sum_n \frac{RF_i * \log(RF_i)}{\log(n)} \quad (1)$$

where RF_i is the relative frequency of alternative response trials sequence i, out of n total possible sequences, in this case 36. RF_i was calculated by using the frequency of certain sequence divided by the total frequency of all sequences. When all sequences occur with equal frequency, U-value will be the maximum of

1. Higher U-values indicate higher levels of variation and lower levels of repetition and lower U-values indicate lower levels of variation and higher levels of repetition.

Due to the limitation of U-value (Galizio et al. 2018; Kong, McEwan, Bizo, & Foster, 2017) which will be affected by the number of trials included in the calculation, the fewer trials were used, the lower U-value it would produce. Galizio et al. (2018) suggests researchers using more than 25 trials while calculating U-value to avoid a ceiling effect. Since the present study arranged extinction on all the responses in Phase 3, frequency of responses was greatly reduced. To avoid a ceiling effect, a pooled U-value was calculated using all trials across three sessions for each component (see Galizio et al., 2018, for related analyses). Pooled U-value was calculated using the final three sessions in Phase 1, the first three sessions in Phase 2, the final three sessions in Phase 2, the first three sessions in Phase 3, and the last three sessions in Phase 3.

Percentage of incorrect trials, frequency of missed trials, and latency were also assessed. Percentage of incorrect trials was calculated as the number of trials responding incorrectly, according to the reinforcement schedules described above, divided by the total number of trials responded and then multiplied by 100. Frequency of missed trials was recorded as the number of trials that participant did not respond within three seconds. Latency was recorded as the time participants spent to touch the squares after the presentation of target or alternative boxes.

Results

Table 1 shows the mean frequency of missed trials, latency, and percentage of incorrect across phase and component for all participants. The average frequency of missed trials, was generally similar in Phase 1 and 2 but greater in Phase 3 during both components. The average latency was lowest during Phase 1, slightly greater in Phase 2, and the greatest in Phase 3 for all three participants. This suggests that participants spent the most time responding in Phase 3 than Phase 2, and the lowest time in Phase 1, regardless the components. The average percentage of incorrect trials shows idiosyncratic results in Phases 1 and 3, but similar in Phase 2 that all participants responded the lowest incorrect trials in Phase 2.

Figure 9 displays the discrimination index (DI), U-Value, response frequency, and reinforcer frequency for Daniel, Ana, and John across Phases 1, 2, and 3. In the top row of Figure 9, a similar pattern of DI was observed for all three participants in Phase 1. In Phase 1, DI increased gradually and stabilized under the VR2 schedule of reinforcement. U-value in the second row decreased to 0 level due to reduced variable responding during Phase 1 for all three participants. However, for John, U-value was more variable than Daniel and Ana. The frequency of target responding in the next row increased rapidly and then stabilized as a result of increasing in responding for all three participants. A similar pattern of reinforcer delivery, in the last row, was observed for all three participants which increased gradually and then stabilized. While increasing, the number of reinforcers earned in the Lag component was slightly more than the number earned in the Yoked-DRA component, but the frequency generally stabilized at the same level in the last three sessions. The results from Phase 1 show how reinforcing one behavior could affect variability and frequency of responding. At the end of Phase 1, DI was high, variability was low, and frequency of target responses was high for all three participants in both components.

In Phase 2 for both components, DI, in the top row, generally was high in the first several sessions indicating appropriate alternative responding across trials in both components. For Daniel and Ana, DI maintained above 90% across components for the rest of sessions in Phase 2. For John, however, DI of the Yoked-DRA component was more variable than in the Lag component that dropped below 90% for three sessions and increased back to 90% in the last session. In the Lag component during Phase 2, the variable sequence was reinforced while placing the target response on extinction. Therefore, U-value in the second row maintained at certain level as the result of increase in variability during Phase 2 in the Lag component for Daniel and Ana. For John, however, U-value was more variable than Daniel and Ana. U-value in the Lag component ended at a similar level for all three participants. In the Yoked-DRA component, the pre-determined alternative sequence was reinforced while the target response was placed on extinction. In this component, U-value remained zero or near-zero level for both Daniel and Ana, indicating little to no variable responding in the Yoked-DRA component. For John, the U-value was first more variable than Daniel and Ana but still decreased to near-zero levels. In the next row, the frequency of alternative responding occurred at a high level in both components for all three participants while the frequency of target responding remained zero level. The changes in frequency of responding resulted from the differential reinforcement arranged during Phase 2. The frequency of reinforcer delivery in the bottom row was generally high in the Lag component for all three participants. In the Yoked-DRA component, for Daniel and Ana, reinforcer delivery showed some level of variability. For John, however, reinforcer delivery was more variable than Daniel and Ana. The frequency of reinforcers John earned in Phase 2 shows that decreases in DI impacted reinforcer delivery. The results in Phase 2 show how reinforcing alternative responses while the target response on extinction affect variability and frequency of responding. At the end of Phase 2, for all three participants, DI was high in both components, variability was higher in the Lag component than in the Yoked-DRA component, and frequency of target responses was low but the frequency of alternative responses was high in both components.

In Phase 3, there were idiosyncratic results for all three participants for both components. In the top row, Daniel's DI remained at a high level for both components. Ana and John's DI decreased to zero or near-zero levels more quickly in the Yoked-DRA component than in the Lag component, except Ana's DI remained at above-zero levels in the Lag component. For Ana and John, the difference in responses meeting the contingencies across trials as presented by DI is likely a result of contingency differences during Phase 2. The frequency of target responses in the third row reappeared and then decreased as a result of the effect of extinction in both components for all three participants. In both components, for Daniel, the frequency of alternative responses maintained at high level. For Ana, the frequency of alternative responses decreased and then maintained at approximately 50% of Phase-2 rates. For John, the frequency of alternative responses decreased to zero or near-zero levels and then maintained at a low level. The similar level of the frequency of alternative responding was not suggestive of the different levels of persistence of responding between Lag and Yoked-DRA contingency. The idiosyncratic results for all three participants for both components might suggest other variables, such as the sequence of the components, controlled the responses.

To avoid a ceiling effect in Phase 3, Figure 10 shows the Pooled U-value for each participant across phases. In Phase 1, the left column, Pooled U-value was 0 for all three participants across components due to no required variability for reinforcement. In the middle column of Phase 2, greater pooled U-values indicated greater variability in the Lag component during Phase 2. In the Yoked-DRA component, Pooled U-value decreased to zero or near-zero levels and remain at this level indicating little to no variable responding for two participants while John's pooled U-value increased across session blocks. In the right column of Phase 3, Pooled U-value first increased in both components at the beginning of Phase 3 as a result of increased extinction-induced variability for all three participants. Daniel's Pooled U-value decreased in both components indicating decreased variability. However, both Ana and John's Pooled U-value maintained at the previous level indicating high levels of variability.

