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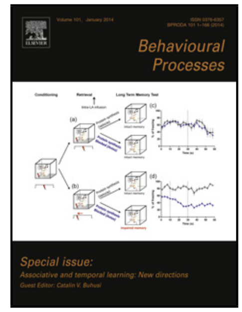

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Evaluating Resurgence Procedures in a Human Operant Laboratory

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Abstract

Resurgence of previously extinguished behavior may occur when a recently reinforced alternative response is placed on extinction. Understanding the conditions that produce and reduce resurgence is important for both basic and applied researchers. Research on resurgence of human behavior may benefit from methods that facilitate comparison and replication of nonhuman animal studies. These studies often include an inactive control response to differentiate resurgence from extinction-induced variability. In contrast, human research typically does not. Sweeney and Shahan (2016) tested a brief, trial-based procedure that included an inactive control response with human participants, but they did not observe resurgence. The current study extended their methods by examining four different conditions in a free-operant task lasting < 1 hr. Modifications across conditions included changing the number of response options available in each phase and how signals associated with each response were presented. Only one condition resulted in responding resembling resurgence. Our results suggest the utility of the inactive control response and the influence of contextual cues in human research should be investigated further.

Keywords: human; free operant; operant conditioning; relapse; resurgence

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1. Introduction

The reoccurrence of previously extinguished behavior is a phenomenon of both basic and applied importance. Basic researchers seek to understand the underlying processes that contribute to the reemergence of a response that has stopped occurring. For applied researchers, successful treatment outcomes may be undone if potentially dangerous problem behavior reoccurs. Parsing out the variables that influence the reemergence of extinguished behavior provides researchers with a more robust understanding of reinforcement history effects on current behavior. Better understanding of controlling variables may subsequently lead to the development and refinement of clinical methods to reduce or prevent reemergence of extinguished problem behavior.

One form of reemergence, resurgence, has received significant interest in behavioral research. Resurgence can be defined as the reoccurrence of previously extinguished behavior when reinforcement for an alternative response is withheld (Epstein, 1983). Stated differently, a behavior that was previously reinforced and subsequently extinguished may reoccur if a recently reinforced alternative behavior no longer contacts reinforcement. For example, reinforcers for an adaptive alternative behavior may not be delivered when a client leaves the treatment environment. This may result in a return to a previously extinguished problem behavior.

Laboratory methods for studying resurgence are most often conducted in three phases. In Phase I, a target response is shaped and reinforced. In Phase II, reinforcement is withheld for the target response and provided contingent upon an alternative response. In Phase III, reinforcement is withheld for both responses (see Doughty & Oken, 2008 and Lattal & St. Peter Pipkin, 2009 for reviews). This final phase is called the “resurgence test.” Consider the following example: In Phase I, a pigeon receives 3-s access to grain for pecking on key A which leads to an increase in pecks on that key. In Phase II, pecking on key A no longer results in reinforcement (i.e., key A

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pecks are extinguished). Instead, the pigeon must peck on key B to receive grain. Pecking on key A subsequently decreases and pecks on key B increase. In Phase III, pecks on both keys are placed on extinction. Resurgence is indicated by an increase in rates of pecking key A from the end of Phase II to the beginning of Phase III.

In the preceding scenario, only two responses are available to the pigeon throughout the experiment. Although the use of just two responses is common to many studies of resurgence (e.g., Schepers & Bouton, 2015; Winterbauer & Bouton, 2010; Winterbauer et al., 2013), researchers have also varied the number of responses available to the organism. For example, other studies have included a third, inactive control response that is available throughout the entire experiment but is never reinforced (e.g., Craig and Shahan, 2016; Sweeney & Shahan, 2013a,b; Sweeney and Shahan, 2016). Including a control response may provide a measure of extinction-induced variability (Doughty & Oken, 2008; Epstein, 1983). Under this arrangement, resurgence is identified by exclusive or higher levels of responding on the previously extinguished target response relative to the control response. In contrast, extinction-induced variable responding is identified if the organism emits levels of control responding in the third phase that are higher than previous phases and undifferentiated from target responding. Thus, rates of control responding in the third phase can help distinguish extinction-induced variability from resurgence (i.e., response recovery; Doughty & Oken, 2008, Sweeney & Shahan, 2016).

Laboratory studies with nonhuman animals in the basic literature have examined the influence of several variables on resurgence including rates of alternative reinforcement, duration of target response extinction, and reinforcer type. With respect to rates of alternative reinforcement, several studies have shown that lean or thinned schedules of reinforcement in Phase II are less effective at suppressing the target response but can reduce resurgence in Phase

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III (e.g., Craig et al., 2016; Craig & Shahan, 2016; Leitenberg et al., 1975, Exp 3; Sweeney & Shahan, 2013b; Winterbauer & Bouton, 2012; cf. Winterbauer & Bouton, 2010). Researchers have also studied the influence of Phase II duration (i.e., how long the target response contacts extinction). For example, Leitenberg et al. (1975, Exp 4) found that longer Phase II durations reduced resurgence, whereas Winterbauer et al. (2013, Exp 2) did not. Further, Schepers and Bouton (2015, Exp 3) observed reduced resurgence following repeated exposure to extinction, whereas Sweeney and Shahan (2013a) did not. Finally, resurgence also occurs when the target and alternative responses are maintained by different reinforcers (e.g., cocaine versus sucrose; Craig et al., 2016; Podlesnik et al., 2006; Winterbauer et al., 2013, Exp 3).

Contrary to the wealth of research on resurgence using nonhuman animals, research on resurgence with humans is scant but remains important for several reasons. For example, replicating and extending nonhuman animal literature demonstrates the generality of resurgence to humans. Additionally, resurgence procedures using humans will show the extent to which the same variables that influence resurgence in nonhuman animals influence responding in humans. Such research may lead to new insights that inform additional investigations of how resurgence can be reduced in clinical populations.

