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RESURGENCE WHEN CHALLENGING ALTERNATIVE BEHAVIOR WITH PROGRESSIVE RATIOS IN CHILDREN AND PIGEONS

RESURGENCE WITH PROGRESSIVE RATIOS

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Resurgence is defined as the recurrence of a previously reinforced and then extinguished target response when reducing or eliminating a more recently reinforced alternative response. In experiments with children and pigeons, we evaluated patterns of resurgence across and within sessions through decreases in reinforcer availability by challenging alternative responding with extinction and progressive-ratio schedules. In Phase 1, we reinforced only target responding. In Phase 2, we extinguished target responding while reinforcing an alternative response. Finally, Phase 3 assessed resurgence by (a) extinguishing alternative responding versus (b) introducing a progressive-ratio schedule of reinforcement for alternative responding. In both children and pigeons, resurgence of target responding occurred in both conditions but generally was greater when assessed during extinction than with progressive ratios. Importantly, within-session patterns of resurgence did not differ between testing with progressive ratios and extinction. Resurgence with progressive ratios tended to be greater with longer durations between reinforcers but we observed similar findings with only simulated reinforcers during extinction testing. Therefore, the present investigation reveals that the events contributing to instances of resurgence remain to be understood, and presents an approach from which to examine variables influencing within-session patterns of resurgence.

Key words: progressive ratio, extinction, resurgence, differential reinforcement, children, pigeons

Differential reinforcement of alternative behavior (DRA) is one of the most commonly used treatments for eliminating problem behavior (Petscher, Rey, & Bailey, 2009). Typical arrangements of DRA withhold the reinforcer for an unwanted target response while simultaneously reinforcing a specific, alternative response (Vollmer & Iwata, 1992). As a consequence, DRA not only decreases the problem behavior but also equips individuals with alternative desirable behavior. Reinforcing alternative behaviors helps avoid or limit unwanted side effects caused by other behavioral treatments, such as extinction or punishment (e.g., extinction burst, emotional responses). Although DRA treatments often result in rapid and clinically significant reductions in problem behavior, failure to implement DRA with perfect fidelity can produce a return of problem behavior, often termed *treatment relapse* (Pritchard, Hoerger, Mace, Penny, & Harris, 2014; Wathen & Podlesnik, in press).

Problem behavior can return due to treatment-integrity errors either by failing to deliver reinforcers contingent upon desirable behavior, *omission errors*, or by delivering reinforcers contingent upon problem behavior, *commission errors* (St. Peter Pipkin, Vollmer, & Sloman, 2010). In this investigation, we will focus on omission errors. Omission errors during DRA treatment can become likely, as excessively high rates of alternative behavior can result from training with a dense schedule of reinforcement during acquisition (e.g., Hagopian, Boelter, & Jarmolowicz, 2011). Reinforcing every instance of alternative behavior, therefore, becomes difficult or undesirable.

To minimize the likelihood of treatment-integrity errors, practitioners typically begin DRA treatment with continuous reinforcement

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and systematically reduce the reinforcement rate to ensure a more practical method of implementation for natural settings (see Hagopian et al., 2011, for a review). Thinning the alternative reinforcement schedule promotes greater treatment fidelity; however, desirable behavior necessarily goes unreinforced by design. As is the case with unintended omission errors, systematically thinning alternative reinforcement schedules also can produce a return of problem behavior in clinical situations (e.g., Hagopian, Toole, Long, Bowman, & Lieving, 2004).

Laboratory studies can simulate reductions in both unplanned (i.e., omission errors) and programmed (e.g., thinning) rates of alternative reinforcement with *resurgence* procedures. Resurgence is defined as the recurrence of a previously reinforced response when reducing or eliminating reinforcement for a more recently reinforced response (see Lattal et al., 2017; Shahan & Craig, 2017). Resurgence offers a platform to examine learning processes underlying programmed and unplanned reductions in alternative reinforcement, as well as to assess novel treatment approaches (e.g., Lambert, Bloom, Samaha, Dayton, & Rodewald, 2015). In a most basic form of the procedure, Winterbauer and Bouton (2012) reinforced rats pressing a target lever according to a random-interval (RI) 30-s schedule in Phase 1, simulating a natural history of reinforcement in clinical cases of problem behavior (see Volkert, Lerman, Call, & Trosclair-Lasserre, 2009). In Phase 2, they extinguished target responding while simultaneously introducing and reinforcing an alternative response according to a RI 20-s schedule to simulate treatment with DRA. In Phase 3, they removed alternative reinforcement and target responding returned, which defines the resurgence effect. Resurgence following reductions in alternative reinforcement has been observed in a wide range of species, including fish (e.g., Kuroda, Mizutani, Cançado, & Podlesnik, 2017a,b), chickens (e.g., Cleland, Foster, & Temple, 2000); pigeons (e.g., Lieving & Lattal, 2003; Podlesnik & Shahan, 2009), rats (e.g., Craig & Shahan, 2016; Podlesnik, Jimenez-Gomez, Ward, & Shahan, 2006), monkeys (Mulick, Leitenberg, & Rawson, 1976), humans diagnosed with disabilities (e.g., Kimball, Kelley, Podlesnik, Forton, & Hinkle, 2018; Lambert et al., 2015) and typically developing humans (e.g., Doughty, Cash, Finch, Holloway, & Wallington, 2010). Therefore, resurgence appears to be a general behavioral phenomenon.

Laboratory research has also examined resurgence to simulate thinning alternative reinforcement during DRA treatments (e.g., Hagopian et al., 2011) with nonhuman animals (e.g., Winterbauer & Bouton, 2012; see Shahan & Craig, 2017, for a review). In a separate group of rats from above, Winterbauer and Bouton (2012) reduced the rate of alternative reinforcement by half across successive sessions. As alternative reinforcement rate decreased, target response rate increased. Therefore, the common patterns of responding between clinical and laboratory studies further suggest laboratory studies can be used to understand aspects of resurgence in clinical situations.

In addition to demonstrating resurgence when thinning reinforcement across sessions following DRA treatment in clinical and laboratory situations, some laboratory studies examined resurgence in target responding within experimental sessions (Bai, Cowie, & Podlesnik, 2017; Lieving & Lattal, 2003). In general, time following the most recently reinforced alternative response increases the likelihood of resurgence. Lieving and Lattal (2003) tested for resurgence of target responding by reducing the overall rate of alternative reinforcers. They found greater numbers of responses as time between reinforcers, or interreinforcer interval, increased. These findings complement those of resurgence when thinning alternative reinforcement across sessions (Hagopian et al., 2004; Winterbauer & Bouton, 2012). Specifically, they suggest momentary reductions in alternative reinforcement availability could produce resurgence. The implication for DRA treatment in clinical situations is that even brief omissions of alternative reinforcement could produce a return of problem behavior.