Figure 11 shows the average frequency of responses for each participant across sessions in Phase 3. The black portions represent target responses and the white portions represent the alternative response. There was similar overall responding in both components for all three participants. Additionally, for all three participants, target responses occupied a similar but slightly greater percentage of total responding in the Lag component than the Yoked-DRA component.

Figure 12 shows the frequency of control responses for Daniel, Ana, and John across Phase 1, 2, and 3. During Phase 1, a similar pattern of frequency was observed for all three participants that the frequency of control response steadily decreased to 0 level due to no reinforcement. In Phase 2, the frequency of control response maintained at zero or near zero-level in both components for all three participants. During phase 3, Daniel's frequency of control response reappeared only for the first session in the Yoked-DRA component. For Ana, the frequency of control responses steadily increased in both components. For John, however, the frequency of control response varied across sessions in both components.

Discussion

The purpose of this study was to evaluate the effects of the Lag reinforcement schedules and DRA on reinforced variability and resurgence by comparing the effects of Lag and Yoked-DRA components with students as participants. For only 1 out of 3 participants, Lag component resulted in greater levels of variability than the Yoked-DRA component during the resurgence phase. The results showed the similar level of behavioral variability in two components for two out of three participants. In contrast with Falcomata et al. (2018), similar level of resurgence was observed in the Lag component than in the Yoked-DRA component for three participants with low percentage of response allocated to target responding in both components.

Consistent with current literature (Page & Neuringer, 1985; de Souza Barba, 2012), behavioral variability is an operant dimension of behavior which can be maintained through reinforcement depending on the reinforcement contingency in place and can be influenced by antecedent stimuli. We observed greater U-value in the Lag component than in Yoked-DRA component during Phase 2, which suggests control occurred in the two components. In the beginning of Phase 3, levels of behavioral variability increased and occurred at high levels for two components for all three participants, supporting the evidence of extinction-induced behavioral variability (Neuringer et al., 2001). However, we observed a subsequent decrease of U-values for only one out of three participants. This is inconsistent with current literature suggesting that extinction can disrupt behavioral variability by removing alternative reinforcement (Page & Neuringer, 1985; Craig, Nevin, & Odum, 2014). Additionally, in contrast with Doughty and Lattal (2001), the high levels of behavioral variability in the resurgence phase in both components provides limited evidence to support the idea that while facing extinction, behavioral variation is less disrupted than repetition.

Consistent with current literature (Silbaugh & Falcomata, 2017; Galizio et al., 2018; Tiger, Hanley, & Bruzek, 2008; Volkert, Lerman, Call, & Trosclair-Lasserre, 2009), we observed that all participants' target responding decreased and alternative responding increased in both Lag and Yoked-DRA components in Phase 2 due to the differential reinforcement. During Phase 3 while all target and alternative responses were placed on extinction, some of the resurgence effects were observed, consistent with current literature (Craig, Browning, & Shahan, 2017; Adami, Falcomata, Muething, & Hoffman 2017; Falcomata et al., 2018). Specifically, we saw some resurgence of target responding in both components due to removing alternative reinforcement. However, we found that greater resurgence of target responding in the Yoked-DRA component than in the Lag component (Neuringer, 1991; Doughty & Lattal, 2001) was not observed. Instead, this study demonstrated similar level of resurgence of target responses in both components for all three participants, with allocation of responding being higher on the alternative responses in both components. This is in line with Adami et al. (2017) that similar but low levels of problem behavior were observed in the FCT/Lag 1 and FCT/Lag 0 condition relative to baseline. However, in contrast with Falcomata et al. (2018), the present study suggests that using a Lag schedule could not mitigate resurgence effects. Additionally, frequency of alternative responses were at a similar level in both components for three participants, which suggests that the same level of persistence was observed during the Lag component relative to the Yoked-DRA component. In contrast with previous basic research (Doughty & Lattal, 2001; Odum, Ward, Barnes, & Burke, 2006), the current study suggests operant variability is similar in persistence as operant repetition.

The reason for inconsistency in results between current literatures in behavioral variability and resurgence and this study may be due to some contributing variables and limitation. One possible explanation for the disparity may because of the population targeted. Many basic, translational, and applied studies examined behavior of pigeons, mice, children with autism or with developmental disabilities, or undergraduate students, typically with limited to no prior experimental histories. In contrast, the participants of the present study were three graduate students. Due to their past experiences of engaging or conducting research studies, they might figure out the purpose of the study and change their behavior based on that. For Daniel, especially, he reported to the researcher that he realized the purpose of the study was to test his responding in the last phase with no coin presentation and he did the same thing as in Phase 2.

Another explanation for inconsistency in results may be due to the different types of disruptors used (Galizio et al., 2018). In research studying the factors disrupting behavioral variability, researchers chose to use non-extinction disruptors, including delay to reinforcement (Odum et al., 2006) and response-independent food presentations (e.g., Doughty & Lattal, 2001). Extinction is a theoretically and clinically important disruptor to study across species. However, extinction disrupts both response frequency and reinforced behavioral variability which makes it challenging to observe the effect of extinction on reinforced behavioral variability only. This might be the reason why extinction on behavioral variability has not been widely studied (Neuringer et al., 2002).

Additionally, U-value as the current analysis technique to study behavioral variability has some limitations (Galizio et al., 2018; Kong, McEwan, Bizo, & Foster, 2017). As the most commonly used measure, U-value has many advantages such as providing a clear summary distribution of responses, discovering changes in behavioral variability, and being computed easily (Page & Neuringer, 1985; Neuringer, Kornell, & Olufs, 2001; Neuringer & Jensen, 2013; Doughty & Lattal, 2001). However, the accuracy of U-value depends on the total number of responses used in the calculation. While few trials were used (fewer than 25), more dependent U-value would be on the number of trials (Galizio et al., 2018). This limitation is very important for the current study because extinction was arranged. When assessing resurgence in Phase 3, the number of sequences decreased rapidly for two out of three participants. Researchers were not able to calculate the U-value for all sessions (see Figure 9) and the red data points indicate when participants responded in fewer than 25 trials per session. Due to the few trials and low accuracy of U-value for some sessions, we used a pooled U-value calculating trials in three-session blocks, which prevents the calculation of U-value from having too few trials and meeting a ceiling effect. In this way, we were able to measure behavior variability in the resurgence phase. This calculation provides a broader view with a distribution of three-session blocks, instead of single sessions. This limitation and constraint of U-value is something to consider for future study when assessing extinction on behavioral variability.

