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Evaluation of a Cue Associated with Alternative Reinforcement to Mitigate Resurgence

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Treatment relapse due to the extinction of a previously reinforced alternative behavior is known as resurgence. Understanding the conditions under which resurgence is mitigated may be important for improving the maintenance of the effects of interventions. One method that has been found to effectively mitigate resurgence is pairing a cue or stimulus with alternative reinforcement and then continuing to present that cue when alternative reinforcement is terminated. Animal studies have found that cues must be paired with alternative reinforcement and target extinction to be effective. However, this finding has not yet been replicated with humans. Demonstration of a similar effect in humans could impact clinical decision-making, as not all behaviors can be easily extinguished. Therefore, this study was designed to replicate findings from resurgence studies involving rats as subjects by using a human operant task and evaluating whether cues are still effective at mitigating resurgence. Results demonstrate that the original animal findings were not replicated in humans indicating that more work is needed to identify the mechanisms of resurgence in human populations.

Evaluation of a Cue Associated with Alternative Reinforcement to Mitigate Resurgence

by

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Hayley D. Brown

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Introduction

In most cases, relapse involves the recurrence of a behavior that had been extinguished. Treatments involving extinction are most successful when the reinforcer for the problem behavior is made available contingent upon an alternative, more appropriate behavior (Lerman & Iwata, 1996). If that is not possible, then treatments often involve a competing reinforcer that is made contingent on the occurrence of an alternative behavior that is incompatible with the problem behavior. In either case, treatment success depends on reinforcement of an alternative behavior. In these cases, relapse can be the result of a discontinuation of reinforcement for the alternative behavior. Relapse that has come about due to this reason is known as resurgence (Epstein & Skinner, 1980).

In controlled research studies, resurgence is commonly examined with a three-phase within-subjects procedure (Podlesnick et al., 2023). In Phase 1, a target behavior is reinforced. In Phase 2, the target behavior is put on extinction and an alternative behavior is reinforced. In Phase 3 (the resurgence test), both the target and alternative behavior are put on extinction. Generally, an increase in the rate of target behavior in Phase 3 is characterized as resurgence (Podlesnick et al., 2023). This increase may be relative to a variety of variables including, but not limited to, target responding at the end of Phase 2 (e.g. Ritchey et al., 2020), alternative responding in Phase 3 (e.g., Doughty et al., 2014), responding on a control response (e.g., Craig et al., 2020), and Phase 3 target responding of a control group (e.g. Trask, 2019). The definition of resurgence in past work has often been unclear and unspecified (Lattal et al., 2017; Podlesnick et al., 2023); however, an increase of target responding in Phase 3 relative to the end of Phase 2 is the most common definition used (Podlesnick et al., 2023) and as such will be the definition used here.

Methods to mitigate resurgence have been examined as a means of improving post-intervention maintenance of treatment effects (Fuhrman et al., 2021; Perrin et al., 2021; Radhakrishnan, 2020). These methods are informed by the theory that extinction does not erase original learning, but instead produces new context-dependent learning (Bouton, 2004). Therefore, when target and alternative behaviors are extinguished within a resurgence paradigm, those behaviors are not unlearned. Rather, the organism learns *not to* engage in those behaviors and/or to engage in other behaviors under the specific environmental context that the extinction occurs. Because of this, changes in the environment may bring about or mitigate resurgence depending on the learning that occurred under those conditions. This concept is now widely accepted and forms a significant part of two of the main theories of resurgence, namely context theory (Trask et al., 2015) and the resurgence as choice in context model (Shahan & Craig, 2017).

Because learning is context-dependent, a common strategy evaluated to mitigate resurgence is to modify the physical attributes of the environment. These environmental changes may reduce the likelihood of a target behavior resurging when reinforcement for an alternative behavior is discontinued or thinned by evoking the learning associated with the contrived context. This has been explored in a few different ways in the resurgence literature: altering the general context, using discriminative stimuli, and associating cues with the extinction of the target behavior and/or the reinforcement of the alternative behavior. Of those three environmental manipulations, changing the general context has been the most extensively explored. Context change can independently bring about relapse of previously reinforced behavior, even when no alternative behavior is introduced, a phenomenon known as renewal (Saini & Mitteer, 2020). In typical renewal studies, a target behavior is learned in one context and extinguished in another. Returning to the original context or a third novel context then causes the extinguished behavior to reoccur, or renew. This can be observed alongside resurgence, where a target behavior is learned in one context, suppressed, and an alternative behavior encouraged in a different context. Upon returning to the original or moving to a novel context, the impact of the context on resurgence can be assessed.

In these studies, the context refers to visual, olfactory, and reinforcement stimuli. In general, it has been found that maintaining similar contexts across treatment can attenuate resurgence. This result has been replicated across non-human animals (e.g., Bouton & Trask, 2016; Craig et al., 2018; Kincaid et al., 2015; Nighbor et al., 2018; Podlesnick et al., 2019), neurotypical adults (e.g., Alessandri & Cancado, 2020; King & Hayes, 2016; Podlesnick et al., 2019; Podlesnick et al., 2020; Ritchey et al., 2021; Thrailkill et al., 2019), and clinical populations (Dube et al., 2017; Suess et al., 2020). Nevertheless, it may be challenging to sufficiently control the general context in real-world settings, which suggests the need for a more targeted approach.

Incorporating discriminative stimuli to solidify the associations between context and behavior may be one such targeted method. Studies evaluating the effects of discriminative stimuli on resurgence typically involve training a target behavior, extinguishing that behavior, and then implementing a multiple schedule in which one stimulus (the S^D) is paired with alternative reinforcement and another is paired with alternative extinction or thinning (S^Δ). In testing, if the discriminative stimulus is effective, resurgence will be mitigated in the presence of the S^Δ. This has generally been the case in studies of children with developmental disabilities (Fisher et al., 2020; Fuhrman et al., 2016) and also with non-human animals (Bai et al., 2017). However, there are some notable exceptions (e.g., Browning & Shahan, 2021; Podlesnick &

Kelley, 2014). Both studies used non-human animals and found that the presence of the S^{Δ} did not mitigate resurgence above a control group (Podlesnick & Kelley, 2014) or above the presence of the S^{D} (Browning and Shahan, 2021). It is possible that positive contrast may have contributed to these findings as it is well documented that manipulating the reinforcement rate of one component of a multiple schedule can influence responding in the other component. It is also possible that these discrepant findings may be due to the fact that a schedule thinning component was not included in the studies that foud discriminative stimuli to be ineffective in mitigating resurgence. Studies that found the S^{Δ} to be an effective mitigator thinned the multiple schedule before testing (Fisher et al., 2020; Fuhrman et al., 2016; Nighbor, 2015). This thinning also extended the length of target extinction and decreased the rate of alternative reinforcement, both of which have been shown to reduce resurgence (Leitenberg et al., 1975). In summary, it may be that the positive results obtained with human populations is due to factors outside of the discriminative stimuli manipulations. Additionally, the effect of discriminative stimuli on resurgence has yet to be evaluated in neurotypical and adult human populations. Still, these results are encouraging for identifying a more targeted context approach to mitigating resurgence.

A similar targeted approach found to be effective is the pairing of a stimulus or cue with alternative behavior reinforcement. If this cue is effective, continuing to present it during extinction of the alternative behavior should mitigate resurgence of the target behavior. This has been explored only in a few studies. Craig et al. (2017) conducted a study with rats to evaluate the effects of reinforcer-correlated stimuli on resurgence. A three-phase procedure was used with three groups of rats. A set of stimuli were correlated with target and alternative reinforcement throughout the procedure. In testing, one group continued to receive reinforcement and the correlated stimuli for alternative responding. Another group received the stimuli but no reinforcement for alternative responding, and the final group received no consequences, stimuli or reinforcement, for alternative responding. The two groups that did not receive reinforcement displayed resurgence, while the group that continued to receive reinforcement did not. Of the two groups that displayed resurgence, the group that continued to receive reinforcement-correlated stimuli displayed less resurgence. Shvarts et al. (2020) replicated these results with pigeons and children diagnosed with autism spectrum disorder using a within-subjects design, further indicating that a cue may be a useful mitigation technique.

Trask (2019) further explored the conditions under which a cue may be effective in a series of experiments with rats. All experiments used the three-phase resurgence procedure. Experiment 1a replicated Shvarts et al. (2020) using a within-subjects design with rats. Experiment 1b was similar except that two groups of animals were used. One group experienced a cue in conjunction with alternative reinforcement. The other group experienced a cue that was contingent on responding but on a schedule separate from reinforcement. Only the group in which the cue was paired with alternative reinforcement showed attenuated resurgence. In Experiment 1c, one group continued to receive the cue unaccompanied by reinforcement contingent on alternative lever-pressing in testing. The other group received the cue on a random time (RT) schedule rather than contingent on alternative responding. Both groups displayed similar rates of resurgence indicating that a cue need not be contingent on alternative responding to mitigate resurgence; its presence is enough.

The use of a cue is similar to the discriminative stimuli approach. However, there is an important difference in the procedures. In the case of a cue, an S^{Δ} for the alternative behavior is not used. Rather, the cue associated with alternative reinforcement, or the S^{D} in the discriminative stimuli approach, is delivered in extinction to mitigate resurgence. This seems to directly oppose the findings of the discriminative stimuli resurgence literature, as continuing to present the S^D in those studies did not mitigate resurgence (e.g., Fisher et al., 2020; Fuhrman et al., 2016). This may be because the mechanisms behind cues and discriminative stimuli are different. A cue may work because it is paired with target extinction as well as alternative reinforcement, making the cue an S^Δ for the target behavior. This may also help to explain discrepant findings in the discriminative stimuli literature (Browning & Shahan, 2021; Podlesnick & Kelley, 2014). It may be that the S^Δ does not mitigate resurgence because it is paired with the extinction of the alternative behavior rather than the target behavior as a cue is.