The purpose of the present research was to examine the effects of within-session changes in alternative reinforcement on patterns of resurgence of target behavior in two experiments, one with children (Experiment 1) and the other with pigeons (Experiment 2). We examined the effects of gradually increasing the omission of alternative reinforcers within sessions by arranging progressive-ratio

(PR) schedules to obtain alternative reinforcers. Progressive-ratio schedules increase the response requirement to access reinforcement after every obtained reinforcer within the course of a single session (Killeen, Posadas-Sanchez, Johansen, & Thrailkill, 2009; Kincaid & Lattal, 2018; Roane, Lerman, & Vorndran, 2001). Specifically, we reinforced a target response during training in Phase 1. In Phase 2, we introduced extinction for the target response while introducing and reinforcing an alternative response. In Phase 3, we either (a) systematically increased the response requirement to obtain alternative reinforcement using PR schedules, or (b) arranged a typical resurgence test by arranging extinction of alternative responding (e.g., Craig & Shahan, 2016; Podlesnik & Kelley, 2014).

We expected the overall levels of resurgence to be greater when arranging extinction of alternative responding during the typical resurgence tests than during PR tests. Nevertheless, the primary goal of these experiments was to assess differences in within-session patterns of resurgence when differentially omitting alternative reinforcers between tests with extinction and PR schedules. Analyses of response patterns during extinction and PR tests in Phase 3 could provide insight into factors influencing resurgence. Specifically, resurgence of target responding could be a function of competition between alternative and target responding in Phase 3 (e.g., Podlesnik & Kelley, 2014) or the elimination of alternative reinforcers in Phase 3 could serve to withdraw disruption of target responding, consistent with Behavioral Momentum Theory (e.g., Nevin et al., 2017; Shahan & Sweeney, 2011). The assessment of resurgence with extinction of alternative responding provided a comparison with a typical assessment of resurgence in the absence of reinforcers available in Phase 3. Finally, arranging similar conditions with children and pigeons assessed the generality of the effects across species.

Experiment 1

In Experiment 1, we examined resurgence when arranging extinction versus PR schedules in a laboratory setting with children as participants. The reason for conducting this experiment with children is that DRA treatments are used frequently in homes, schools, and clinics to promote appropriate communicative behavior and eliminate undesirable forms of communication (e.g., aggression, tantrums; see Petscher et al., 2009).

Method

Participants. Five children participated in this experiment and are identified by pseudonyms. Becky (4 years) and Emma (3 years) were typically developing girls. David was a 3-year-old boy diagnosed with Autism Spectrum Disorder (ASD). During the experiment, David received 30 hr per week of early intervention services. He scored as Level 2 learner on the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; Sundberg, 2008). Whitney was an 8-year-old girl who had been diagnosed with ASD. Whitney received 15 hr per week of early intervention services. She scored as a Level 1 learner on the VB-MAPP. Matt was a 5-year-old boy diagnosed with ASD and idiopathic epilepsy. His verbal behavior repertoire had not been assessed using the VB-MAPP, but he had an extensive vocabulary. Matt had received various interventions and therapies but was not in an early-intervention program at the time of the experiment.

Setting and materials. We conducted sessions in a 3 m x 3 m room at The Scott Center for Autism Treatment for Becky, Whitney, David, and Matt, and at home for Emma. All sessions were conducted in the same room with the same therapist and materials present every day. The rooms contained a table, chairs, video camera, and edibles to serve as reinforcers. We recorded audio and video during all sessions. We used Montessori Object Permanence boxes to evaluate target and alternative responses, with the number of boxes present depending on the phase. Figure 1 shows a picture of the arrangement when presenting both boxes. It includes a small plastic golf ball and a 13.97 x 11.94 x 28.96 cm wooden box with a 3.18-cm diameter hole in the top of the box. Participants could repeatedly put the ball into the hole on top and retrieve it from the bottom tray. We used one natural wood box, as shown on the left in Figure 1, to evaluate target responding. We used a green but otherwise identical box on the right to evaluate alternative responding. The natural wood box was placed on the participant's left and the green box was on the participant's right, with

Fig. 1. A Montessori Object Permanence Box used for responses for all participants in Experiment 1. Note the box for target responding was naturally colored as in the figure and the box for alternative responding was painted green. Image retrieved from: https://images-na.ssl-images-amazon.com/images/I/411%2BolvcAZL._SY355_.jpg

approximately 8 cm between boxes. The boxes were affixed to a 38 x 53-cm wooden board during sessions to prevent participants moving the boxes. The two boxes were placed on the table symmetrically in front and to the sides of the participants. Only one ball was available in all phases and was placed between the two boxes at the beginning of all sessions. A laptop was used for recording all relevant events (e.g., responses, reinforcer presentations, etc.).

Response definition and measurement. The primary dependent variables were target and alternative responses per minute in each session. The target response was dropping the ball into the natural wood box through the hole on top of the box. The alternative response was dropping the ball into the green box. We also measured *emotional responses*, defined as crying, screaming, whining, and any other noise above conversation level (i.e., could be heard from more than 6 feet away). Recording duration of emotional responding began immediately on onset and ended when 3 s elapsed without emotional responding.

Another measure was *other responses*, which were defined as any responses functionally equivalent to target and alternative responses (see also Liggett, Nastri, & Podlesnik, 2018). Other responses for David were attempts to take edibles without permission. Emma's other responses were "I want raisin, please" and attempts to steal edibles. Matt's other responses were requests for edibles (e.g., "I want M&M's"), attempts to steal edibles, and touching the experimenter's hand. Whitney's other responses included saying "a-f-ee" as a request for Laffy Taffy®, attempts to steal edibles, and grabbing and placing the experimenter's hand on the plate holding the edibles. Becky emitted requests for edibles (e.g., "Can I have [potato] chips please?").

Procedure. All children participated in the experiment from one to five times per week. During each visit, we conducted two to six sessions depending on availability of the participant and the phase of the experiment, as specified below. The top of Table 1 shows the Typical and PR resurgence conditions and the three phases within each condition for all participants. David and Emma received PR then Extinction conditions. Matt, Whitney, and Becky received Extinction then PR conditions.