Although comparatively small, resurgence research with humans is a growing body of literature that has examined the phenomenon under a variety of conditions (Kestner & Peterson, 2016). For example, researchers have demonstrated that resurgence will occur with humans when two response options are available and reinforced on interval or ratio schedules, providing initial evidence for generality of the phenomenon (e.g., Kuroda et al., 2016; Marstellar & St. Peter, 2012; Romano & St. Peter, 2016). In addition, King and Hayes (2016) found that contexts associated with reinforcement influenced the reoccurrence of behavior in a procedure where

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three responses were reinforced in the presence of different colored screens. The resurgence test re-presented one of those colors, and the response reinforced in the context of that color was the most likely of the three responses to reoccur. Finally, a translational study by Lambert et al. (2015) examined whether training multiple alternative behaviors would reduce resurgence of an arbitrary response in adults with developmental disabilities. Resurgence was greatly mitigated in the component where multiple alternatives were trained but occurred as expected in the component where only one alternative was trained. This study provides preliminary evidence for one promising way to reduce resurgence with humans.

Notably, one recent study did not observe resurgence with human participants. Sweeney and Shahan (2016) examined resurgence during brief discrete trial procedures that included a third control response. In each phase, participants chose one of three shapes and earned points based on the contingencies in effect for each phase (i.e., points were awarded for selecting the target shape in Phase I, the alternative shape in Phase II, and points were never awarded for selecting the control shape). Across seven conditions, the authors manipulated the number of trials presented in Phase I and the probability of reinforcement for the target and alternative responses in Phases I and II. Resurgence (i.e., target responding that was "readily distinguishable" from control responding) did not occur. These results contrast with studies using nonhuman animals that do not show appreciable differences in control responding across phases when a control response is present (e.g., Craig & Shahan, 2016; Sweeney & Shahan, 2013b). Thus, including a control response may clarify behavioral processes in these preparations for both human and nonhuman responding.

The current study used the exploratory framework exemplified by Sweeney and Shahan (2016) to assess a computer-based free operant procedure that participants could complete in one

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session lasting less than 1 hr. We included a control response per their recommendations. However, we used a free operant arrangement instead of discrete trials to more closely replicate methods used in nonhuman animal research. Rather than manipulate the duration of Phase I or the probability of reinforcement in Phases I and II (Sweeney & Shahan, 2016), we sought to determine if changing the number of response options and signals in each phase would result in resurgence with human participants. We predicted that changing the number of response options and signals would influence resurgence based on previous research suggesting that context influences this phenomenon (e.g., King & Hayes, 2016). We assessed whether changes to the number of response options or signals increased rates of target responding at the onset of Phase 3, relative to any increases in control responding.

2. Methods

2.1. Subjects. Twenty-five undergraduate college students (mean age = 19 yrs, SD = 1.8) attending a large university in the southeastern United States participated. Seventeen students identified as female, and seven identified as male. One participant did not provide demographic information. All were enrolled in an introductory psychology course and received course credit for their participation. Participants were assessed for color blindness prior to their participation as red and green stimuli were included throughout the experiment.

2.2. Apparatus. The experimental task was presented in a campus laboratory room on a desktop computer or laptop. Participants used a computer mouse to complete the experimental task and a computer keyboard to answer the reflection task. All conditions were coded using Visual Basic 2013 Community Edition. Code for the task can be found at the website: https://github.com/BHAT-RC/resurgence.

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2.3. Stimuli. Appendix A contains screenshots of the stimuli in each phase across all conditions. Target, alternative, and control "levers" were visible on the computer screen located approximately 4 cm below three colored circles (hereafter called "signals"). These signals were 1.7 cm in diameter and spaced 6.4 cm apart horizontally across the screen. The levers were grey and were always presented against a white background. Levers were 6 x 1.3 cm in perimeter and were spaced horizontally across the screen with 4 cm between the ends of the levers, approximately 10 cm from the middle of one lever to the middle of the next. Finally, text boxes were located in the upper right corner of the screen with the label "Bank," which displayed the points the participant had earned. Signal colors and the presence or absence of levers were manipulated across conditions to determine whether these variables influenced resurgence (described below).

2.3. Setting and Instructions. After completing the informed consent and a demographics form, participants were instructed to sit in front of the computer or laptop in a windowless laboratory room with dimensions of 9 x 6 x 6.5 ft. There was one overhead light, two chairs, and a locked filing cabinet. Participants were given general verbal instructions to attend to the more specific instructions on the computer screen that guided them through the task. After answering any of the participants' general questions, the research assistant loaded the task on the computer and left the room until the task was complete. Instructions on the screen were as follows: "You will see several images on the screen. Manipulating these images may or may not result in points. Please ask the research assistant if you have any questions about the experiment before it starts. When you are ready to begin, please click this box."

2.4. Experimental Task. The experimental task consisted of three phases. During each phase, participants made responses on virtual "levers." Participants clicked on the levers using

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the computer mouse. One response consisted of six consecutive clicks on a lever, which moved down the screen by 0.6 cm with each click. Responses consisted of multiple clicks as an attempt to require reasonable response effort and prevent rapid switching between levers. If a participant made a partial response on one lever then began to respond on a different lever, the initial lever would reset to its starting location on the screen. The levers would also reset to their starting locations when a complete response was made (i.e., after the sixth click). Each time a schedule requirement was met, an image appeared on the screen reading “+5 points” along with a button labeled “Collect Points.” Clicking this button resulted in points being added to the bank and re-presentation of the levers for continuation of the task (e.g., Catania et al., 1982; Shimoff et al., 1986).

Participants transitioned between phases if one of two criteria was met. The first criterion required stable responding across levers. Beginning 10 min into the first phase and 6 min into the second and third phases, the program divided responses over the previous 6 min into three, 2-min bins. Responses were defined as stable if the response rate over each of these three bins was less than a 15% deviation from the average of all three bins and the range of response rates was no greater than 6 responses. The second criterion was time-based. The programmed maximum duration for Phases I and II was 16 min, but participants could transition to the next phase before 16 min elapsed if the stability criterion was met. However, participants were automatically transitioned from Phase II to Phase III if stability in Phase II was not met within the duration of Phase I. In other words, Phase II was programmed to always cap at the duration of Phase I unless stability occurred. This was done to simulate clinical scenarios where the intervention phase is no longer than the time during which problem behavior is acquired and maintained. Participants remained in Phase III until they met the stability criterion or total time in the experimental task

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reached 48 minutes. At the end of a phase, a box appeared instructing the participant to wait while the next condition loaded, and a 20 s inter-phase interval began. Following this interval, participants had to click a button reading "Start Next Phase" to begin the next phase.