This study has a limitation too. For all three participants in this study, the level of resurgence was lower in the Yoked-DRA component than the Lag component (see Figure 11). Because the Yoked-DRA component was always yoked and followed the Lag component, exposure to extinction in the Lag component might have decreased resurgence in the subsequent Yoked-DRA component. This is in line with previous literatures that resurgence can be decreased due to multiple exposures to extinction (Cleland, Foster, & Temple, 2000; Kestner, Diaz-Salvat, Peter, & Peterson, 2018). This shows the present results might have been influenced by sequence effects, in which the exposure to earlier components affected responding in following components, regardless of the contingencies in place. Future studies could either randomize the order of which component came first or conduct a group design to directly compare both components.

Overall, all findings provide a better understanding of the behavioral variability as an operant dimension which can be maintained through reinforcement and affected by antecedent stimuli and extinction. Even though the current results remain challenging to explain because we observed no obvious difference between Lag and DRA schedules on resurgence, more research is needed to study relapse of reinforced behavioral variability empirically and clinically. Findings from this study contributes to current translational and applied literature on techniques to potentially mitigate resurgence during DRA procedures using lag schedules of reinforcement (Galizio et al., 2018; Adami et al., 2017; Falcomata et al., 2018). Although the results were not consistent with Falcomata et al. (2018), they continue to pave the way for further understanding the factors that disrupt behavioral variability and contribute to resurgence of problem behavior within behavioral treatments. Because the current study is translational and conducted in a laboratory setting, the methods and findings can be developed further to provide understanding of the processes and procedures affecting treatment relapse and behavioral variability. This approach provides a platform to assess novel treatments that could help to create more clinically effective treatment.

References

Adami, S., Falcomata, T. S., Muething, C. S., & Hoffman, K. (2017). An evaluation of lag schedules of reinforcement during functional communication training: effects on varied mand responding and challenging behavior. *Behavior Analysis in Practice*, *10*(3), 209–213. doi: 10.1007/s40617-017-0179-7

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5™* (5th ed.). Arlington, VA: American Psychiatric Publishing, Inc. http://dx.doi.org/10.1176/appi.books.9780890425596

Baruni, R. R., Rapp, J. T., Lipe, S. L., & Novotny, M. A. (2014). Using lag schedules to Increase toy play variability for children with intellectual disabilities. *Behavioral Interventions*, *29*(1), 21–35. doi: 10.1002/bin.1377

Carr, E. G., & Durand, V. M. (1985). Reducing behavior problems through functional communication training. *Journal of Applied Behavior Analysis*, *18*(2), 111–126. doi: 10.1901/jaba.1985.18-111

Cherot, C., Jones, A., & Neuringer, A. (1996). Reinforced variability decreases with approach to reinforcers. *Journal of Experimental Psychology: Animal Behavior Processes*, *22*(4), 497–508. doi: 10.1037//0097-7403.22.4.497

Cohen, L., Neuringer, A., & Rhodes, D. (1990). Effects of ethanol on reinforced variations and repetitions by rats under a multiple schedule. *Journal of the Experimental Analysis of Behavior*, *54*(1), 1–12. doi: 10.1901/jeab.1990.54 1

Craig, A. R., Nevin, J. A., & Odum, A. L. (2014). Behavioral momentum and resistance to change. In F. K. McSweeney & E. S. Murphy (Eds.), *The Wiley Blackwell handbook of operant and classical conditioning* (pp. 249 274). Wiley-Blackwell. http://dx.doi.org/10.1002/9781118468135.ch11

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. http://dx.doi.org/10.1002/jeab.278

de Souza Barba, L. (2012). Operant variability: A conceptual analysis. *The Behavior Analyst, 35*, 213–227. http://dx.doi.org/10.1007/BF03392280

Denney, J., & Neuringer, A. (1998). Behavioral variability is controlled by discriminative stimuli. *Animal Learning & Behavior*, *26*(2), 154–162. doi: 10.3758/bf03199208

Doughty, A. H., & Lattal, K. A. (2001). Resistance to change of operant variation and repetition. *Journal of the Experimental Analysis of Behavior*, *76*(2), 195–215. doi: 10.1901/jeab.2001.76-195

Doughty, A. H., & Galizio, A. (2015). Reinforced behavioral variability: Working towards an understanding of its behavioral mechanisms. *Journal of the Experimental Analysis of Behavior*, *104*(3), 252–273. doi: 10.1002/jeab.171

Doughty, A. H., Giorno, K. G., & Miller, H. L. (2013). Effects of reinforcer magnitude on reinforced behavioral variability. *Journal of the Experimental Analysis of Behavior, 100*, 355–369. http://dx.doi.org/10.1002/jeab.50

Esch, J. W., Esch, B. E., & Love, J. R. (2009). Increasing vocal variability in children with Autism using a lag schedule of reinforcement. *The Analysis of Verbal Behavior*, *25*(1), 73–78. doi: 10.1007/bf03393071

Falcomata, T. S., Muething, C. S., Silbaugh, B. C., Adami, S., Hoffman, K., Shpall, C., & Ringdahl, J. E. (2017). Lag schedules and functional communication training: Persistence of mands and relapse of problem behavior. *Behavior Modification*, *42*(3), 314–334. doi: 10.1177/0145445517741475

Galizio, A., Frye, C. C. J., Haynes, J. M., Friedel, J. E., Smith, B. M., & Odum, A. L. (2018). Persistence and relapse of reinforced behavioral variability. *Journal of the Experimental Analysis of Behavior, 109*, 210–237. http://dx.doi.org/10.1002/jeab.309

Grow, L. L., Kelley, M. E., Roane, H. S., & Shillingsburg, M. A. (2008). Utility of extinction-induced response variability for the selection of mands. *Journal of Applied Behavior Analysis, 41*, 15–24. http://dx.doi.org/10.1901/jaba.2008.41-15

Heldt, J., & Schlinger, H. D. (2012). Increased variability in tacting under a lag 3 schedule of reinforcement. *The Analysis of Verbal Behavior*, *28*(1), 131–136. doi: 10.1007/bf03393114

Kestner, K. M., Diaz-Salvat, C. C., Peter, C. C. S., & Peterson, S. M. (2018). Assessing the repeatability of resurgence in humans: Implications for the use of within-subject designs. *Journal of the Experimental Analysis of Behavior*, *110*(3), 545–552. doi: 10.1002/jeab.477