Preference assessment. The experimenter conducted a multiple-stimulus-without-replacement (MSWO) preference assessment according to procedures described by Carr, Nicolson, and Higbee (2000) at the beginning of every session in all phases. During reinforcer deliveries, one of the two top-ranked edibles identified by the MSWO was delivered randomly from one delivery to the next (see Egel, 1981). We selected edibles taking negligible consumption time to

Table 1

Participants and procedures across the two experiments

			Typical Resurgence		PR Resurgence	
Experiments	Participants	Phases	Target	Alternative	Target	Alternative
1	Children	1	VR 2	–	VR 2	–
		2	Extinction	FR 1	Extinction	FR 1
		3	Extinction	Extinction	Extinction	FR 1, 2, 4, 8, …
2	Pigeons	1	RR 10	–	VR 10	–
		2	Extinction	FR 5	Extinction	FR 5
		3	Extinction	Extinction	Extinction	FR 5, 10, 20, 40, …

ensure little interference with responding. The edibles mainly were poosa (fried noodle snack from India) and lentils for David; LaffyTaffy® and candy sprinkles for Whitney; potato chips and M&Ms® for Becky; M&Ms® and Sweetarts® for Emma; and M&Ms®, marshmallows, chocolate chips, and Cheerios® for Matt.

Phase 1: training. Sessions lasted 5 min and only the natural wood box was available to the left of the participant. The experimenter provided the instruction "[Name of the participant], you can drop the ball in the box. You can do as much or as little as you want. Start." The experimenter reinforced every target response according to a fixed-ratio (FR) 1 schedule until the participant responded reliably, defined as 10 unprompted responses at FR 1. Next, the target response was reinforced according to a variable-ratio (VR) 2 schedule, selected from a list of randomized numbers consisting of one, two, and three responses. However, the first target response of each session was always reinforced. We used this VR schedule to provide experience with unreinforced target responses because not all responses would be reinforced during later resurgence testing. Phase 1 ended when target response rate was judged by visual inspection to be occurring reliably for at least three successive sessions.

Phase 2: Differential reinforcement. In this phase, sessions also lasted for 5 min. Instructions were identical to Phase 1. We introduced a green box to the participant's right placed symmetrically with the box on the left. The experimenter provided the same instruction as in Phase 1. In this phase, the target response was placed on extinction and the alternative response was reinforced according to an FR-1 schedule until the target-response rate was reliably near zero.

Phase 3: Extinction or PR. In Phase 3, participants experienced both the Extinction and PR phases, as shown in Table 1. In both the Extinction and PR phases, there were two boxes placed on the table as in Phase 2. Participants all received the same instruction as in Phases 1 and 2. In the Extinction phase, neither alternative nor target responses were reinforced. In the PR phase, target responding was placed on extinction while alternative responding was reinforced according to a PR schedule. After every reinforcer delivery, the response requirement doubled from the previous ratio starting at FR 1, and increased thereafter to FR 2, FR 4, FR 8, FR 16, etc. Both Extinction and PR sessions ended when the participant stopped emitting either response for 1 min or if the session duration reached 20 min, whichever came first.

Interobserver agreement. Table 2 shows interobserver agreement scores for all participants. A second independent observer collected data on target, alternative, other, and emotional responses on a laptop computer. The trained observer collected data either simultaneously with the primary observer or from a video recording. Agreement scores for each session were calculated by dividing the total number of intervals in which two observers recorded the same count by the total number of 10-s intervals, and converting the result to a percentage. Interobserver agreement was calculated for an average of 35% of sessions (range, 32 – 40%).

Procedural integrity. The independent observers also collected data on procedural integrity for an average of 35% of sessions (range, 32 – 40%) across phases. They scored an instance of procedural integrity for each trial if the experimenter: (a) presented the MSWO at the beginning of the session; (b) provided a clear and concise instruction; and (c) correctly followed the reinforcement schedules for target and alternative responses. Procedural integrity for each session was calculated by dividing the total number of trials implemented with integrity by the total number of trials in a session, and then converting the result to a percentage. Mean procedural integrity was 100% for all participants.

Results

Table 3 shows target and alternative reinforcer rates and number of sessions across Phases 1 and 2. Figure 2 shows rates of target and alternative responses across sessions for individual participants. We saw common patterns of

Table 2

Percent (range) interobserver agreement for target, alternative, and emotional/other responses for all participants

	Responses		
Participant	Target	Alternative	Emotional/Other
David	93 (70-100)	91 (73-100)	99 (97-100)
Emma	94 (76-100)	93 (63-100)	100
Matt	93 (63-100)	94 (60-100)	99 (94-100)
Whitney	91 (63-100)	88 (77-100)	89 (73-100)
Becky	95 (70-100)	91 (72-100)	100

Table 3

Number of sessions and mean obtained reinforcers per minute in last three sessions of Phase 1 and Phase 2 in Experiment 1

Participant	Procedure	Phase	Reinforcers/min	Sessions
David	PR	1	6.44	11
		2	8.96	7
	EXT	1	5.4	11
		2	7.92	9
Emma	PR	1	5.52	10
		2	4.92	3
	EXT	1	9.8	5
		2	11.56	7
Matt	PR	1	8.76	6
		2	9.96	6
	EXT	1	8.4	12
		2	11.12	10
Whitney	PR	1	9.68	14
		2	16.4	8
	EXT	1	9.36	10
		2	13.52	8
Becky	PR	1	8	8
		2	15.6	7
	EXT	1	13.4	6
		2	15.84	6

responding in all five participants. Specifically, target responding during Phase 1 occurred reliably before initiating Phase 2, with the exception of the drop in rate during a single session during the second Phase 1 for Becky. In Phase 2, target response rates decreased to near zero while alternative response rates increased for all participants. In Phase 3, alternative response rates decreased across sessions for both the Extinction and PR tests. There were no systematic order effects between conditions on resurgence, likely due to the return to Phase 1 between tests (see da Silva, Maxwell, & Lattal, 2008; Doughty, da Silva, & Lattal, 2007). Alternative response rates decreased faster and to a lower level across sessions during the Extinction test than during the PR test for all participants. We calculated the mean breakpoint for alternative responding during the PR test, which is the final ratio in effect at the end of the session. Breakpoints differed across sessions due to the changes in levels of responding. Therefore, we calculated breakpoints for the last five PR sessions when alternative response rates were relatively stable. Breakpoints were 4, 8, 2, 4.4, and 4.4 for Becky, Whitney, Emma, David, and Matt, respectively. Target response rates during the Extinction test resurged to higher levels compared to the PR test in four out of the five participants, with Becky being the exception.