The above hypothesis about the mechanism that underlies the effectiveness of cues in mitigating resurgence has been explored in animal studies. Trask (2019, Exp 2) conducted a study using the typical three-phase resurgence procedure described above with rats. Two cues were associated with alternative responding. Cue 1 was associated with alternative reinforcement in the presence of the target and alternative response operandum. Cue 2 was associated with alternative reinforcement only in the presence of the alternative response operandum. Resurgence was attenuated when Cue 1 was presented in testing but not Cue 2, indicating that cues must be paired with target extinction to be effective.

However, these findings about cues have not been replicated in humans outside of Shvarts et al. (2020) which used a small sample of children diagnosed with autism spectrum disorder. This small, specific sample can hardly be generalized to all populations. Additionally, the evaluation of the mechanism behind cues in mitigating resurgence has yet to be evaluated in humans at all. This finding could have impacts on clinical decision-making as not all behaviors can be easily extinguished. For example, automatically-maintained problem behaviors or drug use are not easily extinguished and so a cue may not help to mitigate resurgence of these behaviors following extinction of an alternative response. Furthermore, it is important to solidify the mechanism behind cues in resurgence as this may improve treatment efficiency. That is, it may be easier and less resource-intensive to pair one stimulus with alternative reinforcement and target extinction than to train two separate stimuli as an S^D and an S^Δ. As such, the purpose of this study is to replicate the findings of Trask (2019) using a human operant task.

Methods

Participants

Subjects were recruited through a crowdsourcing platform similar to Amazon's Mechanical Turk (MTurk) called Prolific. Prolific has been shown to produce data quality similar to MTurk but with a more diverse sample (Peer et al., 2017). Additionally, Prolific participants have been shown to be less naïve and dishonest than MTurk participants (Peer et al., 2017). The study was available for Prolific members who were in the U.S., over 18 years of age, had a Prolific approval rate of at least 95%, and had between 100 and 500 previous Prolific submissions to view. The approval rate and minimum submissions criteria are standard criteria in crowdsourcing samples to ensure quality data (Newman et al., 2021). A maximum submissions criterion of 500 is also recommended to ensure a non-naïve sample (Meyers et al., 2020). In summary, participants were eligible to participate if they were 1) in the United States, 2) at least 18 years old, 3) had a Prolific approval rate of at least 95%, and 4) had completed between 100 and 500 previous Prolific submissions.

Power analyses of previous resurgence literature using crowdsourced samples indicate that 5-8 subjects are required to meet adequate power (Ritchey et al, 2021; 2022). However, a larger sample is typically used to reduce Type II errors (Ritchey et al, 2021; 2022). This study used similar procedures to past crowdsourcing literature so that a similar number of measures were collected. As such, this study recruited 20 subjects to reduce Type II errors and be in-line with previous research.

Apparatus

The study task was adapted from a task previously used in resurgence research and made publicly available (Ritchey et al., 2021). WordPress was used for designing the study task, and Amazon Lightsail was used as the hosting server where study performance files were stored. The study task was programmed in Javascript on the front-end and in PHP for managing the server and file storage. The task was accessible with a desktop or laptop computer via Google Chrome, Mozilla Firefox, and Microsoft Edge.

Procedures

General

The study was posted on Prolific with the following description: "Complete an easy button-pressing task for academic research. Participants will receive a base pay of $4.80 for completion of the 30-minute task. Up to $4.50 in bonuses can be earned based on performance on the task." People interested in the study based on the description clicked a link which led to the consent form. After reading the consent and agreeing to participate, participants were given the following instructions pertaining to the study task,

> "After pressing the PROCEED button below, you will play a game to earn as much money as you can. A new page will appear and you will see a button. Pressing the button could sometimes increase your earnings or do nothing. Earnings will be tracked by a bar on the screen. The game will take approximately 15 minutes to complete. If you complete the game, you will receive a payment for completing the game along with the amount earned in the game. Failing to begin engaging with the game within 30 seconds after proceeding will terminate the opportunity to participate in this task and the opportunity for payment. Therefore, do not proceed unless you are ready to begin and complete the

game. Press the PROCEED button when ready to continue and please begin the game as soon as the interface appears."

Then, participants who clicked "PROCEED" moved on to the study task. Following the study task, participants were asked to complete a short demographic questionnaire. The demographic questionnaire included questions about the participants' age, gender, race, ethnicity, education, and socioeconomic status. Participants also completed attention check questions as this is recommended to ensure data quality when using crowdsourcing to acquire data (Newman et al., 2020). Specifically, participants were asked if they remembered seeing stimuli present in the experiment (black circle and blue triangle) and not present in the experiment (green star).

Study Task

The study task involved participants clicking buttons on their computer screen. Figure 1 displays the task as viewed by participants. The browser background was blue and either one or two buttons were visible on the screen during the task. Buttons were square and 100 px by 100 px. Each button contained an image of either a black square or black circle and was contained within a 350 px by 350 px workspace. Workspaces were yellow and situated on each side of the screen. The buttons randomly moved 20px either up, down, left, or right within the workspaces at 0.2s intervals throughout the task. In addition to the buttons, a bar detailing the participants earnings was visible. In conditions where reinforcement was available, clicks to buttons that resulted in reinforcement momentarily changed the color of the earnings bar from grey to green, flashed "+.01" above the button, and added $.01 to the earnings bar. In conditions where a cue was associated with reinforcement, clicks to buttons that resulted in reinforcement did everything listed above but additionally flashed an image of a blue diamond or a blue triangle above the button. Throughout the task, all responses that did not result in reinforcement produced no consequence. Between phases and sessions of the task, all objects were removed from the screen and replaced with a countdown timer that stated the session number and counted down from 15 seconds. At the end of the timer, the timer was removed and the objects relevant to the next phase or session of the task were replaced. The task consisted of three phases outlined below.

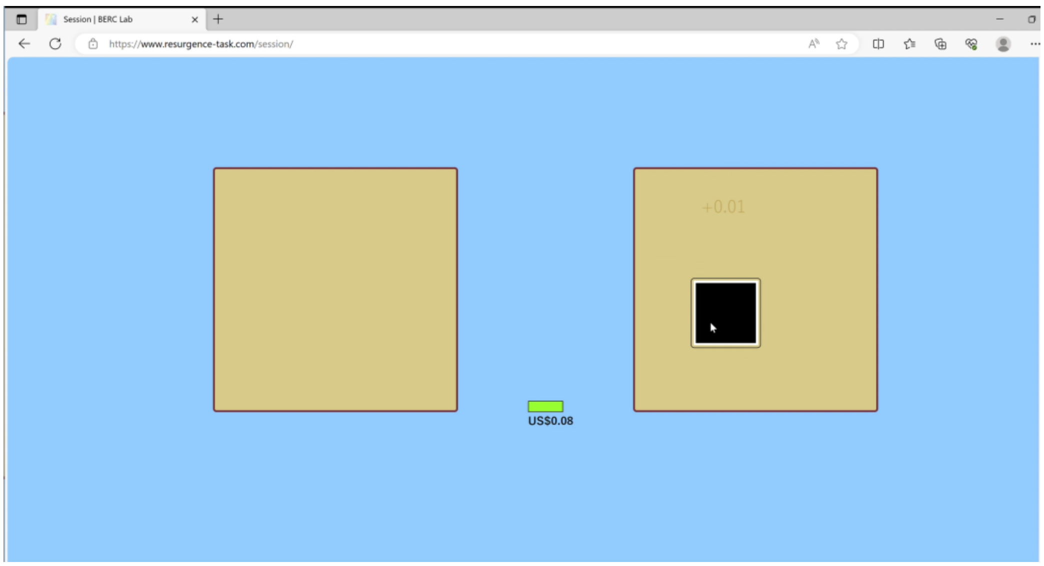

Figure 1

Participant View of the Study Task

Phase 1

Phase 1 lasted 180 s, and clicking the only available button (the target button) resulted in an increase of $0.01 to the earnings counter on a VI-2s schedule. A VI-2s schedule was used as this has reliably produced resurgence in crowdsourced samples (Ritchey et al., 2021; 2022), and allowed for more controlled responding and reinforcement rates. Additionally, 180 s has been shown sufficient to acquire the target behavior (Ritchey et al., 2021; 2022; Robinson & Kelley, 2020). Earnings of $0.01 were chosen to allow for the relatively dense schedule of reinforcement in order to produce resurgence. The button that serves as the target button (square or circle) and the location of the target button (left or right side of the screen) was counterbalanced across participants.

Phase 2

Phase 2 consisted of four sessions presented consecutively. Each session lasted a minimum of 60 s and was terminated when participants reached a target responding rate below 80% of their mean Phase 1 target responding rate for two consecutive 12 s bins or after 30 12 s bins, whichever occurred first. This was to ensure sufficient extinction of the target behavior and acquisition of the alternative behavior (Ritchey et al., 2021; 2022). In Phase 2, the alternative button was presented in all sessions. The alternative button was the button that was not designated the target button and appeared on the other side of the screen as the target button. There were two Target Extinction (T-EXT) and two No Extinction (NO-EXT) sessions. In the T-EXT sessions, the target and alternative buttons were present. Clicks to the target button resulted in no consequences, and clicks to the alternative button resulted in an increase of $.01 to the earnings counter and an associated cue on a VI-2s schedule. In NO-EXT sessions, only the alternative button was available, and clicks to the alternative button resulted in reinforcement and an associated cue on a VI-2s schedule. The cue associated with each type of session (triangle or diamond) was counterbalanced across participants. Participants were randomly assigned to receive sessions in one of the two following sequences: T-EXT, NO-EXT, NO-EXT, T-EXT or NO-EXT, T-EXT, T-EXT, NO-EXT.