In the first phase, participants earned five points on VI-20 s schedule when they responded (i.e., clicked the target lever six times) on the target lever. Selecting the alternative or control lever did not result in points. In the second phase, participants earned five points on VI-10 s schedule when they responded on the alternative lever. All VI durations were sampled from 15 intervals calculated using the procedure described by Fleshler and Hoffman (1962). Programmed reinforcement rates changed in the second phase to simulate clinical situations that attempt to provide denser reinforcement for an appropriate alternative behavior. Selecting the target or control stimuli did not result in points. A changeover contingency was imposed on responding during these first two phases to prevent adventitiously reinforcing patterns of switching between the levers. The contingency involved withholding a scheduled reinforcer for one response if the participant had just switched from one lever to another. In the final phase, no points were awarded following responding on any lever (i.e., extinction).

Once the participant completed all three phases, a brief questionnaire appeared on the computer screen. These questions were taken from Sweeney and Shahan (2016). All questions were in free-response format (see Appendix B for question details).

2.5. Procedural modification. Similar to Sweeney and Shahan (2016), modifications were made when the data from at least 6 participants did not show resurgence of the target response in the absence of increased responding on the control response. Modifications to the procedure are outlined in the condition descriptions below. In general, each condition differed with respect to how responses and signals were presented across phases.

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2.5.1. "Sequential" Condition. This condition simulated a resurgence preparation that only presents the target and control response in the first phase and introduces the alternative response in the second phase (e.g., Sweeney & Shahan, 2015). In Phase I, the signal above the target lever was green and the signal above the control lever was grey. The alternative lever was not present on the screen, but its associated signal was present and was grey. In Phase II, the alternative lever became available and the signal changed to red. The target and control levers were present and the signals above them were the same as in Phase I. In Phase III, all levers and signals were the same as Phase II.

2.5.2. "All Signals" Condition. This condition was similar to the "Sequential" condition with the exception that the alternative signal was presented in Phase I. In order to test the effect of presenting the alternative response in Phase II, we held all signals constant across all phases in this condition. In Phase I, the signal above the target lever was green, and the signal above the control lever was grey. The alternative lever was not present on the screen, but its associated signal was present and was red. In Phase II, the conditions were identical to Phase I with the addition of the alternative lever. In Phase III, conditions were the same as Phase II.

2.5.3. "All Signals and Responses" Condition. This condition differed from the "Sequential" condition in that the alternative response and its signal were available throughout all three phases. This condition systematically replicated the procedure used by Sweeney and Shahan (2016), who presented all responses throughout all three phases. We sought to determine if resurgence would occur in a preparation similar to theirs but using free operant procedures. That is, in all phases, all signals remained the same (green, red, and grey for target, alternative, and control levers, respectively) and all levers were always available.

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2.5.4. "Target Signal" Condition. This condition was similar to the "Sequential" condition with the exception that the target signal changed from green to grey during Phase II and changed back to green in Phase III. The target lever, however, was never removed. We hypothesized that removing and re-presenting the green signal would evoke differentially elevated levels of target responding in Phase III because the green signal would not be paired with extinction in Phase II. In Phase I, the signal above the target lever was green, and the signal above the control lever was grey. The alternative lever was not present on the screen, but its associated signal was present and was grey. In Phase II, the alternative lever became available and its signal turned red. The target and control levers were still present, but the target signal switched from green to grey. In Phase III, all the levers were available, the target signal returned to green as in Phase I, and the alternative and control signals remained red and grey, respectively.

2.6. Statistical Analysis. All statistical tests reported below were considered significant at α level of 0.05. Statistical tests were conducted to examine the extent to which target and control responding differed from the end of Phase II and the onset of Phase III in each condition and the extent to which the control responding changed across phases in each condition. First, a one-way repeated measures ANOVA was used to compare target and control responding in the last 2-min bin of Phase II and first 2-min bin of Phase III. This analysis was completed for each condition separately. Second, a one-way repeated measures ANOVA was used to compare changes in control responding across the last 2-min bin of Phases I and II and the first 2-min bin of Phase III for each condition. Greenhouse-Geisser corrections were used for tests when the assumption of sphericity using Mauchly's test was violated. For significant ANOVAs, post-hoc tests using

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Bonferroni corrections were conducted to isolate differences between individual phases. All statistical tests were conducted using SPSS (IBM SPSS Statistics Version 24).

3. Results

3.1. Experimental Task. Table 1 presents the average time to complete the experimental task across conditions. Durations ranged from 33.0 min, SD = 4.3 in the "All Signals" condition to 40.6 min, SD = 9.1 in the "Target Signal" condition.

Figure 1 shows the average responses per minute across all conditions for the final bins of Phase I and II and the first bin of Phase III. On average, participant responding demonstrated control by the reinforcement contingencies in Phases I and II across all conditions. In Phase I, responding on the target lever was elevated compared to control and alternative lever responding. In Phase II, rates of target responding decreased from Phase I (this response was now on extinction) and alternative lever responding increased relative to responding on the target and control levers. Appendix C contains individual participant graphs.