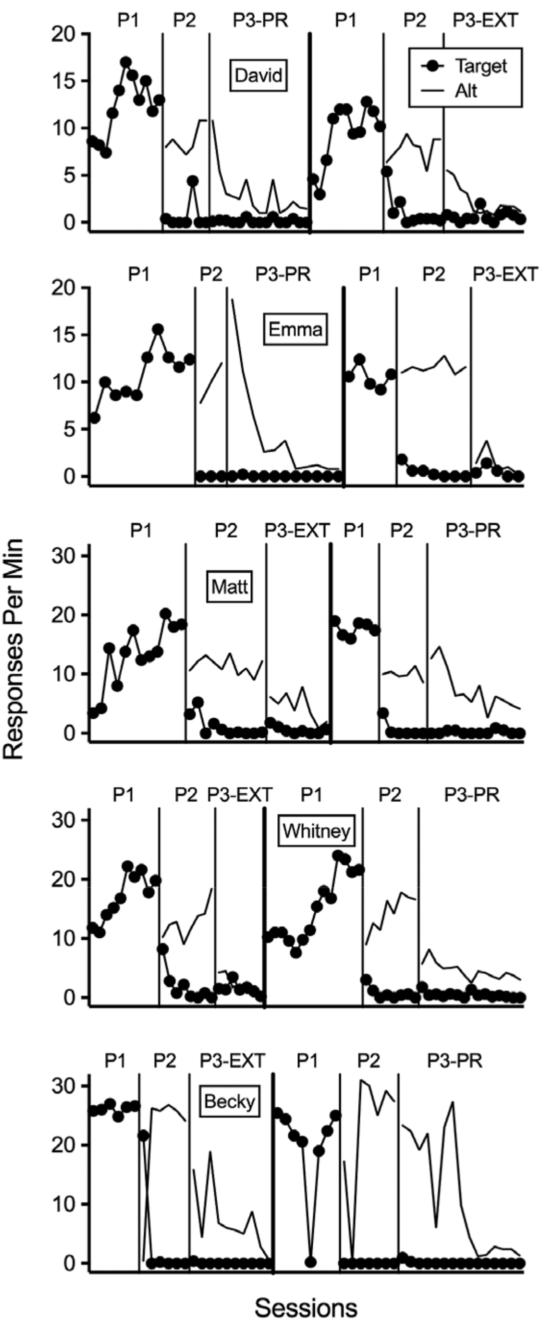

Fig. 2. Target and alternative responses per minute across Phase 1 (P1), Phase 2 (P2), and Phase 3 (P3) during the PR and Extinction (EXT) tests in Experiment 1. The solid vertical line indicates transitions between assessing Typical and PR resurgence.

The left column of Figure 3 shows target response rates during each Extinction- and PR-test session of Phase 3 minus response rate

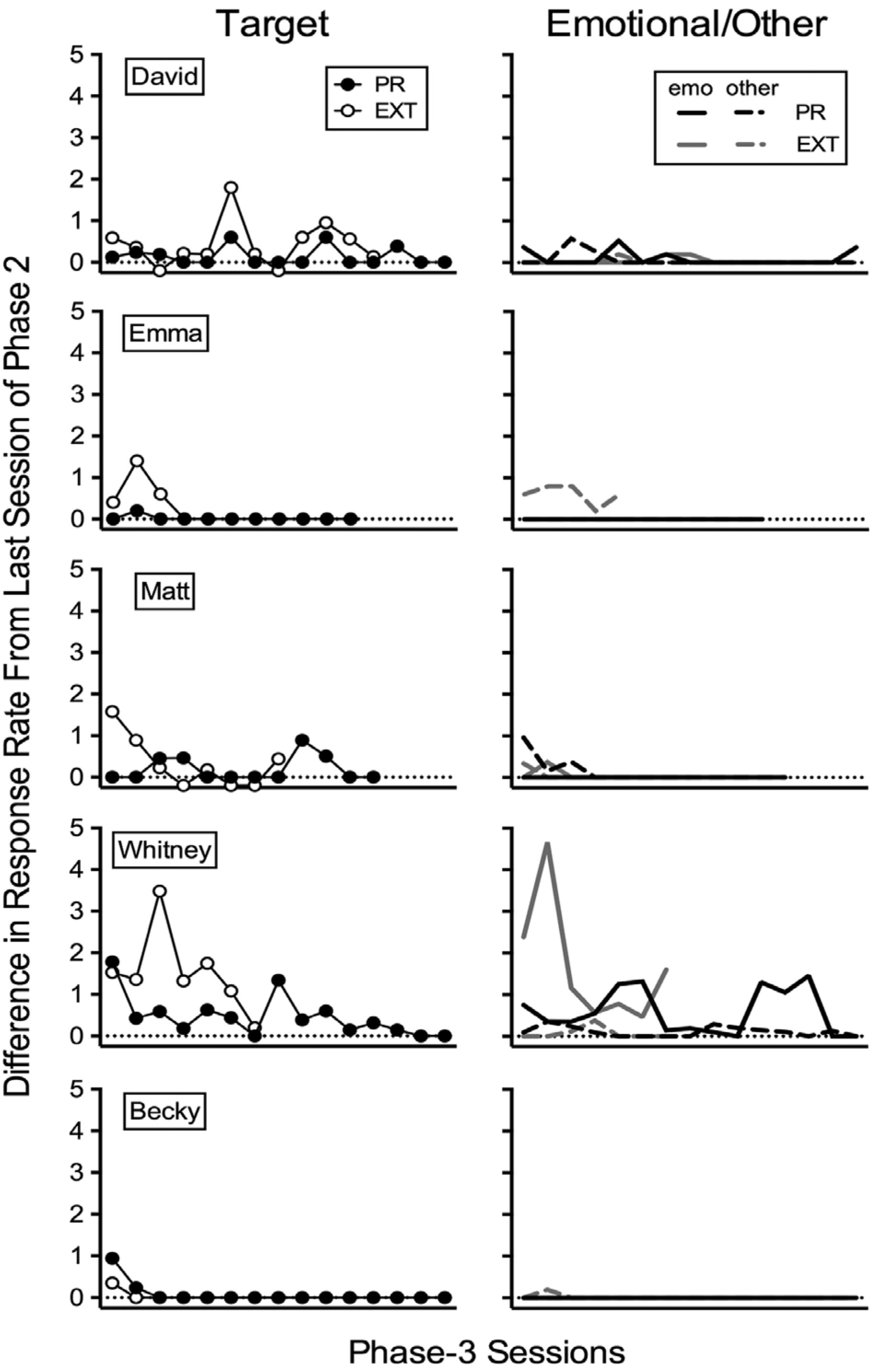

Fig. 3. Difference in response rate during PR- and Extinction-test sessions of Phase 3 relative to the last session of Phase 2 for target responding (left column) and emotional or other responding (right column) in Experiment 1.

from the final preceding Phase-2 session (see also Kuroda, Cançado, & Podlesnik, 2016; Liddon, Kelley, & Podlesnik, 2017). Points above zero indicate an increase in target responding relative to target responding from Phase 2. Overall, response rates on average were greater during Extinction-test sessions than during PR tests. Becky was the clear exception. Matt and Whitney also showed increases in target responding during later sessions of PR testing. Note the number of Extinction-test sessions was fewer than PR-test sessions for all participants. Nevertheless, the ordinal difference in resurgence between tests was the same across all participants regardless of whether mean effects were based on the different number of sessions or based on the number of sessions from Extinction tests.