Phase 3

Phase 3 consisted of three 60 s sessions. This was to allow for examination of each cue and their absence separately. Additionally, resurgence has been found to occur within one minute of extinction in similar three-phase paradigms (Ritchey et al., 2021; 2022; Robinson & Kelley, 2020). In all sessions, both alternative and target buttons were present, but clicks to either button resulted in no reinforcement. In one session (T-EXT session), clicks to the alternative button resulted in the cue associated with T-EXT conditions. In another session (NO-EXT session), clicks to the alternative button resulted in the cue associated with NO-EXT conditions. And in the third session (NO CUE session), clicks to the alternative button resulted in no consequences. In all sessions, clicks to the target button resulted in no consequences. The order of sessions was counterbalanced across participants.

Data Screening

Data sets were to be excluded from analysis if more than 25 responses occurred in a one-second interval, there were fewer than one response per 12-seond bin in Phase 1 and/or Phase 2, the attention check was failed, or the experiment was not completed. These criteria were selected to ensure quality data from crowdsourcing participants and to be in-line with previous crowdsourced resurgence work (Ritchey et al., 2021). No data sets met these criteria and all were included in analysis.

Data Analysis

Changes in target and alternative button clicks per minute across contingencies were examined with generalized linear mixed-effects modeling. Separate models for alternative and target responding were fit. Mixed-effects modeling was selected to account for individual subject variability such that the model could predict both group and individual behavior (DeHart & Kaplan, 2019). Responding was divided into 12 s bins across the experiment (Ritchey et al., 2021; Robinson & Kelley, 2020). Response rates were then calculated by multiplying the number of clicks in each bin by five. Analyses were conducted in R (R Core Team, 2023) using the lme4 package (Bates et al., 2014). To account for the variable length of Phase 2 sessions only the final five bins of each session of Phase 2 were included in analyses.

A generalized linear model was initially fit with fixed effects of Age, Gender, Phase 3 Session Order, Cue, Session, and Bin, as well as all possible interactions between Session, Bin, and Cue. A random intercept of Participant was also included to account for inter-individual variability. A cube root transformation was applied to response rate to meet the assumption of randomly distributed residuals. Upon evaluation, demographic factors and the order of sessions in Phase 3 were found to contribute insignificantly to the model and were thus eliminated from subsequent analysis. Model comparisons were undertaken using Akaike In-formation Criterion (AICc) via the MuMIn R package (Barton, 2009). Fixed effects were evaluated using Wald tests via the car package (Fox and Weisberg, 2019). AICc comparisons supported the use of the initial model with one random-slope effect across all analyses.

Results

Participant Demographics

Twenty participants completed the study and were included in data analysis. The average age of the sample was 30.75 years (SD = 11.553), and the majority of participants identified as White (85%, N=17) and male (65%, N=13). See Table 1 for a detailed breakdown of demographics.

Table 1

Demographics of Sample

Demographic Variable	N	Percent	Mean	SD
Age			30.75	11.55
Gender				
Male	13	65		
Race				
White	17	85		
Black	1	5		
Asian	2	10		
Ethnicity				
Hispanic/Latin	1	5		
Education				
High school	6	30		
College	9	45		
Graduate	2	10		
Prefer not to answer	3	15		
Income				
< 25	1	5		
25-50	7	35		
50-75	2	10		
75-100	3	15		
> 100	4	20		
Prefer not to answer	3	15		

Target Response Rates

The left panel of Figure 2 shows the average target response rates across all phases. Target responding increased across Phase 1 and decreased across each session of Phase 2. In Phase 3, target responding increased from the previous phase at similar levels across all sessions.

The final mixed-effects model included significant effects of Bin ($\chi^2[14] = 77.61$, $p < .01$), Session ($\chi^2[7] = 339.57$, $p < .01$), Cue ($\chi^2[2] = 10.37$, $p < .01$), a Cue x Session interaction ($\chi^2[8] = 117.99$, $p < .01$), and a Cue x Session x Bin interaction ($\chi^2[27] = 74.75$, $p < .01$) were found. The remaining interactions, Bin x Session and Bin x Cue, were insignificant ($ps > .05$).

To further evaluate the interactions, post-hoc tests of target responding in the final bins of Phases 1 and 2 and the first three bins of Phase 3 were conducted. Specific comparisons identified that target responding was not different during the last bin of Phase 1 compared to the last bin of Phase 2 ($ts \leq 4.05$, $ps > .05$). This may seem to indicate that target responding was not extinguished in Phase 2. However, data inspection reveals that this finding is due to a lack of target responding at the end of Phase 1 as opposed to increased target responding at the end of Phase 2. Eight participants completed 0-1 target responses in the final bin of Phase 1 while no participants completed target responses in the final bin of Phase 2.

Specific comparisons between the last bin of Phase 2 and the first three bins of Phase 3 were also conducted. These results are summarized in Table 2 and discussed below.

Table 2

Summary of Comparisons between Target Response Rates in the Final Bin of Phase 2 and the First Bins of Phase 3

	Session 1			Session 2			Session 3		
Bin of Phase 3	NO-EXT	T-EXT	NO-CUE	NO-EXT	T-EXT	NO-CUE	NO-EXT	T-EXT	NO-CUE
1	X	X	X	X	X	X	X	X	X
2	+	+	X	+	+	+	X	X	+
3	+	+	X	+	+	X	X	X	+

Note. X denotes nonsignificant difference in response rates. + denotes significant difference in response rates.

Final Bin of Phase 2 – First Bin of Phase 3

Target responding was not different during the last bin of Phase 2 compared to the first bins of each session of Phase 3 ($ts \leq 4.14$, $p > .05$).

Final Bin of Phase 2 – Second Bin of Phase 3

Target responding in the second bin of Phase 3 did differ from responding in the last bin of Phase 2 depending on session and cue. Specifically, target responding was significantly greater in the second bin of Session 1 of Phase 3 compared to the last bin of Phase 2 only when a cue was presented in Session 1 of Phase 3 ($ts \geq 6.57$, $ps < .01$). When a cue was not presented, target responding did not differ ($ts \leq 2.50$, $ps > .05$). Target responding was always significantly greater in the second bin of Session 2 of Phase 3 compared to the last bin of Phase 2 ($ts \geq 5.39$, $ps < .01$). In Session 3, target responding in the second bin of Phase 3 was only significantly greater than that of the last bin of Phase 3 when no cue was presented in Session 3 of Phase 3 ($ts \geq 5.90$, $ps < .01$). When a cue was presented, target responding did not differ ($ts \leq 1.23$, $ps > .05$).

Final Bin of Phase 2 – Third Bin of Phase 3

Target responding was greater in the third bin of Session 1 of Phase 3 when a cue was presented (ts ≥ 5.87, ps < .05) but did not differ when a cue was absent (ts ≤ 4.31, ps > .05). In the third bin of Session 2 of Phase 3, target responding was greater than that of the last bin of Phase 2 when a cue was presented in Session 2 of Phase 3 (ts ≥ 5.24, ps < .01) but did not differ when a cue was absent (ts ≤ 4.02, ps > .05). Target responding was significantly greater in the third bin of Session 3 of Phase than in the final session of Phase 2 when a cue was absent (ts ≥ 4.89, ps < .01) but did not differ when a cue was present (ts ≤ 1.62, ps > .05).

Overall, these comparisons indicate that resurgence did occur in the second and third bins of each session depending on the session and whether a cue was presented or not. When cues were presented in the first two resurgence tests, target responding resurged. When no cue was presented resurgence of target responding did not occur. The opposite was seen in the final resurgence test. When a cue was present resurgence of the target response was not seen, but when no cue was presented, resurgence occurred.

While the above results indicate that responding did not change as a function of which cue was presented, visual inspection of each participant's responding (available in Appendix B) reveal that some participants did respond discriminably to the cues. Specifically, five participants (participants 001, 005, 012, 014, and 016) displayed decreased response rates in the presence of the cue paired with target extinction compared to the cue unpaired with extinction and the absence of a cue in extinction testing.

Correlational analyses were conducted between mean Phase 1 target response rates and target response rates in the first three bins of each session of Phase 3. There was a significant positive relationship between target responding in Phase 1 and Phase 3 (r = .56, p < .01).

Participants who showed greater target responding in Phase 1 also displayed greater resurgence in Phase 3, a finding well-documented in the resurgence literature (da Silva et al., 2008; Ritchey et al., 2021; Sweeney & Shahan, 2013; Winterbauer et al., 2010).