Three of the four conditions failed to produce responding representative of resurgence. For the "Sequential" condition, a one-way repeated measures ANOVA indicated a significant difference between average target and control responding in the last bin of Phase II and the first bin in Phase III (F (3, 15) = 15.589, $p < .001$). Post hoc tests using a Bonferroni correction indicated there was a significant difference in target responding from Phase II to III ($t_{15} = 3.7328$, $p = .002$), but there was no significant difference between target and control responding in Phase III ($p = 1.00$). For the "All Signals" condition, a one-way repeated measures ANOVA with a Greenhouse-Geisser correction indicated there was a significant difference between average target and control responding in the last bin of Phase II and the first bin in Phase III (F (1.088, 5.441) = 6.728, $p = .043$). However, post hoc tests using a Bonferroni correction did not reach

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significance. In the "All Signals and Responses" condition, a one-way repeated measures ANOVA with a Greenhouse-Geisser correction indicated there was no significant difference between average target and control responding in the last bin of Phase II and the first bin in Phase III (F (1.044, 5.221) = 4.482, p = .085). In sum, none of these manipulations resulted in resurgence.

Responding in the "Target Signal" condition was most consistent with the results of nonhuman animal resurgence studies. A one-way repeated measures ANOVA indicated there was a significant difference between average target and control responding from the last bin of Phase II and the first bin in Phase III (F (3, 18) = 16.528, p < .001). Post hoc tests using a Bonferroni correction indicated a significant difference in target responding between Phases II and III (t_{18} = 2.2946, p = .034) and a significant difference in target and control responding in Phase III (t_{18} = 2.1544, p = .045). However, no difference in control responding was observed between Phases II and III (t_{18} = 1.9416, p = .068).

Separate one-way repeated measures ANOVAs were conducted to determine whether control responding significantly changed across the last bins of Phases I and II and the first bin of Phase III for each condition. A significant difference was observed in the "Sequential" condition only (F (2, 10) = 8.138, p = .007). Post hoc tests using a Bonferroni correction revealed a significant difference from Phase II to III only (t_{10} = 2.547, p = .029). There was no significant difference in control responding across the three remaining conditions.

Figure 2 shows individual participant target and control responding in the last bin of Phase II and the first bin of Phase III across all conditions. Although target response rates increased from Phase II to III, control response rates also increased to similar or higher levels for most participants in three of four conditions. Data for the "Target Signal" condition show a

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smaller relative increase in control responding. Visual analysis of these data corresponds with the statistics described above.

3.2. Reflection Task. Appendix B shows the set of questions asked to all participants following completion of Phase III. All participants provided a response to the question asking what they thought was the purpose of the study. Three main categories of responses emerged for this question. Many participants responded, “I don’t know” (n = 11). Four participants wrote it was to test whether participants could learn patterns, and four wrote it was to evaluate how points or rewards influenced responding. These results are similar to those found by Sweeney and Shahan (2016).

When describing how decisions were made during the task, most participants (n = 16) indicated looking for patterns and persisting with options that resulted in points (e.g., “I repeated the patterns that got me points. After I clicked around and recognized which patterns got me points I continued to repeat them.”). Three indicated that they were not sure and two indicated they would wait for some period before responding. Responses regarding overall strategy were similar to reports regarding decision-making. Approximately half of the participants (n = 12) indicated that their strategies did not change during the task. Others responded that they chose according to “new” shapes (i.e., responses options) or colors incorporated into subsequent phases (n = 5).

4. Discussion

The current study sought to investigate resurgence in a brief human free-operant procedure. We modified each condition after responding for at least 6 participants did not result in resurgence. Modifications included varying how many responses were available in each phase and how signals for each response were presented. Only the “Target Signal” condition resulted in

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responding that most closely demonstrated resurgence when resurgence is defined as an increase in target responding at the onset of Phase III that exceeds control responding. This condition changed the target signal color from green to grey in Phase II and back to green in Phase III.

Although the “Target Signal” condition resulted in response patterns resembling resurgence, changing the signal associated with the target response in Phase II (i.e., from green to grey) is not typical in the resurgence literature. Due to the establishment of stimulus control in Phase I, it may be expected that participants reallocate responding to the target lever when that signal was re-presented in Phase III. Additionally, these participants were given additional exposure to the grey signal as a signal for non-reinforcement because responding on any lever associated with a grey signal did not produce points in Phases I or II. Participants with this history of reinforcement may be less likely to respond on a lever associated with a grey signal (i.e., the control response) at the onset of Phase III. In other conditions, the target signal color was held constant, which provided participants with a history of extinction with that color prior to Phase III. These data and those reported by King and Hayes (2016) both indicate that re-presenting stimuli associated only with reinforcement for a target response impacts resurgence of that behavior.

In the three remaining conditions, rates of control responding were the same or greater than rates of target responding at the onset of Phase III. It is possible that the history of reinforcement with one lever in Phase I and a second in Phase II resulted in participants responding on the third lever that had not yet been reinforced in Phase III (i.e., the control). That is, generalization to the untrained control response may have occurred because of the reinforcement history across Phases I and II wherein similar behaviors were directly reinforced (Stokes & Baer, 1977). When the control response was not reinforced, participants might have

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then responded across all levers. This would produce data consistent with extinction-induced variability at the onset of Phase III. Nevertheless, the results of these conditions converge with other studies of resurgence with humans that observed variable behavior in Phase III (e.g., King & Hayes, 2016; Sweeney & Shahan, 2016).

The results of the “All Signals and Responses” condition indicate that constant stimulus conditions across phases may inhibit control by the reinforcement contingencies in human operant settings. Half of the participants’ data in this condition showed variable responding across levers, which meant these participants rarely contacted reinforcement due to the changeover contingency (see Appendix C). Failure to contact reinforcement and the absence of changes across phases likely affected these participants’ behavior. In Sweeney and Shahan (2016), all three responses were available in every trial of each phase, and resurgence was not observed. However, target and alternative responding appeared to be under control of the relative reinforcement contingencies by the end of Phases I and II in their study. Previous human laboratory research using free-operant methods to study resurgence has included two responses (e.g., Kuroda et al., 2016; Marstellar & St. Peter, 2012) and target and alternative responding also appeared to be under control of the relative reinforcement contingencies in Phases I and II. Marstellar and St. Peter (2012) presented both responses in each phase but did not present any schedule-correlated stimuli across phases, whereas the alternative response was not available until Phase II in Kuroda et al. (2016). Thus, an important area of future research is to determine methods that promote efficient target and alternative responding in free-operant arrangements that include a control response in each phase. This research will provide a critical next step towards further closing the gap between methods used in nonhuman versus human laboratory contexts.