The right column of Figure 3 shows emotional and other response rates during each Extinction- and PR-test session of Phase 3 minus response rate from the final session of Phase 2. For all participants, there were zero emotional or other responses during Phases 1 and 2 (data not shown). Only individuals with a diagnosis of ASD (i.e., David, Matt, and Whitney) emitted emotional responses. Whitney's emotional responses occurred at a higher rate than the other participants. The right column shows all participants emitted other responses in Phase 3 that were functionally equivalent to the target response. We examined correlations between the target responding and emotional or other responses during Phase 3 but observed no systematic relations (data not shown). Comparing the two panels of Figure 3, target responding tended to be greater than other and emotional responding, with the exception of Whitney's emotional responding approximating levels of target responding.

The left panel of Figure 4 shows alternative and target responses per minute during the last Phase-2 session (left-most data point) and across increases in the ratio requirement during all PR-test sessions. For each PR-test session, within-session responses per minute were calculated by dividing the number of responses in each interreinforcer interval (IRI) by the duration of the IRI. Furthermore, the right panels of Figure 4 show patterns of alternative and target response rates during Extinction tests. These are the same analyses of responding conducted for PR tests but we simulated reinforcer presentations during the Extinction tests as they would have occurred if alternative responding were reinforced on a PR schedule. Therefore, these simulated reinforcers during Extinction-test sessions partition the session in similar (increasing) intervals as the real reinforcers in PR-test sessions. For both PR and Extinction tests, target response rates during the last session of Phase 2 remained at or near zero while alternative response rates consistently were greater.

During PR testing shown in Figure 4, alternative response rates generally decreased with increased ratio requirement (see also Killeen et al., 2009). We obtained a similar pattern of alternative responding during the Extinction test, although all participants' alternative responding reliably reached larger ratios with the PR test than simulated ratios with the Extinction test. Note that Becky reached FR 128 with both tests but reached that value more frequently with PR than Extinction tests.

When comparing target response rates between PR and Extinction tests, response rates generally increased to a greater degree during Extinction tests, with the exception of Becky. No target responding occurred during the first FR 1 in the first Phase-3 session; increases in target responding with the FR-1 schedule always were from subsequent sessions. Across all ratios, there was no clear relation between target response rates and ratio requirement.

Figure 5 examines whether target responding during PR-test sessions correlated with alternative responding or delivery of reinforcers during PR-test sessions to determine potential causes of resurgence. All data points represent response rates calculated from IRIs within PR-test sessions. Black data points represent instances in which target responding was above zero. Data points in which target responding equaled zero and are plotted at 0.1 on the y-axes to show zero values on the logarithmic axis (see also Podlesnik & Bai, 2015; Podlesnik, Miranda-Dukoski, Chan, Bland, & Bai, 2017). Responses were binned from all PR-test sessions across all IRIs, except the interval following the last obtained reinforcer, which resulted in fewer instances of nonzero data than in Figure 4. We omitted time and responding after the last obtained reinforcer because those intervals meeting the criterion of 1 min without a target or

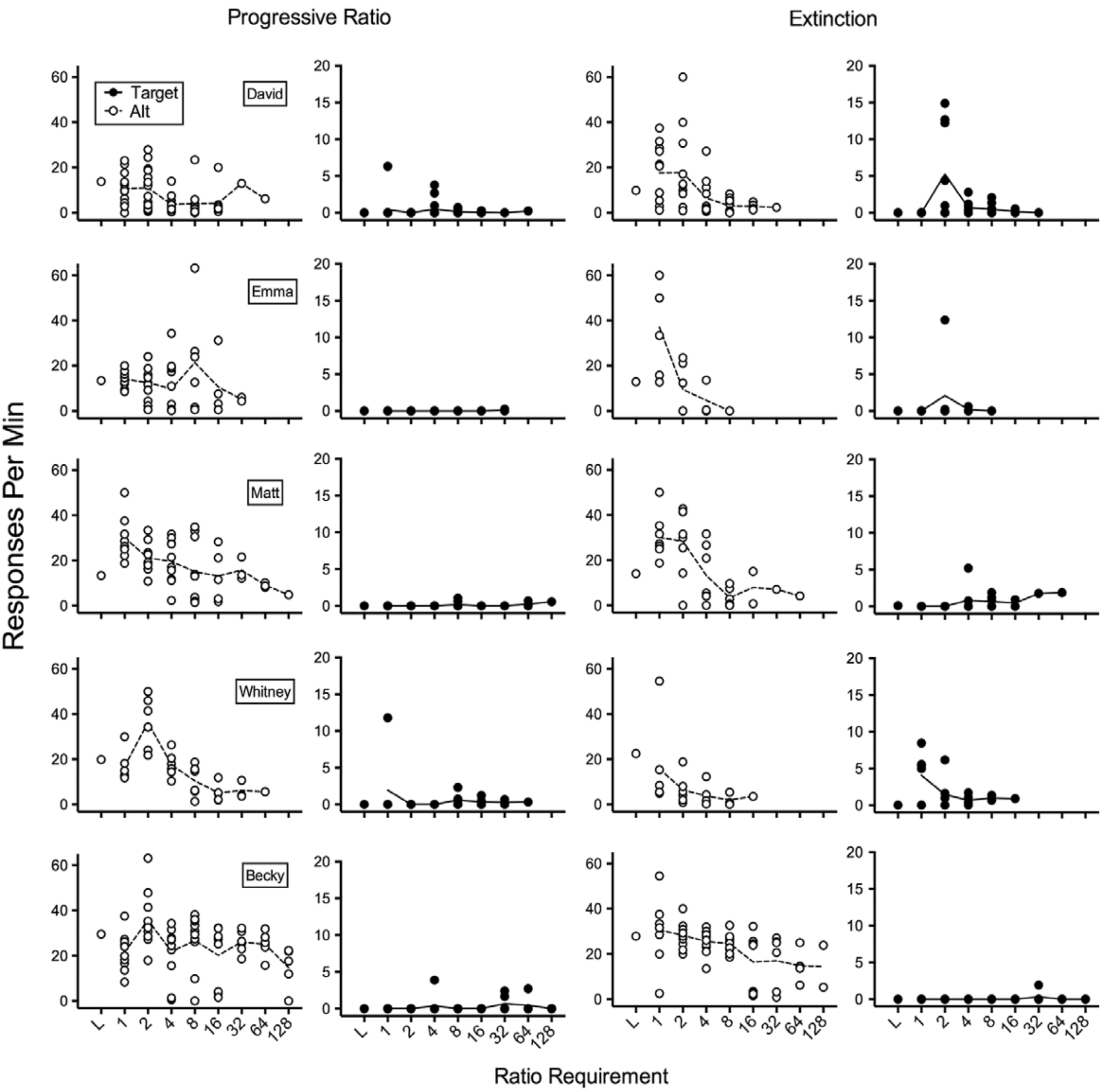

Fig. 4. Target and alternative responses per minute across the last session of Phase 2 (L) and across ratio requirements during PR-test sessions and simulated ratio requirements during Extinction-test sessions in Experiment 1. Lines in each panel indicate means. Note the open data points correspond with alternative responding and filled data points correspond with target responding among the columns.

alternative response would inflate the duration of the last interval.