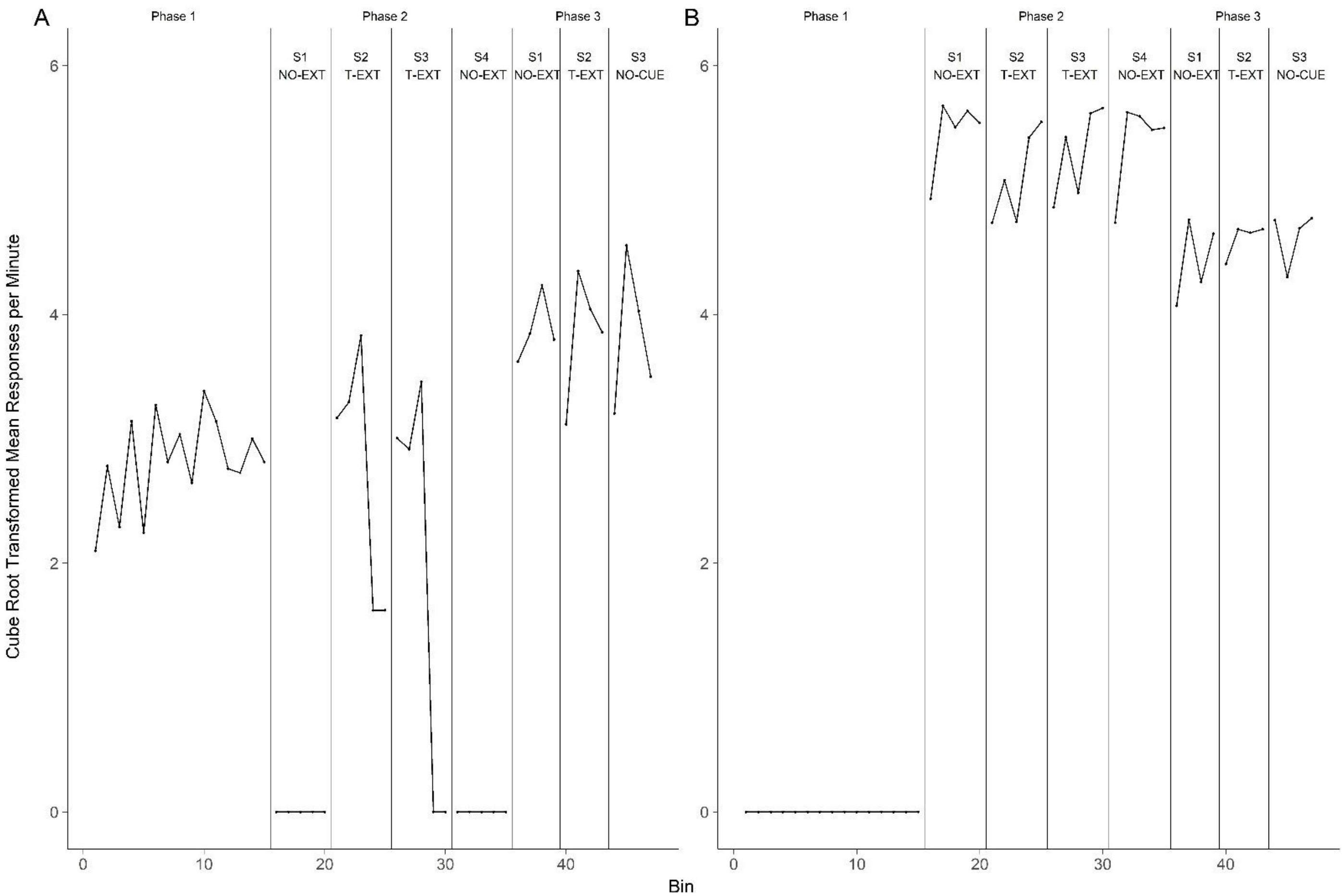

Figure 2

Mean Target and Alternative Responding across Sessions

Note. Panels A and B depict target and alternative responding, respectively, throughout the experiment. Response rate has been cube root transformed as in the fitted model.

Alternative Response Rates

The right panel of Figure 1 shows the average alternative response rates across all phases. No alternative responding occurred in Phase 1. Alternative responding increased in Phase 2 and decreased in Phase 3.

The final mixed-effects model included significant effects of Bin ($\chi^2[14] = 28.54$, $p < .05$), Session ($\chi^2[7] = 789.48$, $p < .01$), and a Cue x Session interaction ($\chi^2[8] = 18.69$, $p < .05$) were found. The remaining predictors and interactions (Cue, Bin x Cue, Bin x Session, and Cue x Bin x Session) were insignificant (ps > .05)

Specific comparisons identified that alternative responding was greater during the last bin of Phase 1 compared to during the final bin of Phase 2 (ts ≥ 12.84, $p < .01$) and the first bins of each session of Phase 3 (ts ≥ 6.39, $p < .01$). This indicates that the alternative response was acquired in Phase 2 and that responding remained elevated in Phase 3 as compared to Phase 1. Alternative responding did not differ from the final bin of Phase 2 compared to the first and final bins of each session of Phase 3 (ts ≤ 3.73, $p > .05$). Alternative responding did not decrease as a result of extinction in resurgence testing.

Resurgence Prevalence

Figure 3 shows the difference in target responses from the last bin of Phase 2 to the first two bins of Phase 3. Panel A shows the differences across sessions. The median increase in responses from the end of Phase 2 to the beginning of Session 1 of Phase 3 was 2 (IQR = 4.13), 2.75 (IQR = 6.5) for Session 2, and 0 (IQR = 4) for Session 3. Panel B shows the differences across cues. The median increase in responses from the end of Phase 2 to the beginning of the EXT cue session was 2.25 (IQR = 5.63), 1.25 (IQR = 6.88) for NO-EXT, and 1 (IQR = 4.75) for NO-CUE. Overall, about half of participants did not display an increase in responding from the final bin of Phase 2 to the first two bins of each session of Phase 3. For those who did, that increase often fell in the range of 1 to 7 responses regardless of session or cue.

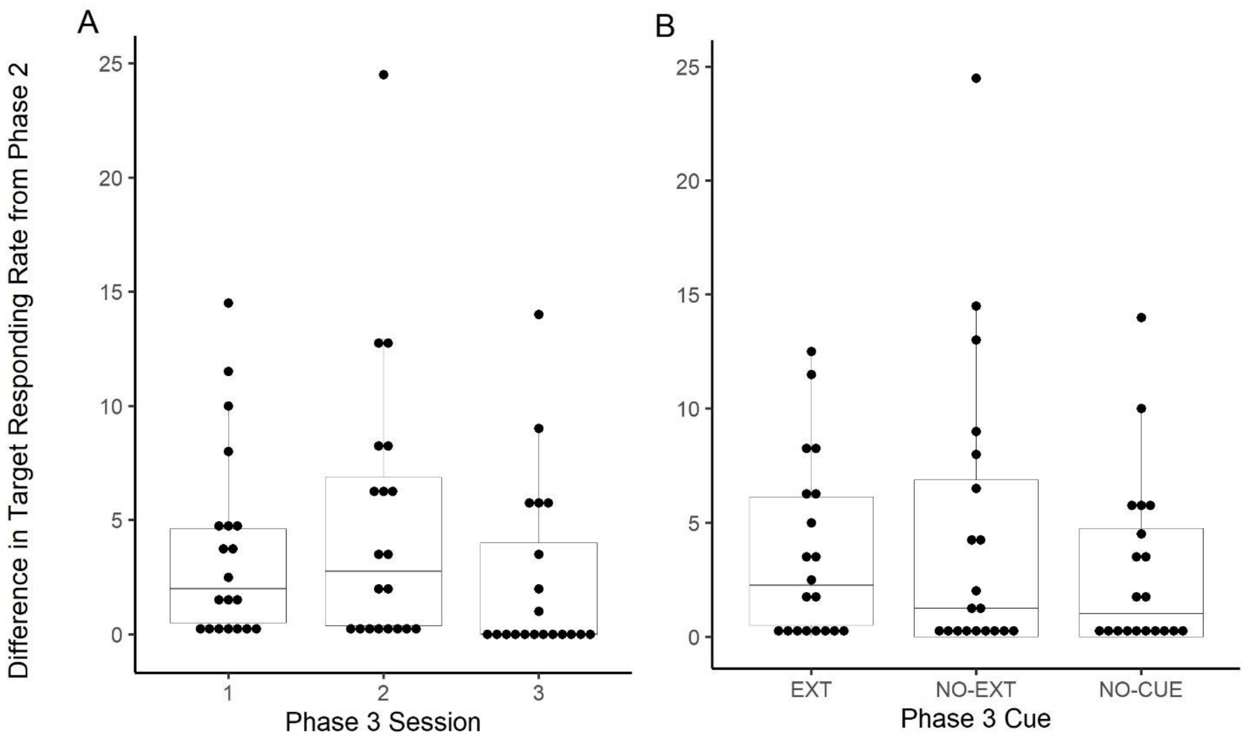

Figure 3

Difference in Number of Responses from the End of Phase 2 to the Beginning of Phase 3

Note. Panel A depicts the difference in target response rate from the end of Phase 2 to the beginning of Phase 3 grouped by session. Panel B shows the difference in response rate grouped by cue.

Panel A of Figure 4 displays the percentage of participants displaying resurgence across each bin of each session of Phase 3. Resurgence was defined as an increase in target responding above that in the final bin of Phase 2. Resurgence was prevalent across each session; however, the final session of Phase 3 induced less resurgence than the earlier sessions. Panel B of Figure 4 displays the percentage of participants displaying resurgence across cues in Phase 3. Resurgence was again prevalent in each presentation of the different cues. However, a larger percentage of participants showed resurgence longer when no cue was presented.