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Overall, contextual changes across phases were critical to observing resurgence in our study. Trask et al. (2015) discuss the context hypothesis of resurgence, which describes resurgence as akin to another type of behavioral recurrence phenomenon called renewal. More specifically, ABC renewal is the reemergence of a response that has been reinforced in context A, extinguished in context B, and re-tested under extinction in context C (Winterbauer & Bouton, 2010). In the resurgence preparation, contextual changes occur in each phase when the reinforcement contingencies shift from target reinforcement (i.e., context A) to alternative reinforcement (i.e., context B) to extinction (i.e., context C). Resurgence is therefore similar to ABC renewal from this perspective (but see Shahan & Craig, 2016, for a recent criticism of this perspective). The current study included reinforcement shifts and signal changes, which provided additional contextual cues. The presence or absence of these signals was particularly influential, as data representative of resurgence did not emerge until the target signal changed across phases. The results of the "Target Signal" condition may also be interpreted as an instance of ABA renewal with respect to the target response because its signal shifted from green (Phase I) to grey (Phase II) to green (Phase III) across the three phases. The results of research examining procedures that combine resurgence and renewal paradigms have been mixed (e.g., Kincaid et al., 2015; Podlesnik & Kelley, 2014; Sweeney & Shahan, 2015), and procedural differences make comparisons difficult. Nevertheless, our results appear to lend support to the importance of contextual changes on resurgence. However, additional research examining these variables is needed.

Some limitations of the current procedure are worth noting. First, only one condition produced responding resembling resurgence, and this condition may be too dissimilar from common nonhuman preparations to be a generally useful model for human resurgence research.

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Second, the duration of each phase varied across participants. Previous research has fixed the duration of each phase across participants. This difference could be important as, for example, the duration of Phase II has been shown to affect resurgence in nonhuman animals (e.g., Leitenberg et al., 1975, Exp 4; Schepers & Bouton, 2015; cf. Sweeney & Shahan, 2013a; Winterbauer et al. 2013, Exp 2). Relatedly, some participants made few or no target responses during Phase II, thus minimally contacting the extinction contingency. Exposure to this contingency may be an influential variable, and such limited contact is not typically observed in the nonhuman animal research. Leitenberg and colleagues (e.g., Leitenberg et al., 1975; Rawson et al., 1977) suggested that alternative reinforcement in Phase II suppresses the target response and prevents it from contacting the extinction contingency. Thus, when alternative reinforcement is discontinued in Phase III, the target response reoccurs. However, later studies (e.g., Winterbauer & Bouton, 2010, 2012) have not observed a relation between the rate of target responding in Phase II and resurgence. Nevertheless, these discrepancies and limitations may reduce the acceptability of our procedure as a model for studying resurgence in humans.

These results, taken in concert with Sweeney and Shahan (2016), highlight the difficulty of translating nonhuman basic research procedures to humans. One important consideration is whether the variables that influence resurgence in nonhuman animals also influence resurgence in humans. Several procedural differences between human and nonhuman animal studies may result in differences in responding on the control response. In nonhuman work, reinforcement history is highly controlled and presumably influences responding to a greater extent than in human resurgence work. Motivation for the reinforcers commonly available in nonhuman animal research (e.g., grain) is also more highly controlled by, for example, maintaining the subjects at 80% of their free-feeding body weight (e.g., Winterbauer & Bouton, 2012). Conversely,

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controlling college students' motivation for arbitrary computer points is more difficult. Delivering points that are exchangeable for other reinforcers (e.g., money; Kuroda et al., 2016) could increase the motivation for points and perhaps evoke more efficient responding. However, it is notable that participants in the current study responded to earn just computer points and most demonstrated responding controlled by the reinforcement contingencies despite the fact that points were not exchangeable for any other reinforcer. Other variables, such as verbal repertoire and extra-experimental histories, also likely influence human responding in addition to within-session reinforcement histories (Baron, Perone, & Galizio, 1991). Future research using human participants should explore ways to control for these important variables.

Another methodological consideration when translating from nonhuman to human participants is the practical relevance of the results. For example, the control response provides important theoretical distinctions between resurgence and extinction-induced variability. However, from a clinical perspective, it may be less important to make such a distinction if an undesirable target response reemerges in conjunction with other behavior (see also Romano & St. Peter, 2016). Stated differently, the presence of response variability does not necessarily reduce the clinical significance of observing a reemergence of the target response. Thus, any of these procedures could still prove useful toward brief assessment of interventions to prevent or reduce the reoccurrence of problem behavior.

There are many avenues for additional research in this area. For example, future research incorporating additional control and/or target responses could attempt to determine the conditions that differentiate response recovery and response novelty in humans. Another potential direction includes increasing the duration of the task to provide longer exposure to the reinforcement and extinction contingencies. That is, participants could come back into the

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laboratory setting over a number of days, rather than completing the study in one short visit (e.g., Kuroda et al., 2016). Additional exposure may produce resurgence in conditions where it did not emerge in the present study. Nonhuman animals typically receive training over several days in each phase, thereby providing a more extensive history of reinforcement for only target and alternative responses. This more extensive history may reduce the likelihood of observing increases in control responding. Further, as noted by Sweeney and Shahan (2016), the duration of the target reinforcement phase is an important variable that, although longer in our procedure, may have still been too brief. Lastly, in order to examine the influence of verbal repertoire, future research may wish to examine whether the same procedures here would produce similar results using individuals with different verbal repertoires (e.g., children).