Kong, X., McEwan, J. S., Bizo, L. A., & Foster, T. M. (n.d.). An analysis of U value as a measure of variability. *Psychological Record*, *67*(4), 581–586. doi: 10.1007/s40732-017-0219-2

Koehler-Platten, K., Grow, L. L., Schulze, K. A., & Bertone, T. (2013). Using a lag reinforcement schedule to increase phonemic variability in children with Autism Spectrum Disorders. *The Analysis of Verbal Behavior*, *29*(1), 71–83. doi: 10.1007/bf03393125

Kuroda, T., Cançado, C. R., & Podlesnik, C. A. (2016). Resistance to change and resurgence in humans engaging in a computer task. *Behavioural Processes*, *125*, 1–5. doi: 10.1016/j.beproc.2016.01.010

Lalli, J. S., Zanolli, K., & Wohn, T. (1994). Using extinction to promote response variability in toy play. *Journal of Applied Behavior Analysis, 27*, 735–736. http://dx.doi.org/10.1901/jaba.1994.27-735

Lambert, J. M., Bloom, S. E., Samaha, A. L., Dayton, E., & Rodewald, A. M. (2015). Serial alternative response training as intervention for target response resurgence. *Journal of Applied Behavior Analysis*, *48*(4), 765–780. doi: 10.1002/jaba.253

Lambert, J. M., Bloom, S. E., Samaha, A. L., & Dayton, E. (2017). Serial functional communication training: Extending serial DRA to mands and problem behavior. *Behavioral Interventions*, *32*(4), 311–325. doi: 10.1002/bin.1493

Lee, R., Mccomas, J. J., & Jawor, J. (2002). The effects of differential and lag reinforcement schedules on varied verbal responding by individuals with autism. *Journal of Applied Behavior Analysis*, *35*(4), 391–402. doi: 10.1901/jaba.2002.35-391

Lieving, G. A., Hagopian, L. P., Long, E. S., & O'Connor, J. (2004). Response class hierarchies and resurgence of severe problem behavior. *The Psychological Record*, *54*(4), 621–634. doi: 10.1007/bf03395495

Maes, J. H. R. (2003). Response stability and variability induced in humans by different feedback contingencies. *Animal Learning & Behavior*, *31*(4), 332 348. doi: 10.3758/bf03195995

Mace, F. C., & Critchfield, T. S. (2010). Translational research in behavior analysis: historical traditions and imperative for the future. *Journal of the Experimental Analysis of Behavior*, *93*(3), 293–312. doi: 10.1901/jeab.2010.93-293

Mercier, C., Mottron, L., & Belleville, S. (2000). A psychosocial study on restricted interests in high functioning persons with Pervasive Developmental Disorders. *Autism*, *4*(4), 406–425. doi: 10.1177/1362361300004004006

Morgan, D. L., & Lee, K. (1996). Extinction-induced response variability in humans. *The Psychological Record, 46*, 145–159.

Nevin, J. A., & Wacker, D. P. (2013). Response strength and persistence. In G. J. Madden, W. V. Dube, T. D. Hackenberg, G. P. Hanley, & K. A. Lattal (Eds.), *APA handbook of behavior analysis, Vol. 2. Translating principles into practice* (pp. 109-128). Washington, DC, US: American Psychological Association. http://dx.doi.org/10.1037/13938-005

Neuringer, A. (1991). Operant variability and repetition as functions of Interresponse time. *Journal of Experimental Psychology: Animal Behavior Processes, 17*(1), 3-12. http://dx.doi.org/10.1037/0097-7403.17.1.3

Neuringer, A., Kornell, N., & Olufs, M. (2001). Stability and variability in extinction. *Journal of Experimental Psychology: Animal Behavior Processes*, *27*(1), 79–94. doi: 10.1037//0097-7403.27.1.79

Neuringer, A., & Jensen, G. (2013). Operant variability. In G. J. Madden, W. V. Dube, T. D. Hackenberg, G. P. Hanley, & K. A. Lattal (Eds.), *APA handbook of behavior analysis, Vol. 1. Methods and principles* (pp. 513 546). Washington, DC, US: American Psychological Association. http://dx.doi.org/10.1037/13937-022

Nevin, J. A. (1988). Behavioral momentum and the partial reinforcement effect. *Psychological Bulletin, 103*(1), 44-56. http://dx.doi.org/10.1037/0033-2909.103.1.44

Odum, A. L., Barnes, C. A., Ward, R. D., & Burke, K. A. (2006). The effects of delayed reinforcement on variability and repetition of response sequences. *Journal of the Experimental Analysis of Behavior*, *86*(2), 159–179. doi: 10.1901/jeab.2006.58-05

Page, S., & Neuringer, A. (1985). Variability is an operant. *Journal of Experimental Psychology: Animal Behavior Processes, 11*, 429–452. http://dx.doi.org/10.1037/0097-7403.11.3.429

Podlesnik, C. A., & Kelley, M. E. (2014). Resurgence: Response competition, stimulus control, and reinforcer control. *Journal of the Experimental Analysis of Behavior*, *102*(2), 231–240. doi: 10.1002/jeab.102

Podlesnik, C. A., & Deleon, I. G. (2015). Behavioral momentum theory: understanding persistence and improving treatment. *Autism Service Delivery Autism and Child Psychopathology Series*, 327–351. doi: 10.1007/978-1-4939-2656-5_12

Podlesnik, C. A., & Shahan, T. A. (2009). Behavioral momentum and relapse of extinguished operant responding. *Learning & Behavior, 37*, 357–364. http://dx.doi.org/10.3758/LB.37.4.357

Ross, C., & Neuringer, A. (2002). Reinforcement of variations and repetitions along three independent response dimensions. *Behavioural Processes, 57*, 199–209. http://dx.doi.org/10.1016/S0376-6357(02)00014-1

Rotating pie. Retrieved from https://loading.io/spinner/wedges/-rotate-pie-preloader-gif

Schwartz, B. (1982). Failure to produce response variability with reinforcement. *Journal of the Experimental Analysis of Behavior*, *37*(2), 171–181. doi: 10.1901/jeab.1982.37-171

Silbaugh, B. C., & Falcomata, T. S. (2016). Translational evaluation of a lag schedule and variability in food consumed by a boy with autism and food selectivity. *Developmental Neurorehabilitation*, *20*(5), 309–312. doi: 10.3109/17518423.2016.1146364

Souza, A. D. S., Abreu-Rodrigues, J., & Baumann, A. A. (2010). History effects on induced and operant variability. *Learning & Behavior, 38*, 426–437. http://dx.doi.org/10.3758/LB.38.4.426