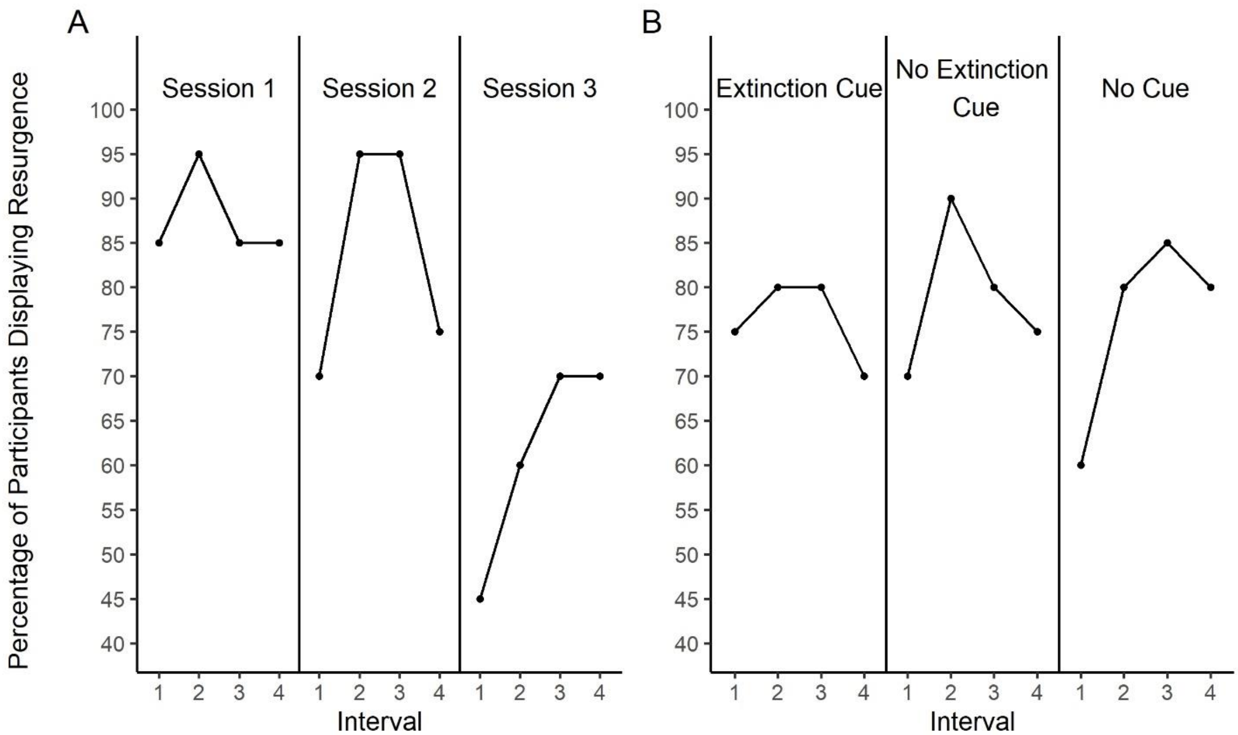

Figure 4

Percentage of Participants Displaying Resurgence in Phase 3

Note. Panel A depicts the percentage of participants displaying resurgence throughout each session of Phase 3. Panel B depicts the percentage of participants displaying resurgence across each cue in Phase 3.

Reinforcement Rate

Reinforcement rates per minute across Phases 1 and 2 are summarized in Table 3 below. Reinforcer delivery did not change as a function of session (F]3, 72] = 1.1, p . 05) or cue (F[1, 72] = 1.2, p > .05) indicating that the VI schedule was sufficient to control reinforcement rate.

Table 3

Means and Standard Deviations of Reinforcement Rates

	NO-EXT	T-EXT	Total
Phase 1			23.93 (3.21)
Phase 2			
Session 1	24 (2.45)	19.66 (3.53)	21.83 (3.70)
Session 2	23.39 (6.59)	20.48 (2.53)	21.93 (5.08)
Session 3	22.27 (5.10)	25.9 (3.07)	24.08 (4.50)
Session 4	21.41 (4.04)	22.4 (5.89)	21.90 (4.94)

Phase 2 Duration

The average number of bins in each session of Phase 2 was 5.84 (SD = 3.02). The number of bins was not significantly different across sessions ($F[3, 76] = 1.99$, $p > .05$) or cue ($F[1, 78] = 3.17$, $p > .05$). The variation in Phase 2 length did not result in unequal time spent in Phase 2 or in the presence of one cue.

Discussion

This research was primarily designed to replicate non-human animal findings pertaining to mitigating resurgence via the use of a cue in humans in order to clarify the effectiveness and underlying mechanisms of such an approach. The obtained findings indicate that a cue did not operate the same way in humans as with animals. Previous findings with rats demonstrated that a cue paired with target behavior extinction and alternative reinforcement was effective at mitigating resurgence while cues only paired with alternative reinforcement were not (Trask, 2019). This study was unable to replicate those findings. Although resurgence was successfully induced, cues were ineffective at consistently mitigating that resurgence in humans whether they were paired with target behavior extinction or not. Specifically, cues were found to evoke resurgence (regardless of pairing with extinction of target responding) in early tests of resurgence, but by the final test of resurgence, that relationship had reversed and resurgence was mitigated by cues.

There are several potential reasons for these discrepant findings. It may be that crowdsourced human behavior data is of less quality than a laboratory sample. In some cases, crowdsourced samples have been found to be equivalent to laboratory samples (Kees et al., 2017; Lee et al., 2018). However, there has been some concern that the quality of crowdsourced data has been decreasing in recent years (Chmielewski & Kucker, 2019). The recommended guidelines for collecting high-quality crowdsourced data were followed in this study, and data was screened for careless or random responding. No data met exclusion criteria indicating that all participants were engaged and responding to the experimental task. Still, participants may have been distracted or confused by the task and future work should evaluate the effect of cues on resurgence with greater control in the laboratory.

The experiment conducted here was also rather brief with most participants completing the full task in under 15 minutes. This differs from the previous study in which rats were exposed to the contingencies in effect across several days (e.g., Trask, 2019). This may be important as resurgence is known to be impacted by the durations of Phases 1 and 2 in the three-phase resurgence paradigm. In general, a longer Phase 1 results in greater resurgence (Winterbauer et al., 2013), and a longer Phase 2 may result in less resurgence (Leitenberg et al., 1975). In particular, comparisons between target responding at the end of Phases 1 and 2 provide some evidence that the target behavior may have not been fully acquired by all participants in this study. Additionally, the length of Phase 2, though allowed to vary across participants to ensure target extinction, did not differ greatly from Phase 1. It may be Phase 2 was too short for the cues to be adequately paired with alternative reinforcement and/or target extinction. Furthermore, in a clinical setting, behaviors that are at risk of resurging are likely to have a much longer history of reinforcement that presented here. Future research would benefit from longer controlled studies in order to isolate the effects of reinforcement history on resurgence.

Another important methodological consideration in this study is the exposure to repeated extinction tests in Phase 3. Repeated extinction tests have been shown to result in decreased resurgence across tests in some cases (Fuhrman et al., 2016; Kestner et al., 2018; Hoffman & Falcomata, 2014; Podlesnik et al., 2020) but in others repeated testing resulted in increased magnitude of resurgence (Redner et al., 2022) or no decrease (Cleland et al., 2000; Cook & Lattal, 2019; DaSilva et al., 2008; Doughty et al., 2007; Garner et al., 2018; Lieving & Lattal, 2003; Volkert et al., 2009). In this study, there was a decrease in resurgence in the final of three resurgence tests. Additionally, this decrease seemed to interact with whether a cue was presented or not such that resurgence was not present when a cue was absent in the final test. This appears to be in contrast to previous studies that found that resurgence was greatest in the presence of no cue (Trask, 2019). It may be that discriminations between the two cues were overshadowed by discriminations between the presence and absence of a cue. That is, the alternative behavior was never reinforced in the presence of a cue such that in testing, the absence of the cue more quickly indicated extinction given that there was no history of reinforcement in that context. It may also be that the mitigating effects of the two cues were hidden by a decrease in resurgence across tests. The order of the testing conditions was counterbalanced to account for this. Still, future work may benefit from using a research design that allows for time between testing or that only tests each participant once to isolate the effects of each type of cue.

Rule-governed behavior may also play a large, and relatively unexplored role in resurgence and its mitigation in humans. Rule-governed behavior may be susceptible to resurgence just as behavior learned through contact with natural contingencies. Dixon and Hayes (1998) explored this in a study with undergraduates. Participants were put into different groups that differed in the type and level of instructions they received. Participants then learned to move a dot on the screen in different patterns under a multiple schedule. When the schedule was then switched to an extinction condition, it was found that participants who received specific or general instructions showed resurgence of the rule-governed behavior they learned, whereas those who received minimal instructions engaged in the most recently reinforced response.

In this study, participants were given relatively little instruction on how to engage with the task. They were simply asked to click buttons with the hope that they would respond to the natural contingencies. However, it is possible that the lack of instruction resulted in participants creating their own rules around the stimuli and consequences built into the task. This was not directly evaluated, but anecdotal evidence from the post-experiment survey supports this notion. Participants were asked what strategy they used in the task and whether that strategy changed throughout the task. Several participants reported strategies or self-directed rules relating to various stimuli and response dimensions within the task. For example, one participant reported clicking first the black square, then the black circle, then clicking randomly until they received points. Another participant reported focusing on the timing of their clicks stating that they counted down in their head between clicks. It may be that these self-directed rules created an insensitivity to the contingencies in place as has been demonstrated with other behavioral phenomena (Hayes et al., 1986; Matthews et al., 1985).

Despite the aforementioned limitations, visual inspection of the data of each individual participant revealed that for a quarter of the sample, the cue paired with target extinction did mitigate resurgence in comparison to the absence of a cue and the cue unpaired with extinction. While no strong conclusions about the effectiveness of a cue paired with target extinction can be drawn from the data presented here, the responding of this subset of participants may indicate that future exploration of the question under more controlled conditions is warranted.

Understanding the mechanisms underlying resurgence in laboratory settings may be helpful in treating relapse in naturalistic settings, especially as it allows for the study of the variables without the risk of harm to the clinical populations whom it stands to benefit (Kestner & Peterson, 2017). This study solidifies this importance as it has demonstrated that a cue paired with target extinction may not effectively mitigate resurgence in human as it does with animals. This is not the first human operant study to fail to replicate non-human animal findings in resurgence (see Bolivar et al., 2017; Cox et al., 2019; Saini et al., 2021; Sweeney & Shahan, 2016). This study does, however, underscore the importance of continued human-laboratory research to identify the differing variables and contexts under which relapse occurs in humans.

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Appendix A

Informed Consent and HSIRB Approval Letter

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: March 22, 2022

To: Anthony DeFulio, Principal Investigator
[Co-PI], Co-Principal Investigator

Re: Initial - IRB-2022-110
Evaluation of a Cue Associated with Alternative Reinforcement to Mitigate Resurgence

This letter will serve as confirmation that your research project titled "Evaluation of a Cue Associated with Alternative Reinforcement to Mitigate Resurgence" has been reviewed by the Western Michigan University Institutional Review Board (WMU IRB) and **approved** under the **Expedited** 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The conditions and duration of this approval are specified in the policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes to this project (e.g., ***add an investigator, increase number of subjects beyond the number stated in your application, etc.***). Failure to obtain approval for changes will result in a protocol deviation.

In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB or the Associate Director Research for consultation.