6. Conclusion

We tested whether resurgence of free operant behavior would emerge across four conditions using a brief (< 1 hr) procedure with undergraduate students. Across conditions, we manipulated how signals and responses were presented across phases. Only one condition produced data resembling resurgence, however, this condition deviated from common resurgence preparations used in the nonhuman animal literature. Nevertheless, the current study provides future researchers with an additional framework for rapidly testing and refining operant procedures that examine questions of human behavioral recurrence. Future research should continue to refine and improve upon this brief resurgence procedure and develop other methods that simulate a variety of clinical scenarios. Ultimately, we believe these procedures will be useful tools for understanding resurgence processes more generally and for evaluating novel interventions to mitigate its occurrence.

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Table 1.
Mean time spent per phase, mean total time spent in the task, and mean total points per experimental condition

	Phase 1	Phase 2	Phase 3	Total
“Sequential”	13.7 (2.3)	8.3 (0.8)	14.0 (6.3)	36.0 (7.7)
“All Signals”	14.3 (2.0)	9.0 (2.1)	20.0 (7.7)	33.0 (4.3)
“All Signals and Responses”	14.0 (3.1)	8.0 (1.8)	16.3 (7.9)	38.3 (10.0)
“Target Signal”	12.6 (3.2)	8.0 (2.0)	20.0 (7.7)	40.6 (9.1)

Note: Time is in minutes. Standard deviations are in parentheses. N = 6 for the “Sequential,” “All Signals,” and “All Signals and Responses” conditions; n = 7 for the “Target Signal” condition. The maximum duration of the experimental task was 48 min.

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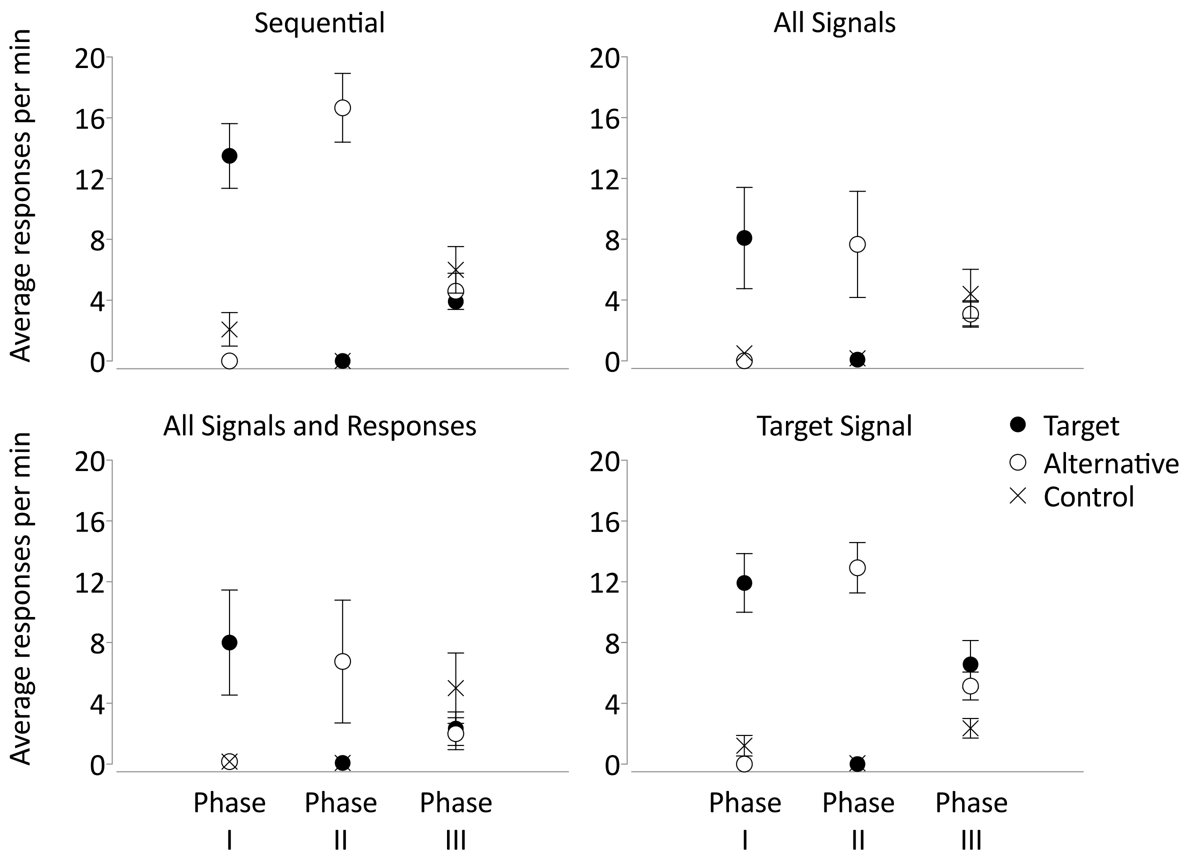

Figure 1. Average responding across the final bins in Phases I and II and the first bin in Phase III. Error bars represent standard error of the mean.