Stahlman, W. D., Roberts, S., & Blaisdell, A. P. (2010). Effect of reward probability on spatial and temporal variation. *Journal of Experimental Psychology: Animal Behavior Processes*, *36*(1), 77–91. doi: 10.1037/a0015971

Tiger, J. H., Hanley, G. P., & Bruzek, J. (2008). Functional communication training: A review and practical guide. *Behavior Analysis in Practice*, *1*(1), 16–23. doi: 10.1007/bf03391716

Volkert, V. M., Lerman, D. C., Call, N. A., & Trosclair-Lasserre, N. (2009). An evaluation of resurgence during treatment with functional communication training. *Journal of Applied Behavior Analysis*, *42*(1), 145–160. doi: 10.1901/jaba.2009.42-145

Vollmer, T., Roane, H., Ringdahl, J., & Marcus, B. (1999). Evaluating treatment challenges with differential reinforcement of alternative behavior. *Journal of Applied Behavior Analysis*, *32*(1), 9–23. doi: 10.1901/jaba.1999.32-9

Wacker, D. P., Harding, J. W., Morgan, T. A., Berg, W. K., Schieltz, K. M., Lee, J. F., & Padilla, Y. C. (2013). An evaluation of resurgence during functional communication training. *The Psychological Record, 63*(1), 3-20. http://dx.doi.org/10.11133/j.tpr.2013.63.1.001

Ward, R. D., Kynaston, A. D., Bailey, E. M., & Odum, A. L. (2008). Discriminative control of variability: Effects of successive stimulus reversals. *Behavioural Processes*, *78*(1), 17–24. doi: 10.1016/j.beproc.2007.11.007

Wathen, S. N., & Podlesnik, C. A. (2018). Laboratory models of treatment relapse and mitigation techniques. *Behavior Analysis: Research and Practice, 18*(4), 362-387.http://dx.doi.org/10.1037/bar0000119

Wing, L., & Gould, J. (1978). Systematic recording of behaviors and skills of retarded and psychotic children. *Journal of Autism & Childhood Schizophrenia, 8*, 79–97. http://dx.doi.org/10.1007/BF01550280

Wolfe, K., Slocum, T. A., & Kunnavatana, S. S. (2014). Promoting behavioral variability in individuals with Autism Spectrum Disorders. *Focus on Autism and Other Developmental Disabilities*, *29*(3), 180–190. doi: 10.1177/1088357614525661

Table 1. Mean of missed trials, latency, and incorrect percentage of trials across phases and components for all participants.

		Missed Trial		Latency		Incorrect %	
Participant	Phase	Lag	Yoked-DRA	Lag	Yoked-DRA	Lag	Yoked-DRA
Daniel	1	1.38	1.25	0.44	0.40	17%	21%
	2	0	0	0.50	0.47	1%	3%
	3	0.07	0	0.57	0.52	3%	5%
Ana	1	0.1	0.1	0.68	0.65	30%	30%
	2	0.67	0.5	0.93	0.74	4%	2%
	3	4.75	5.13	1.52	1.50	34%	80%
John	1	0.75	0.5	0.84	0.90	42%	36%
	2	0.14	1.14	0.90	0.85	5%	13%
	3	16.88	17.75	2.10	2.16	41%	35%

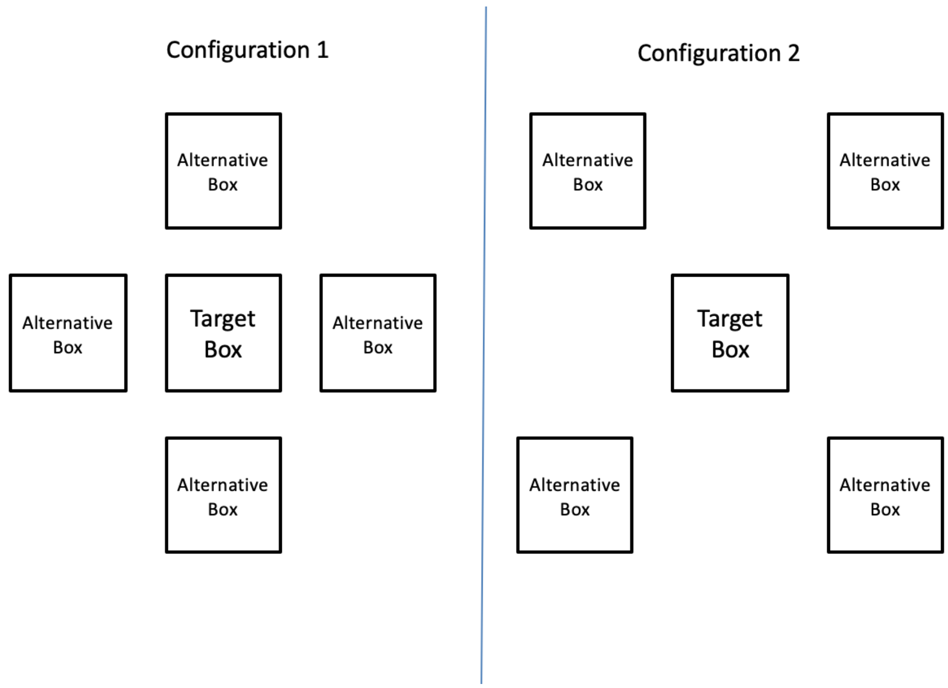

Figure 1. Depicts two configurations used in the study. The target box was located on the middle of the screen. Alternative boxes were located around the target box.

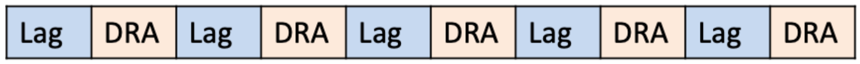

Figure 2. Depicts 10 components alternating in one session with Lag component always preceded the DRA component.