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

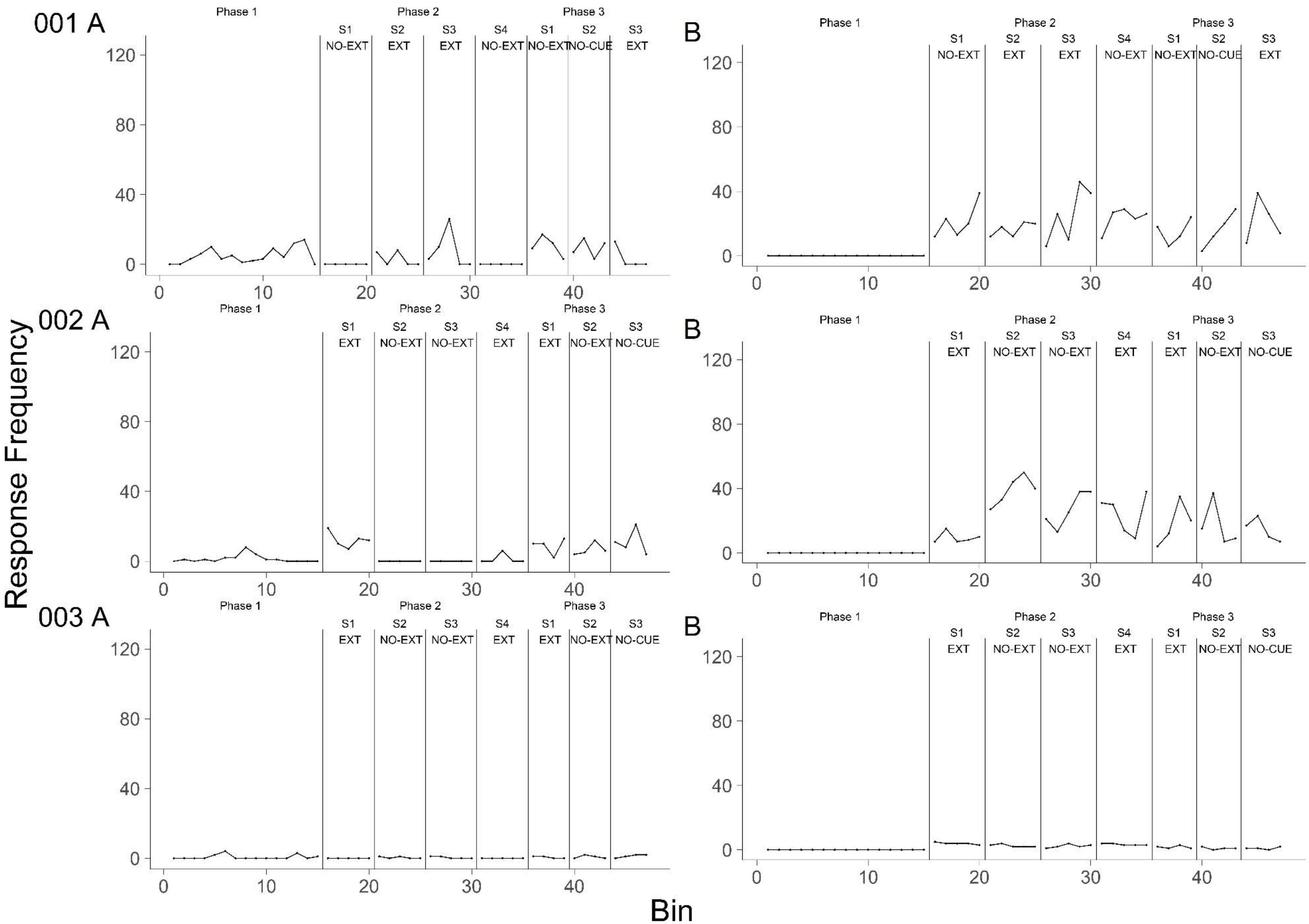
Sincerely,

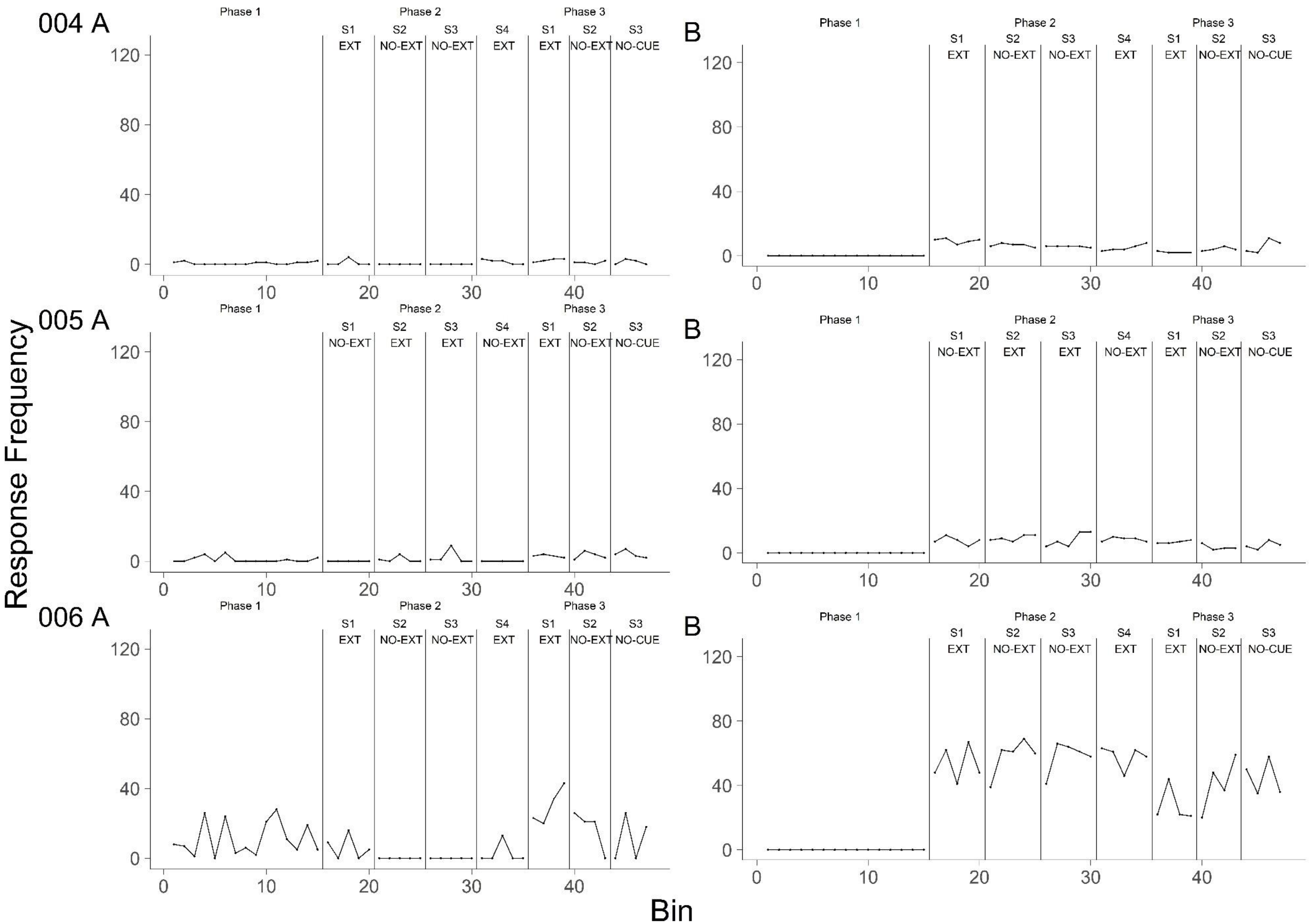
Amy Naugle

Amy Naugle, Ph.D., Chair
WMU IRB

Appendix B

Response Frequency for Each Participant


001 A
002 A
003 A
B
Phase 1
Phase 2
Phase 3
S1
S2
S3
S4
NO-EXT
EXT
NO-CUE
Response Frequency
Bin
0
40
80
120
0
10
20
30
40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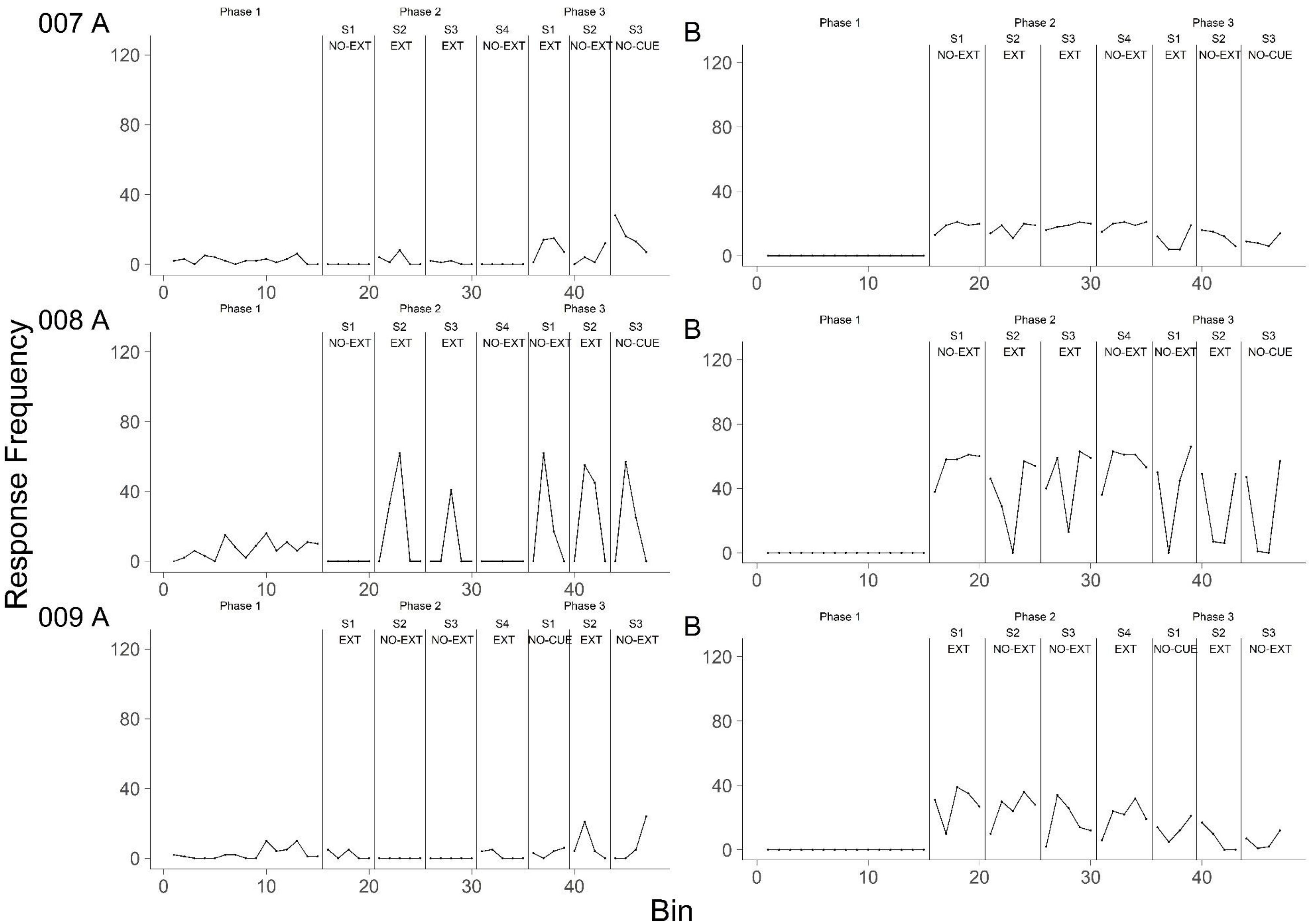