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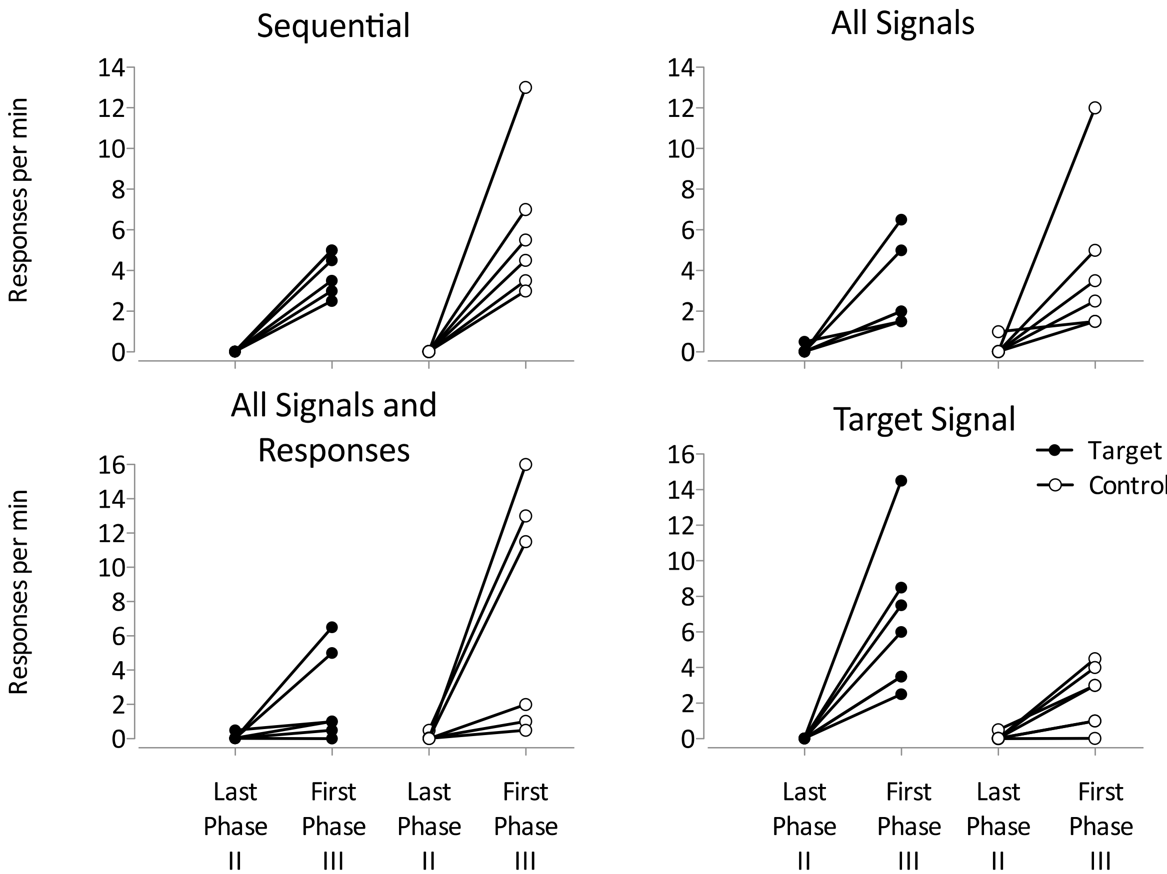

Figure 2. Individual participant rate of responding across the final session in Phase II and the first session in Phase III. Each data path represents one participant in each condition.

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Appendix A.

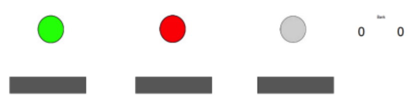
Stimulus presentations and response options across phases in each condition. Point banks for each phase were presented to the right of the levers and signals. Grey circles indicated the signal was not illuminated.

"Sequential"

Phase I

Phase II

Phase III



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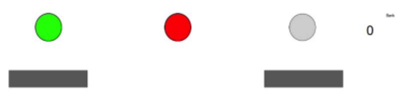
"All Signals"

Phase I



Phase II

Phase III

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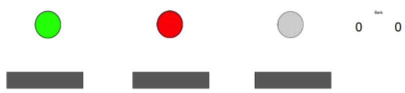
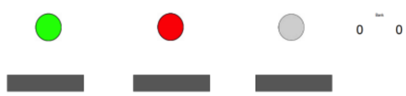
"All Signals and Responses"

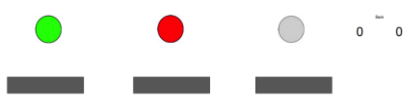
Phase I



Phase II



Phase III



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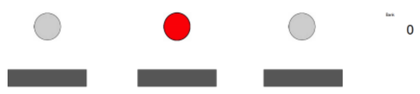
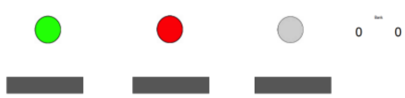
"Target Signal"

Phase I

Phase II



Phase III



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Appendix B.

Debriefing Questionnaire (Sweeney & Shahan, 2016):

What do you think was the purpose of the task you completed? If you do not know, please feel free to respond, “I don’t know.”
How did you make your decisions during the task? If you aren’t sure how you made your decisions, please say so.
Did you have an overall strategy that you used throughout the task? If so, what was that strategy? If not, please write, “I did not have a strategy.”
Did you change your strategy throughout the task? If so, how did it change? If not, please write, “I did not change my strategy.”
Please type any other information you would like to pass along.