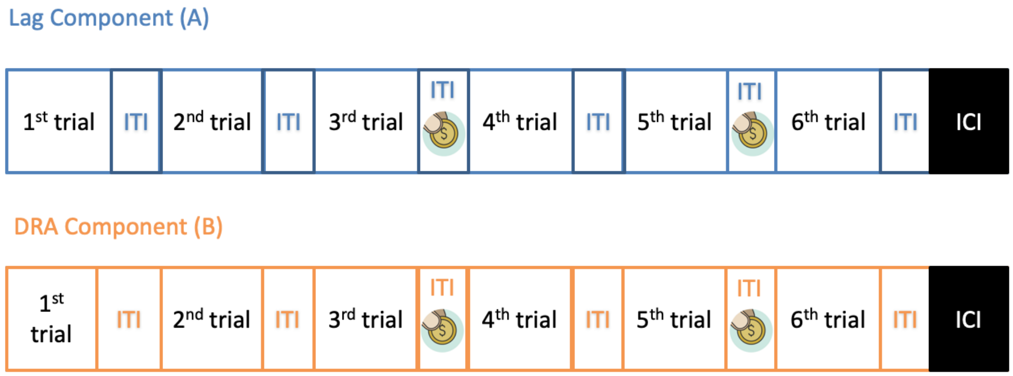

Figure 3. Demonstrates 6 trials in each component and 10 components in each session. In Lag component, there was a 1-s ITI after each trial. In DRA component, the ITI varied from the minimal of 0.5s to ensure the next Lag trial and DRA trial start at the same time. There was a 5s ICI between components to signal the component change.

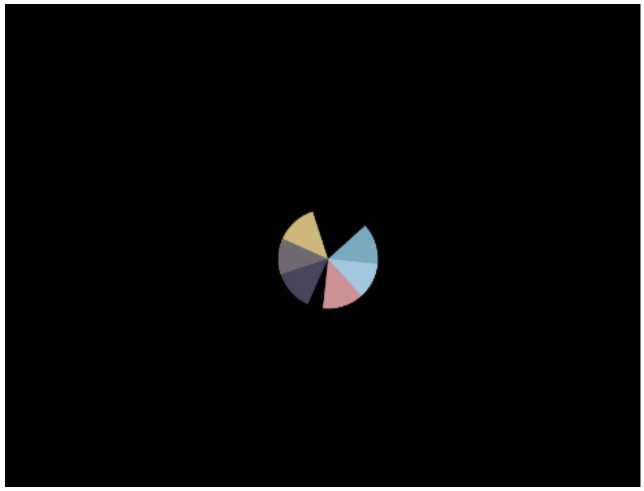

Figure 4. Depicts the presentation of a rotating pie animation during ICI for 5 seconds. Retrieved from https://loading.io/spinner/wedges/-rotate-pie-preloader-gif.

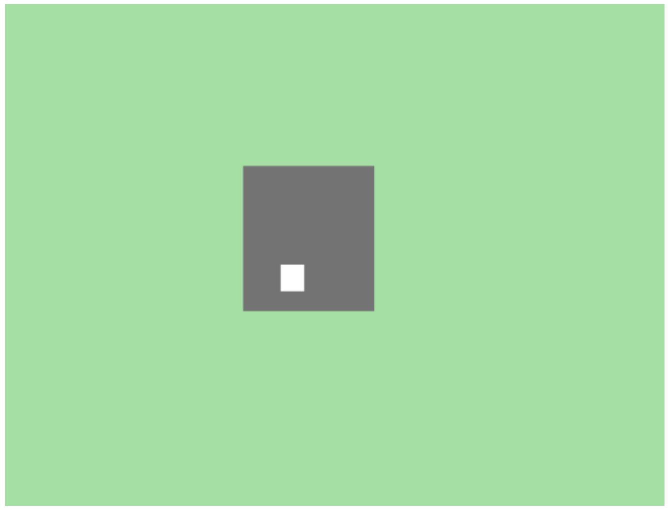

Figure 5. Depicts one design in Phase 1 training. Reinforcer was delivered contingently while target trials meet FR1 requirement. Assignments of the white or pink square as the target response was randomly selected and counterbalanced across participants.

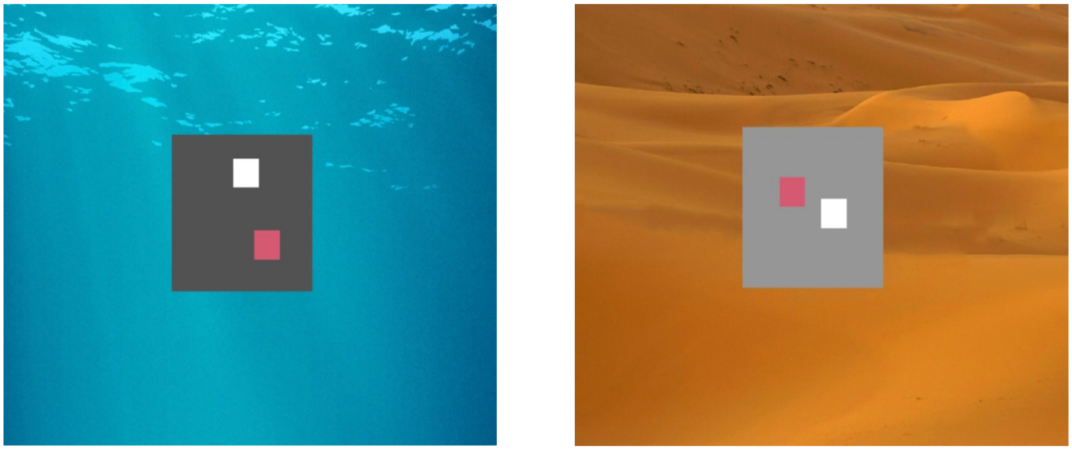

Figure 6. Depicts the design in Phase 1. Target box was located in the middle of the screen. Reinforcer was delivered contingently, according to a VR2 schedule in both components.

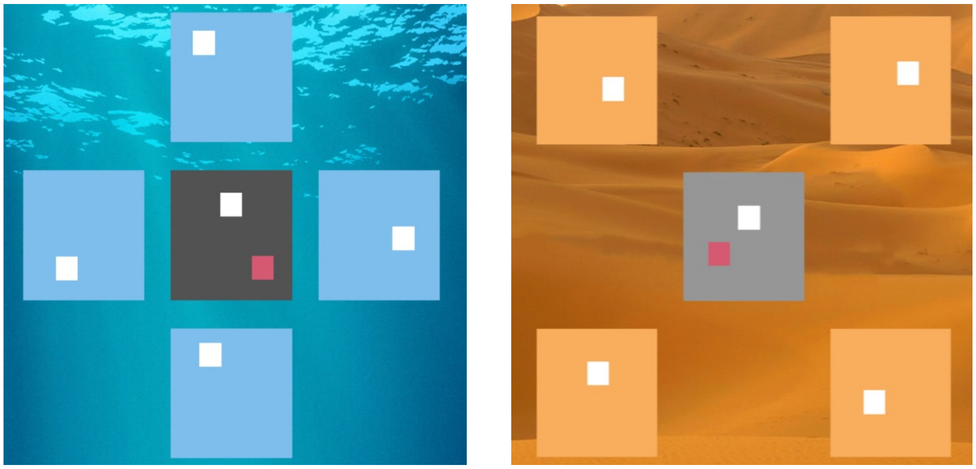

Figure 7. Depicts one design in Phase 2 and 3. Target colored boxes was located on the middle of the screen. Alternative colored boxes, blue and orange, were located around the target boxes. In phase 2, target trials were put on extinction. In the Lag component, alternative trials were reinforced according to a lag 1schedule. In the DRA component, the number of trials to one preselected alternative squares was yoked to a list with the number of trials required to produce reinforcement from the preceding Lag component. In Phase 3, all target and alternative trials were put on extinction within both components.