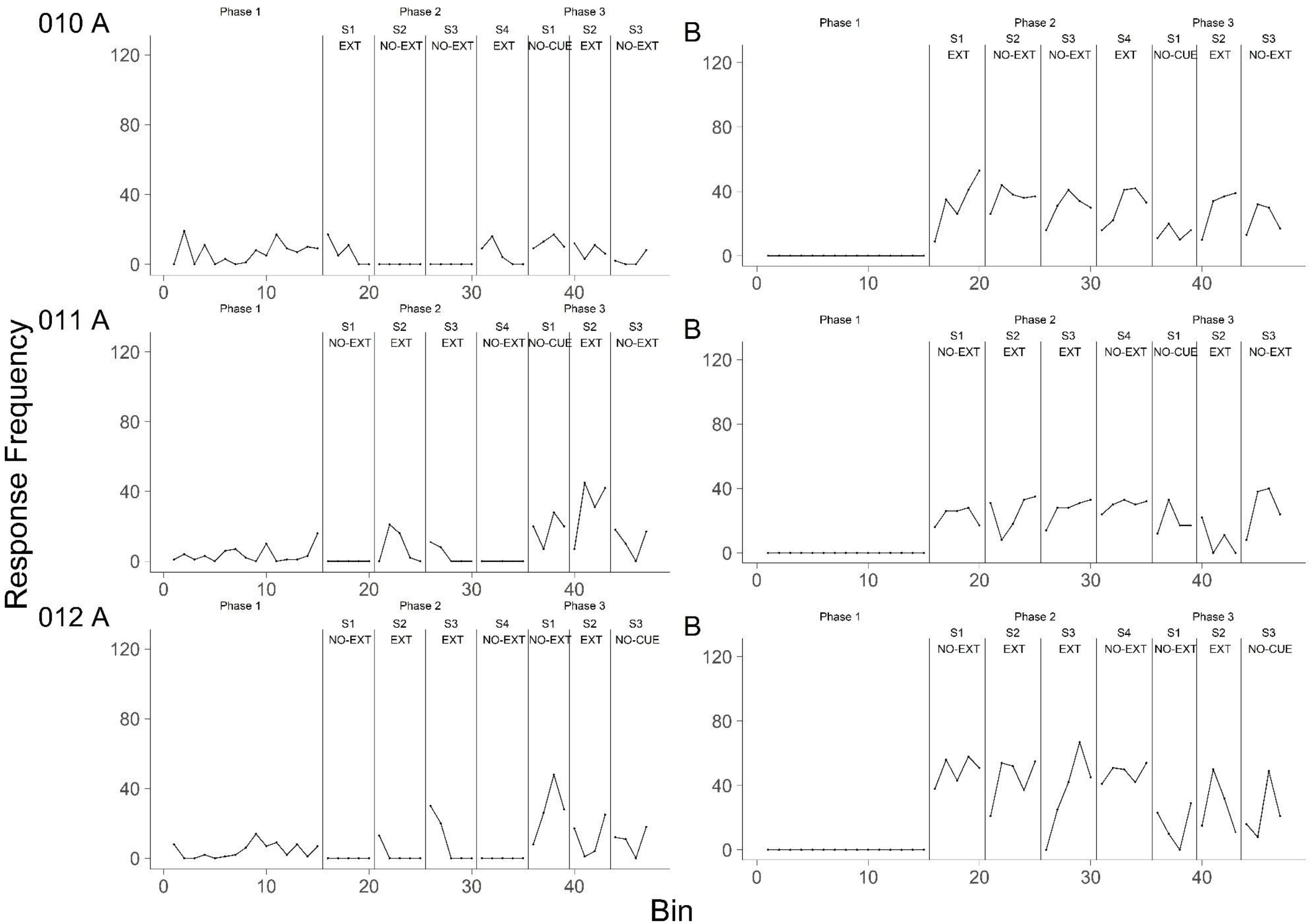
005 A
006 A
B
Phase 1
Phase 2
Phase 3
S1
S2
S3
S4
EXT
NO-EXT
NO-CUE
Response Frequency
Bin
0
10
20
30
40
80
120



007 A
Phase 1
Phase 2
Phase 3
S1 NO-EXT
S2 EXT
S3 EXT
S4 NO-EXT
S1 EXT
S2 NO-EXT
S3 NO-CUE
B
008 A
S1 NO-EXT
S2 EXT
S3 EXT
S4 NO-EXT
S1 NO-EXT
S2 EXT
S3 NO-CUE
009 A
S1 EXT
S2 NO-EXT
S3 NO-EXT
S4 EXT
S1 NO-CUE
S2 EXT
S3 NO-EXT
0
40
80
120
0
10
20
30
40
Response Frequency
Bin