In the left column of Figure 5, we examine target response rates as a function of alternative response rates to assess whether engaging in alternative responding was in competition with engaging in target responding (see Podlesnik & Kelley, 2014, 2015). If so, target and alternative response rates should be negatively correlated. However, there was either no indication of a negative relation for some participants (David, Whitney, Becky) or insufficient data to test this hypothesis (Emma, Matt). The top panel of Figure 7 summarizes the correlations of all nonzero data from the left column of Figure 5. The white bars show no consistently negative correlation between target response rate and alternative response rate across participants. Therefore, response competition between alternative and target responding unlikely accounts for resurgence in the present experiment.

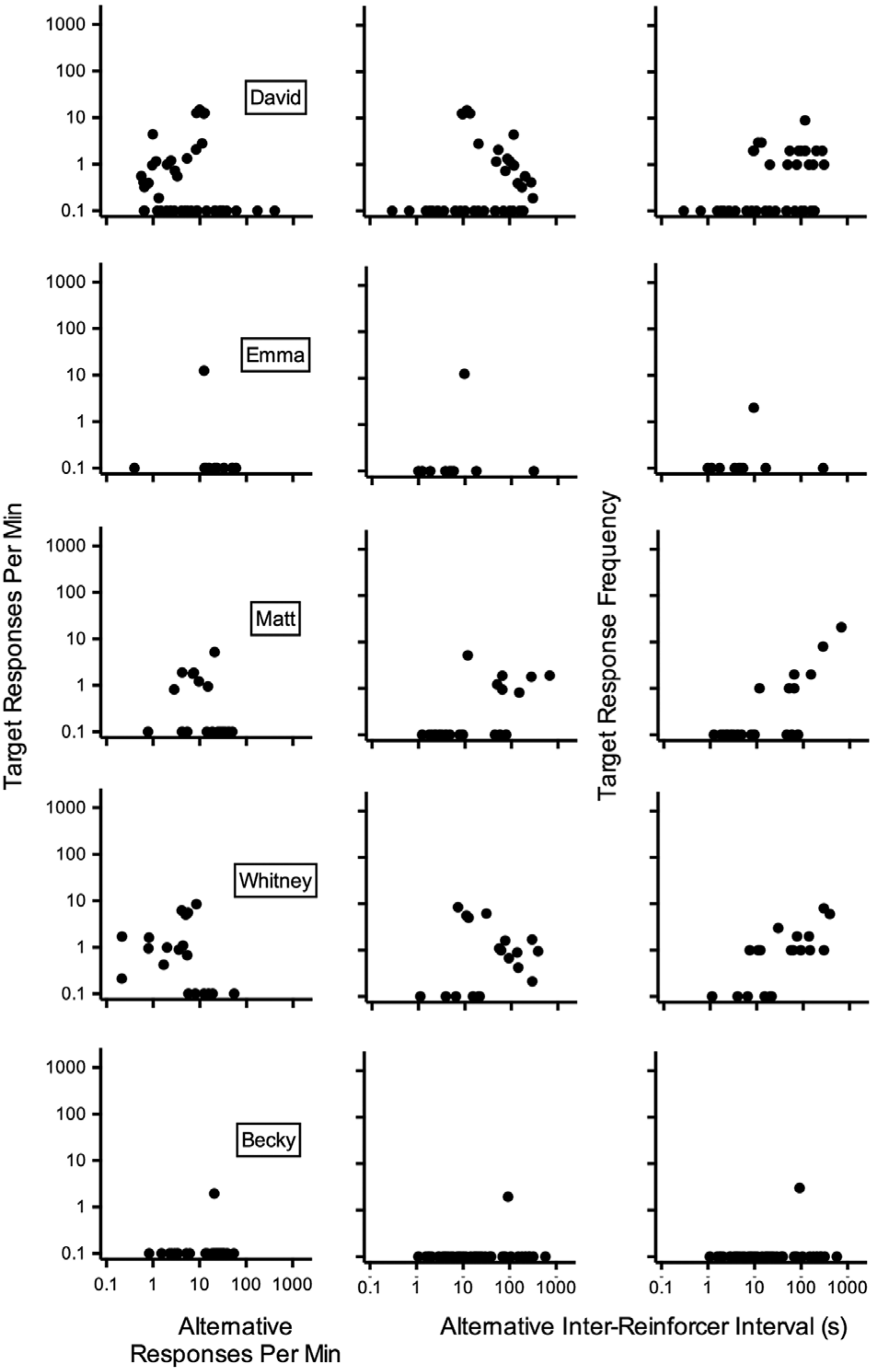

Fig. 5. The relation between target and alternative response rate (left column), between target responses per minute and alternative interreinforcer interval (middle column), and between target response frequency and alternative interreinforcer interval (right column) during PR-test sessions of Experiment 1. Note the logarithmic axes.

In the center column of Figure 5, we examined target response rates as a function of alternative IRI to assess whether longer durations between reinforcers removed a source of disruption of target response rates. Behavioral Momentum Theory asserts that decreases in target response rates in Phase 2 are due to the disruptive effects of increasing time in extinction and the delivery of alternative reinforcers (see Shahan & Sweeney, 2011). From this interpretation, increasing time between reinforcers with the PR schedule is akin to progressively removing alternative reinforcers as a source of disruption. Therefore, this interpretation implies a positive relation between target response rates and alternative IRI durations. However, there was no indication of a positive relation and even some evidence of a negative relation (David, Whitney, Becky), or insufficient data to test this hypothesis (Emma, Matt). The middle panel of Figure 7 summarizes the correlations of all nonzero data from the center column of Figure 5. The grey bars show no consistently positive correlation between target response rate and alternative IRI across participants. Therefore, an interpretation based on Behavioral Momentum Theory does not adequately account for resurgence in the present experiment.

In the right column of Figure 5, we examined target response frequency as a function of alternative IRI to assess whether longer durations between reinforcers occasioned increases in target responding (see Lieving and Lattal, 2003). There is a positive relation for Becky, meager evidence for a positive relation for David and Whitney, and insufficient data to test this hypothesis for Emma and Matt. The right panel of Figure 7 summarizes the correlations of all nonzero data from the right column of Figure 5. The black bars show the positive correlation between target response frequency and alternative IRI across participants. Of this limited evidence from these correlations, the only evidence for any relation was between target response frequency and IRI.