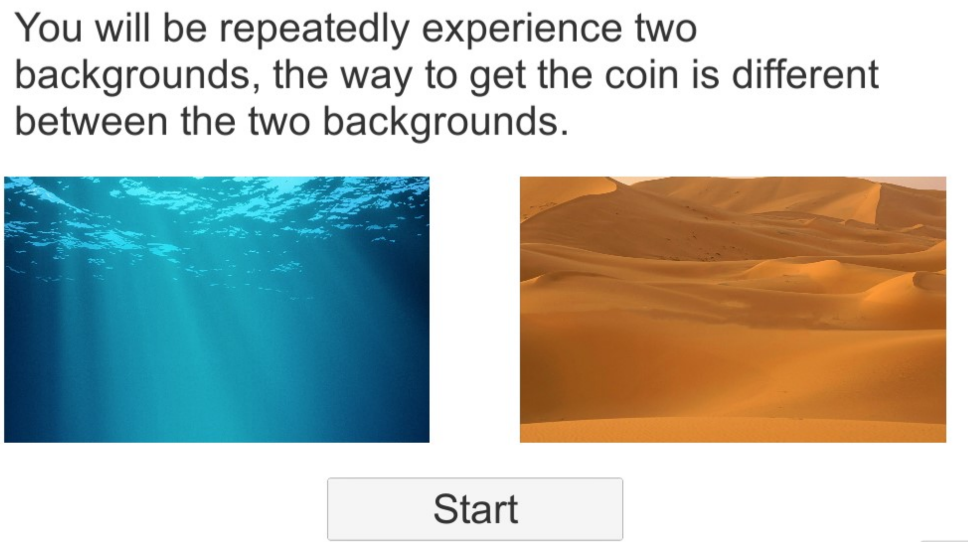

Figure 8. Depicts the instruction in Phase 2 Lag training.

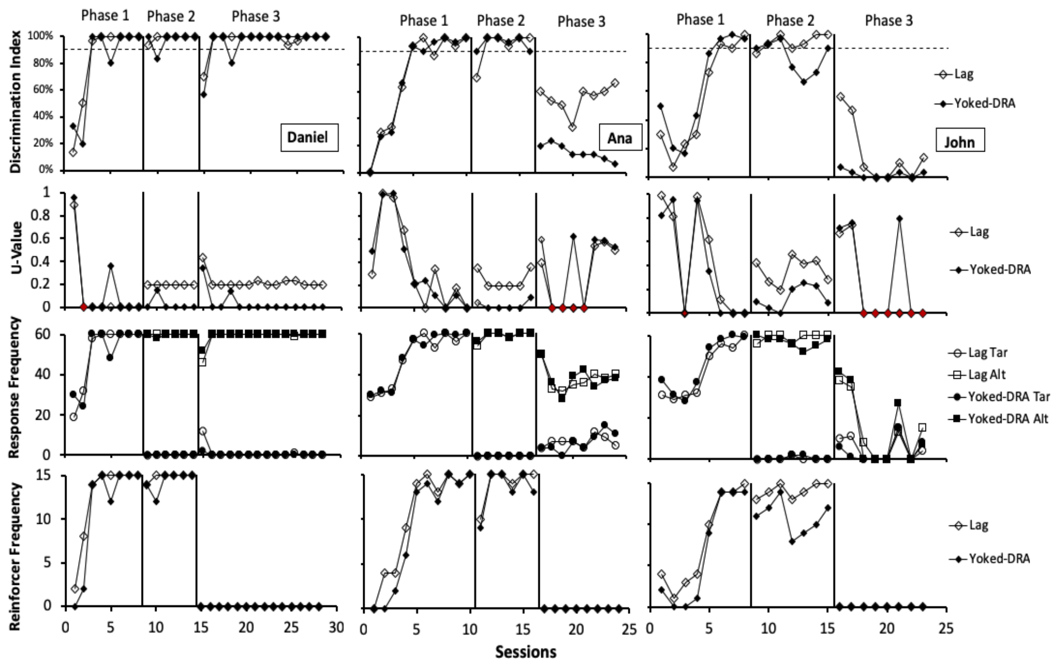

Figure 9. Depicts Discrimination Index (top row), U-Value (second row), Response Frequency (third row), and Reinforcer Frequency (bottom row) across sessions of all three phases for Daniel (left column), Ana (middle column), and John (right column). Red data points in the U-Value panel indicate participants responded less than 25 trials out of 30 trials per session.