010 A
011 A
012 A
B
Phase 1
Phase 2
Phase 3
S1 EXT
S2 NO-EXT
S3 NO-EXT
S4 EXT
S1 NO-CUE
S2 EXT
S3 NO-EXT
S1 NO-EXT
S2 EXT
S3 EXT
S4 NO-EXT
S1 NO-CUE
S2 EXT
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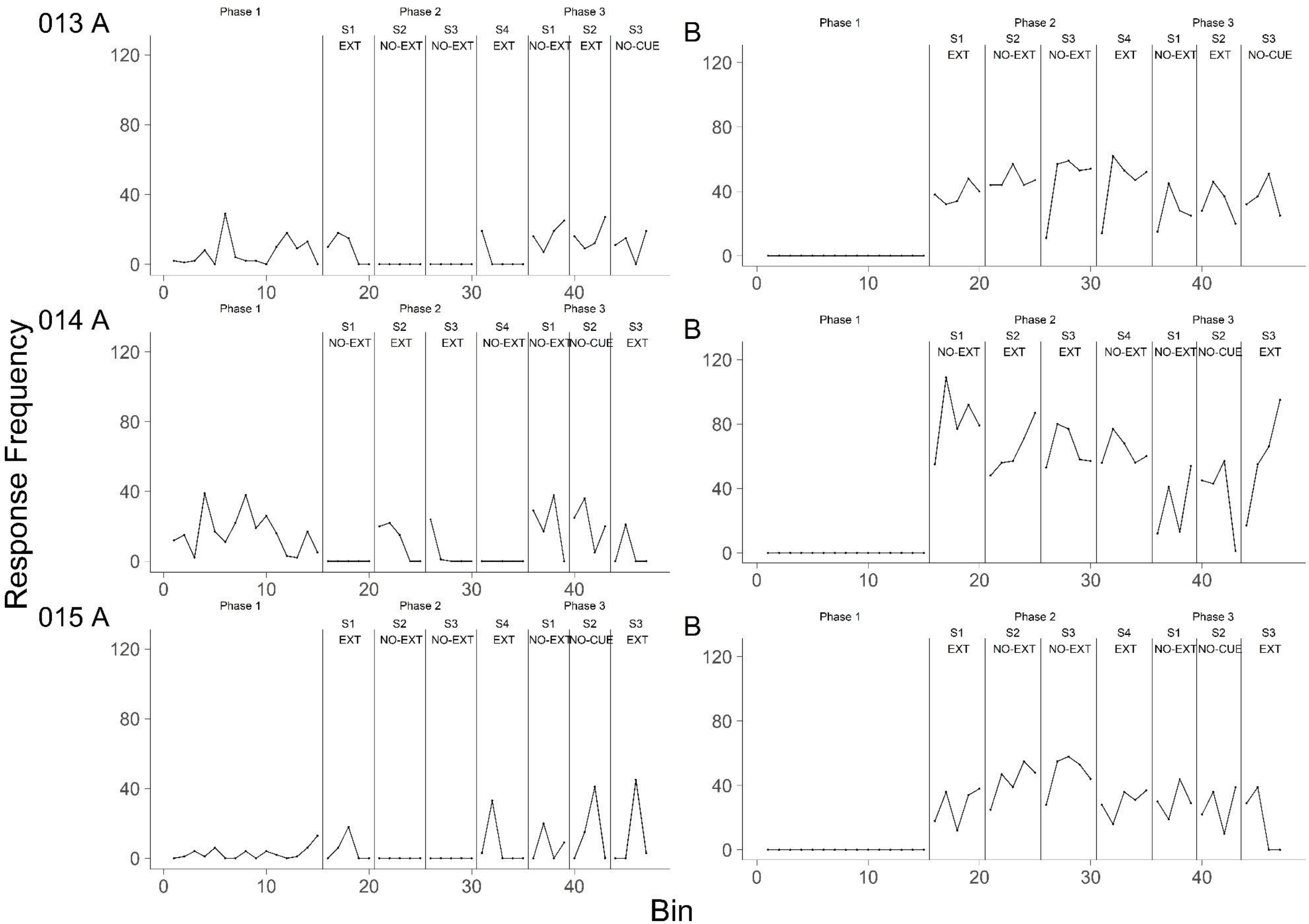
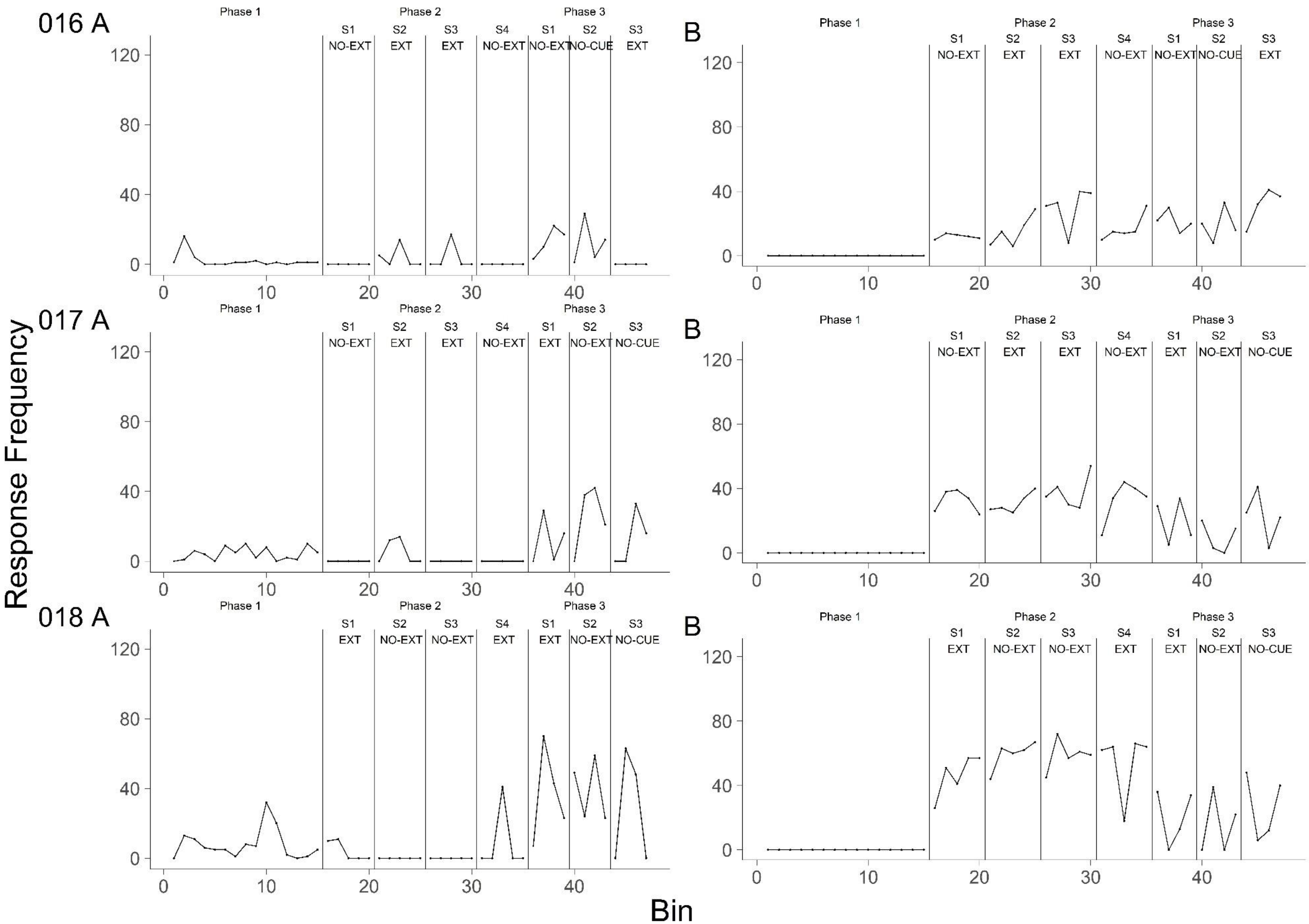
S3 NO-CUE
Response Frequency
Bin


013 A
Phase 1
Phase 2
Phase 3
S1 EXT
S2 NO-EXT
S3 NO-EXT
S4 EXT
S1 NO-EXT
S2 EXT
S3 NO-CUE
B
014 A
S1 NO-EXT
S2 EXT
S3 EXT
S4 NO-EXT
S1 NO-EXT
S2 NO-CUE
S3 EXT
015 A
S1 EXT
S2 NO-EXT
S3 NO-EXT
S4 EXT
S1 NO-EXT
S2 NO-CUE
S3 EXT
Response Frequency
Bin


016 A
017 A
018 A
B
Phase 1
Phase 2
Phase 3
S1 NO-EXT
S2 EXT
S3 EXT
S4 NO-EXT
S1 NO-EXT
S2 NO-CUE
S3 EXT
S1 NO-EXT
S2 EXT
S3 EXT
S4 NO-EXT
S1 EXT
S2 NO-EXT
S3 NO-CUE
S1 EXT
S2 NO-EXT
S3 NO-EXT
S4 EXT
S1 EXT
S2 NO-EXT
S3 NO-CUE
Response Frequency
Bin

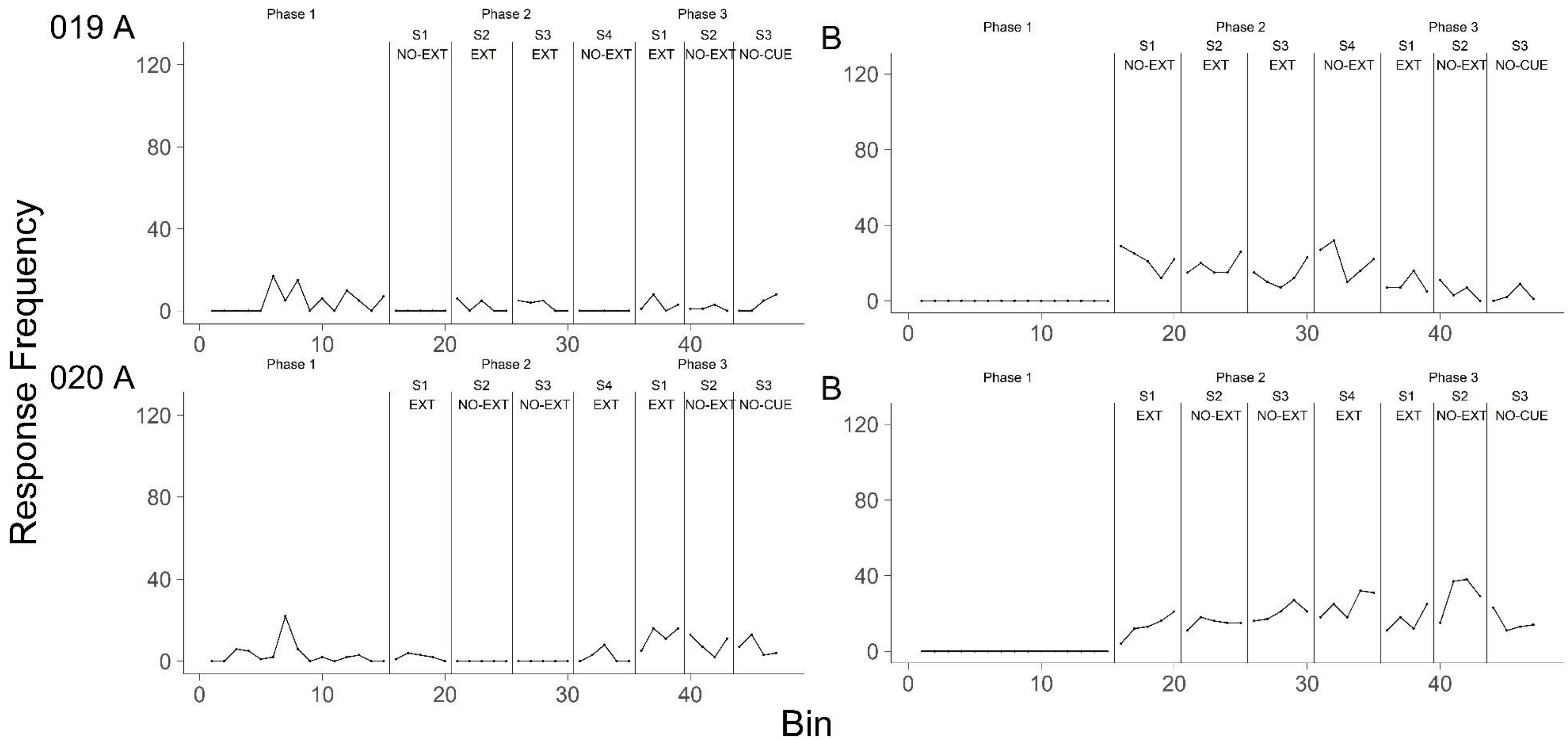


Figure A1

Response Frequency of Each Participant

Note. The number in the top left of figure denotes each participant. Panel A depicts target responding frequency. Panel B depicts alternative responding frequency.