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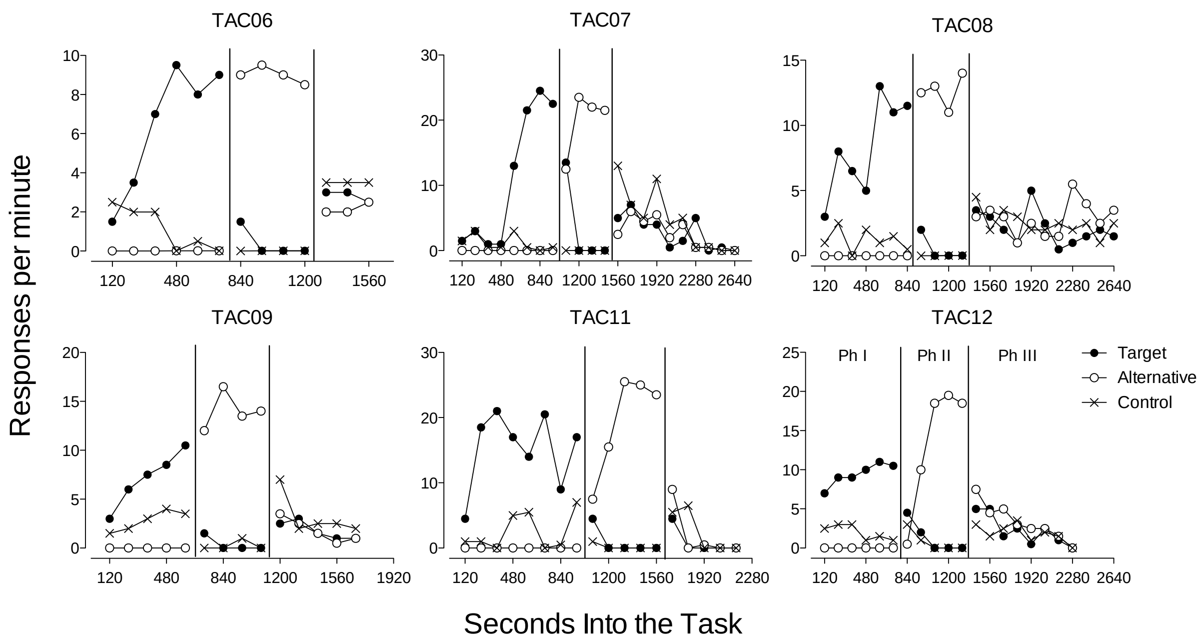
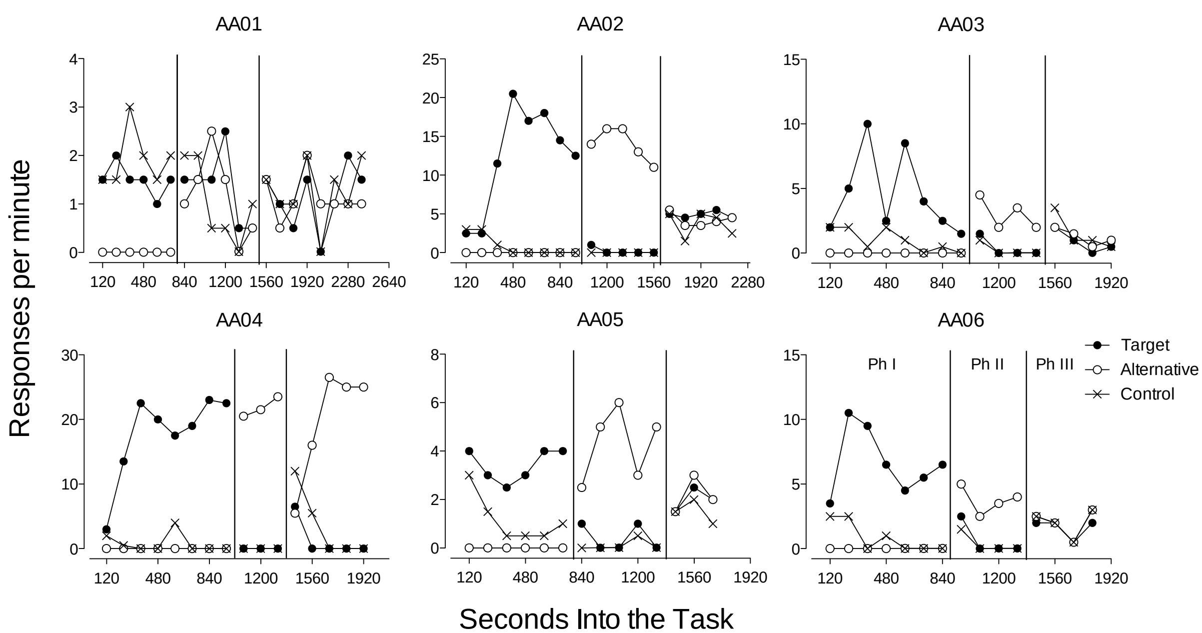
Appendix C.

Individual participant graphs across conditions (note changes in scaling on the y-axes).

Participants who completed the "Sequential" condition.



Participants who completed the "All Signals" condition.



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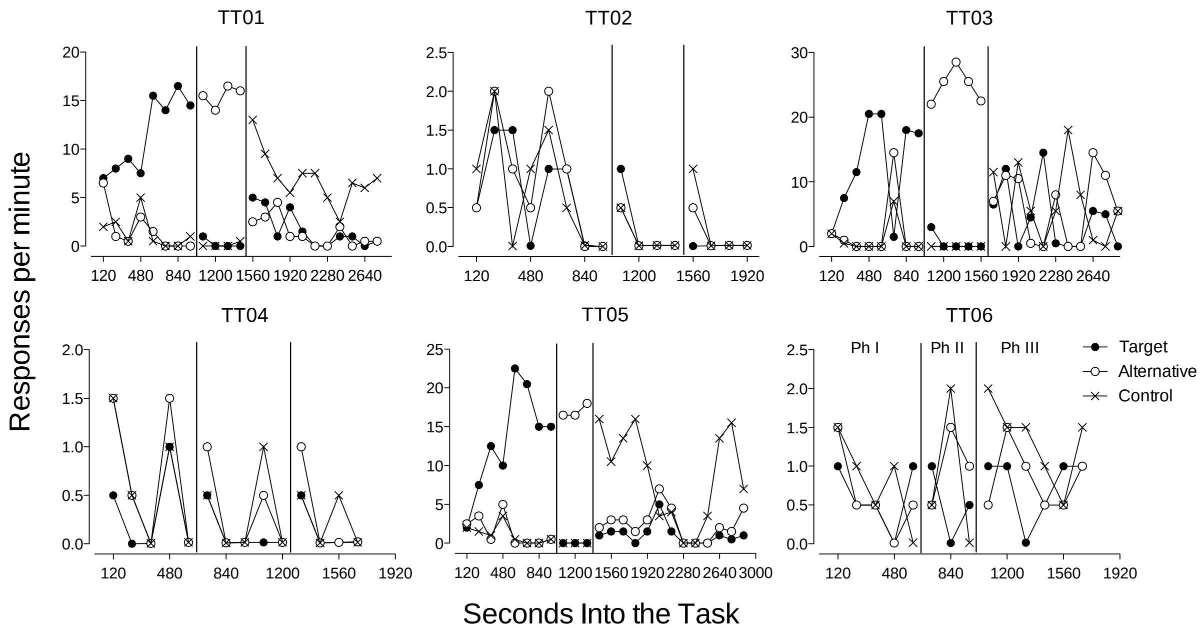
Participants who completed the "All Signals and Responses" condition.



Participants who completed the "Target Signal" condition.