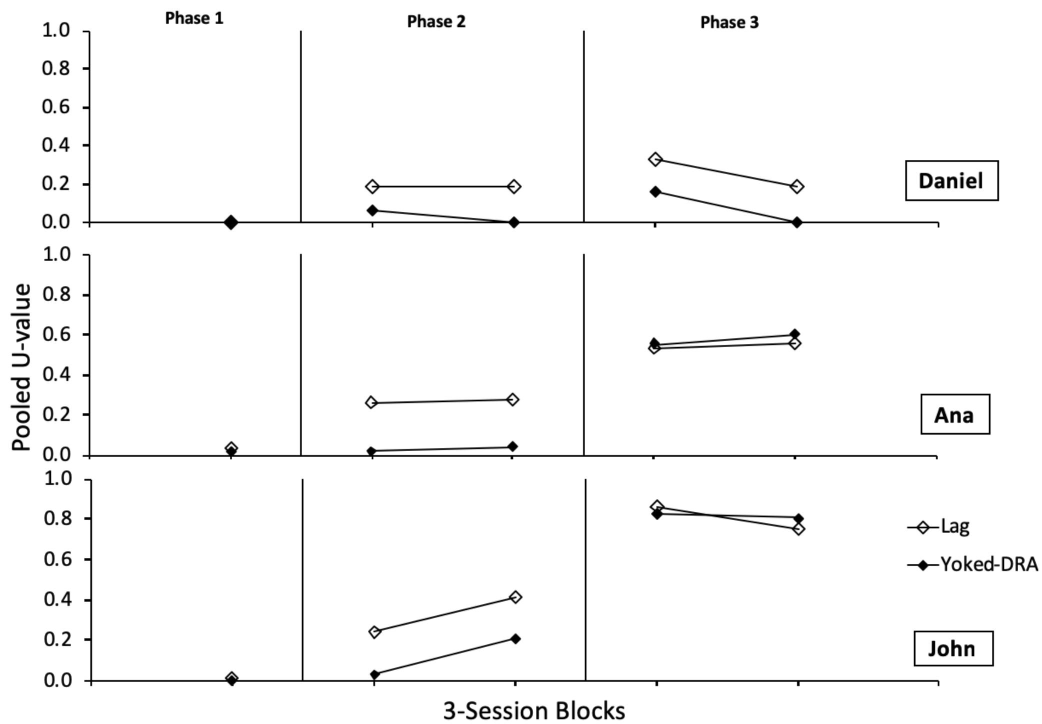

Figure 10. Depicts Pooled U-Value across phase for both components for Daniel (top panel), Ana (middle panel), and John (bottom panel). Each point presents a three-session block.

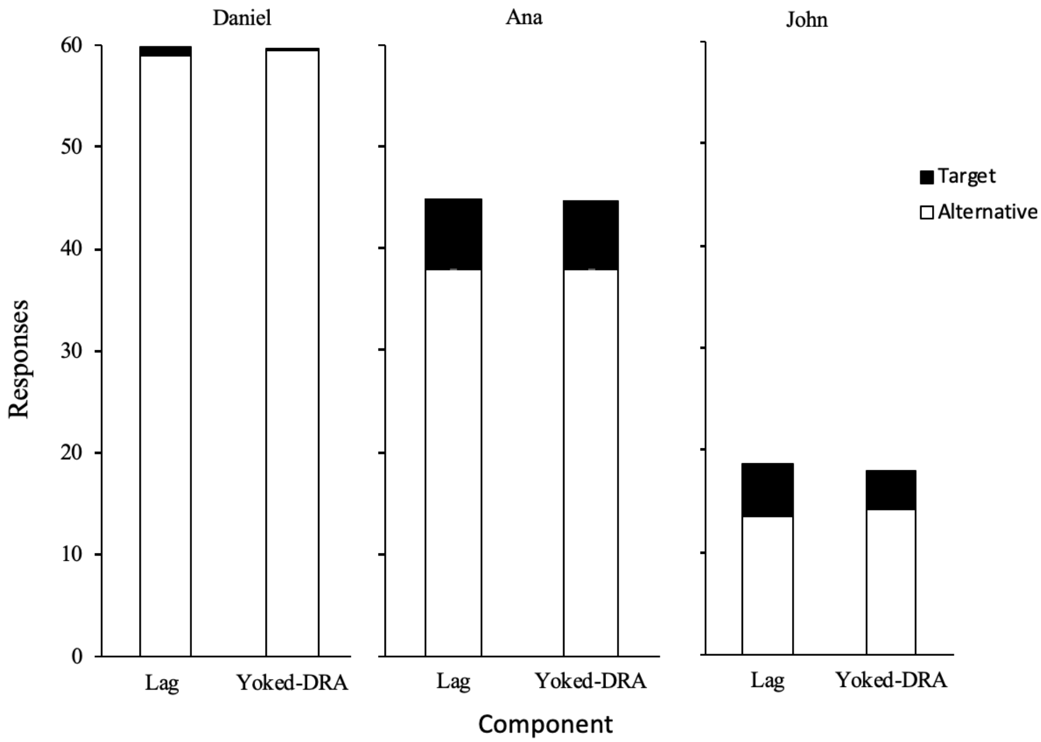

Figure 11. Average frequency of responses across sessions in Phase 3 for Daniel, Ana, and John for both components. The black parts represent the target responses and the white parts represent the alternative response. For all participants, data from the Lag component are on the left and the data from the Yoked-DRA component are on the right.

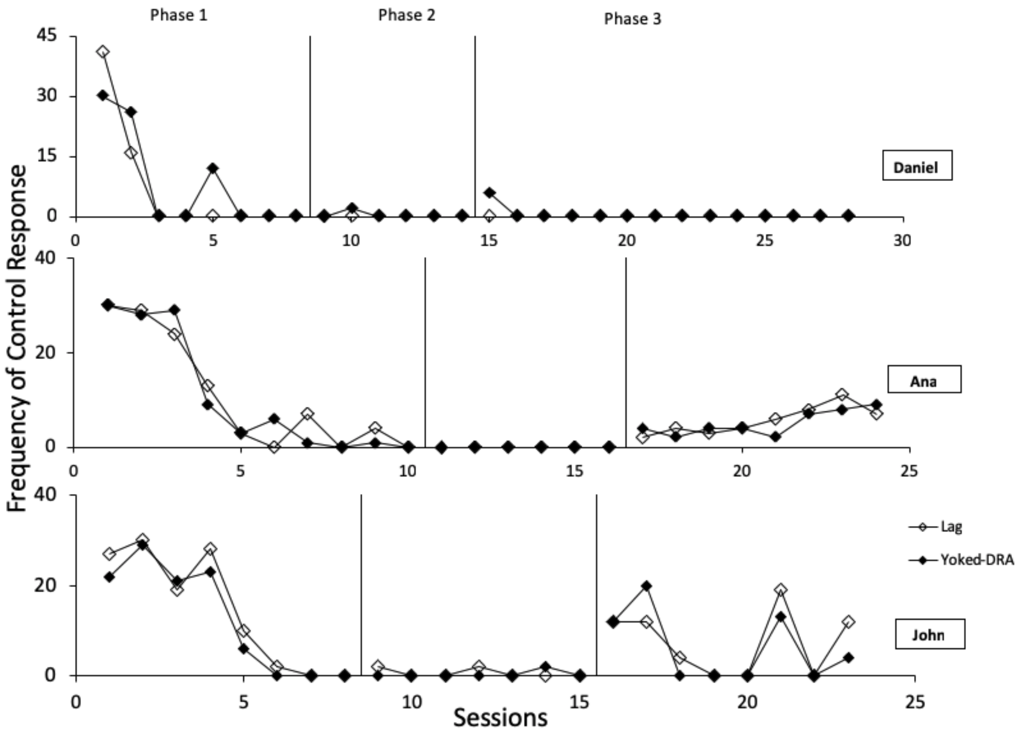

Figure 12. Frequency of control response across sessions of all three phases for Daniel (top row), Ana (middle row), and John (bottom row) for both components. Note the x- and y-axes differ across participants.