The analyses in the three columns of Figure 6 are identical to those shown in Figure 5 but consist of data from the Extinction test. As with Figure 4 (right panels), responding during Extinction-test sessions were partitioned after simulating reinforcers, as they would have occurred if alternative responding were reinforced on a PR schedule. Therefore, differences between Figures 5 and 6 should reveal the effects of continued presentation of reinforcers during PR testing (Fig. 5) and removal of reinforcers with Extinction testing (Fig. 6). The bottom panel of Figure 7 summarizes the correlations of all nonzero data from Figure 6. Overall, with the exception of more target responding during Extinction testing in Figure 6 compared to Figure 5 (Becky was an exception), there were no reliable differences between PR and Extinction testing. Specifically, there was no clear negative relation supporting response competition (left column) or positive relation supporting behavioral momentum (center column). In the right column, target response frequency was weakly positively related with IRI for David, Matt, Whitney, and Becky but data were insufficient for Emma. However, it should be emphasized that reinforcer presentations in Phase 3 were only simulated for data in the center and right columns. Therefore, the IRIs on the x-axis in the center and right columns generally reflect greater time in Extinction testing. Any corresponding positive relation between target response frequency and IRI in the right columns of Figures 5 and 6 either are due similarly to the passage of time within test sessions or reflect different processes. Nevertheless, the limited number of responses during testing for all participants makes evaluating differences between PR and Extinction difficult.

Discussion

In Experiment 1, we examined resurgence during extinction and PR schedules with children as participants. Target responding decreased quickly in Phase 2 when placed on extinction and when reinforcing an alternative response, consistent with the clinical outcome of DRA treatments (e.g., Tiger, Hanley, & Bruzek, 2008). Decreasing alternative reinforcement rate with the Extinction and PR tests tended to produce resurgence, although resurgence typically was greater during Extinction tests. Results of the Extinction tests replicate findings showing resurgence of target responding when extinguishing an alternative response (e.g., Craig & Shahan, 2016). The resurgence of target responding during PR tests systematically replicates previous findings

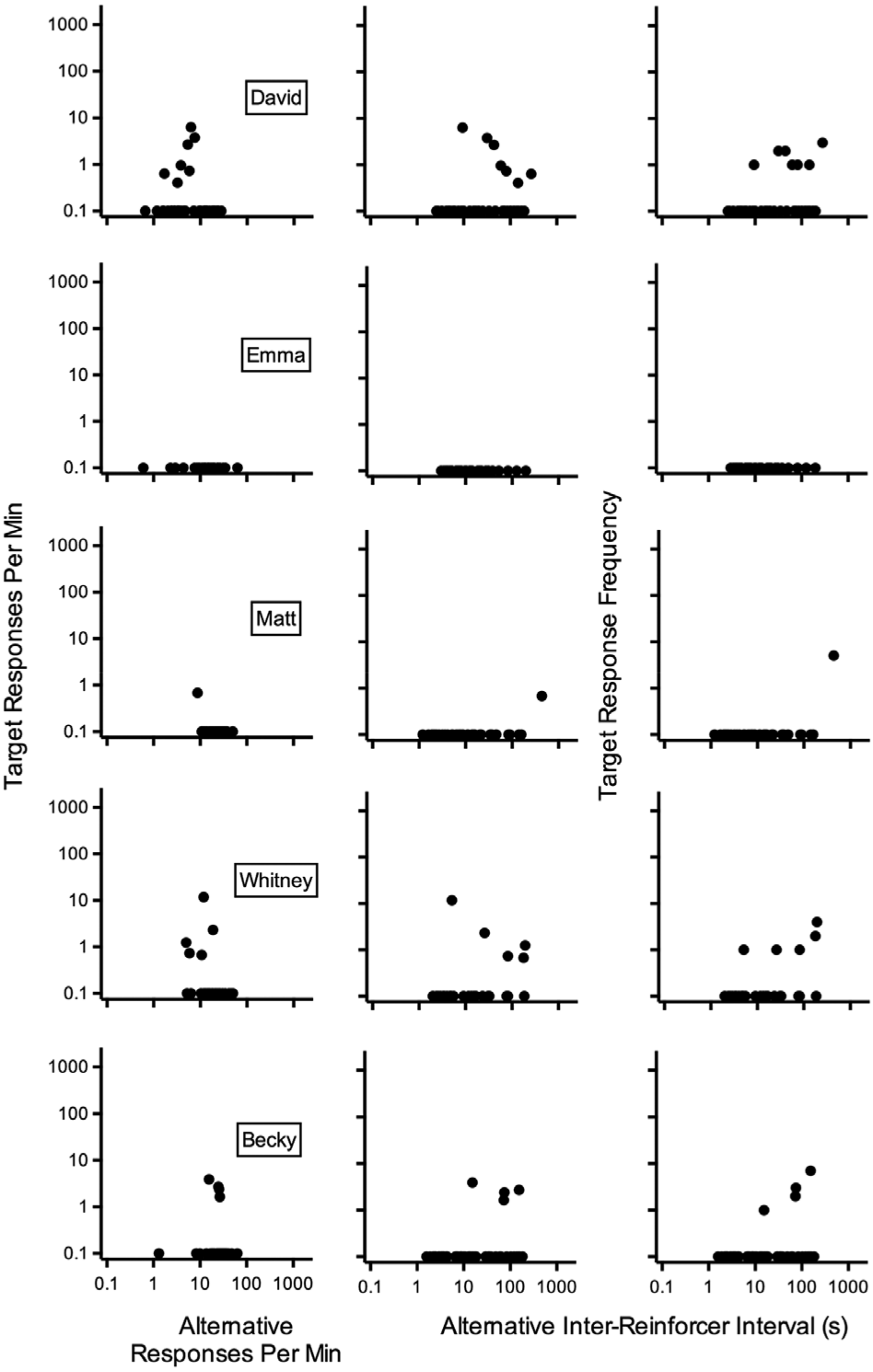

Fig. 6. The relation between target and alternative response rate (left column), between target responses per minute and simulated alternative interreinforcer interval (middle column), and between target response frequency and simulated alternative interreinforcer interval (right column) during Extinction-test sessions of Experiment 1. Note the logarithmic axes.

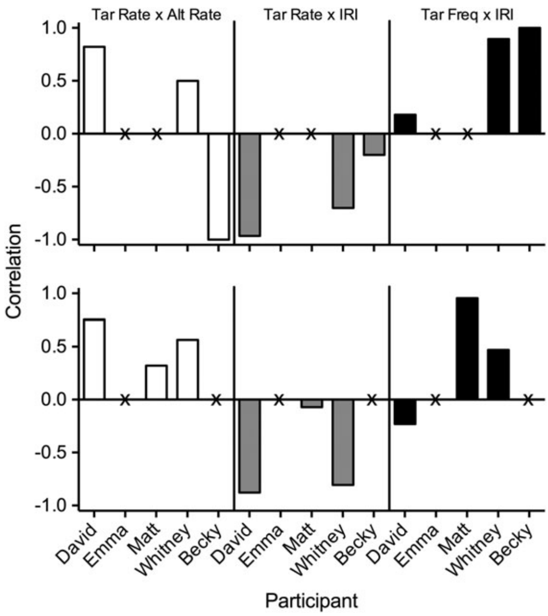

Fig. 7. Spearman's rank-order correlation coefficient during PR testing (top panel) and Extinction testing (bottom panel) across participants. White bars correspond to correlations between target responses per minute and alternative responses per minute, grey bars correspond to correlations between target responses per minute and IRI, black bars correspond to correlations between target response frequency and IRI. The "x" values indicate instances in which there were too few data points to calculate a correlation.

of resurgence when thinning alternative reinforcement across sessions (e.g., Hagopian et al., 2004; Winterbauer & Bouton, 2012). Therefore, these findings support the conclusion that resurgence occurs when conditions of alternative reinforcement worsen, not only upon eliminating alternative reinforcement (see Lattal et al., 2017; Shahan & Craig, 2017, for reviews).

In addition to producing resurgence of target responding, eliminating or reducing alternative reinforcement could increase response variability, including emotional or other functionally relevant behavior (see Lerman & Iwata, 1996; Neuringer & Jensen, 2013, for reviews). We observed some emotional or other functionally relevant behavior during Phase 3, but in no other phases, for all participants. If emotional and other responses were maintained by access to edible items outside the laboratory situation, the appearance of these responses might be considered instances of resurgence of more temporally removed responses when target responses no longer produced reinforcement (e.g., Bàchà-Mendez, Reid, & Mendoza-Soylovna, 2007). In the present experiment, other responses included verbal requests for edibles, attempts to steal edibles, or holding the experimenter's hand and pulling it to the plate of edibles (see also Liggett et al., 2018). The appearance of these other responses in the present experiment likely reveals resurgence within hierarchies of behavior within response classes established outside the experimental context. Clinically, reducing or eliminating alternative reinforcement during DRA treatment potentially could result in the return of previously reinforced and potentially more severe topographies of problem behavior (e.g., Lalli, Casey, & Kates, 1995). Therefore, examining previously learned problematic and appropriate responses that are functionally equivalent to target responding could be useful both for understanding the recurrence of behavior during DRA treatments as well as for designing more effective and durable treatments (see Lambert, Bloom, Samaha, & Dayton, 2017; Lambert et al., 2015).

Despite the extension of resurgence to within-session thinning of alternative reinforcement rates using PR schedules, we were unable to make firm conclusions about the behavioral processes underlying resurgence. Response competition between alternative and target response rates (see Podlesnik & Kelley, 2014, 2015) and removal of disruption from the perspective of Behavioral Momentum Theory (see Shahan & Sweeney, 2011) were clearly unable to account for the present findings. At most, the present findings remained ambiguous about whether greater time between alternative-reinforcer presentations accounted for resurgence during PR testing (cf. Lieving & Lattal, 2003). Moreover, the lack of systematic differences between Extinction and PR tests further complicate any interpretation of how systematically reducing alternative reinforcement rates with the PR schedule influenced resurgence. Overall, target responding in the present experiment might have been too low to detect differences either between the PR- and Extinction-test sessions or among the competing explanations. Therefore, we conducted an additional experiment using pigeons under better-controlled conditions that arranged leaner intermittent reinforcement schedules to potentially increase responding during testing conditions.

Experiment 2

Experiment 1 demonstrated resurgence in children's behavior when systematically increasing the response requirement to obtain alternative reinforcers using PR schedules of reinforcement. However, levels of resurgence tended to be too low to determine the variables potentially influencing resurgence. Therefore, Experiment 2 systematically replicated Experiment 1 with pigeons while arranging more intermittent reinforcement schedules.

Method

Subjects. The subjects were six experienced pigeons numbered 221-226 and maintained at 85% ± 15 g of their free-feeding bodyweights with supplementary feeding after sessions. Pigeons were housed in individual cages with free access to water and grit. The colony-room lights were turned on at 2 a.m. and off at 6 p.m. daily. Experimental sessions ran at 3 p.m., 5 days per week. Transitions between phases always occurred during successive daily sessions.

Apparatus. The experimental chambers were standard MED Associates chambers measuring 300 mm high, 320 mm wide, and 240 mm deep. The ceiling, front wall and back wall were constructed of Plexiglas, and the floor was constructed of steel bars. The left and right walls were constructed of metal, and three translucent response keys were mounted on the right wall in a horizontal row. The keys were 25 mm in diameter, 220 mm above the floor and 80 mm apart, center to center. Only the left and right keys were used and both could be transilluminated red and green. Pecks to a lit key exceeding 0.1 N of force were recorded as responses. A magazine, measuring 50 mm high, 60 mm wide, and 45 mm deep, was located 140 mm below the keys and provided access to a hopper filled with wheat during reinforcement. The magazine was illuminated and all keylights were darkened for 2 s during reinforcement. All experimental events were arranged and recorded by a computer running MED PC® IV.

Procedure. We used a within-subjects design to assess the effects of extinction versus a PR schedule of alternative reinforcement on extinguished target responding. Table 1 shows the conditions and phases. We arranged three phases for both the Typical and PR resurgence procedures, with the two procedures conducted successively. The first two phases for the two procedures were identical and the order of procedures was counterbalanced across pigeons. Pigeons 221, 222, and 223 experienced the Extinction procedure first and 224, 225, and 226 experienced the PR procedure first. In addition, the color (red vs. green) and location (left vs. right) of the target and alternative keys were counterbalanced across pigeons (see Table 3).

Phase 1: Baseline. Only the target key was available during this phase. Reinforcers were programmed according to a random ratio (RR) 10 schedule for responses to the target key using a probability gate of 0.1 after each response. Sessions were 5 min and we arranged 10 sessions of baseline before Phase 2.

Phase 2: Differential reinforcement. Both target and alternative keys were illuminated during this phase. The target key arranged extinction and responses to the alternative key delivered reinforcers according to a FR 5 schedule. Each session was 5 min. Phase 2 continued for a minimum of six sessions and until target responding decreased to 10% of baseline rates (see Bai, Chan, Elliffe, & Podlesnik, 2016; Miranda-Dukoski, Bensemann, & Podlesnik, 2016). In the first exposure to Phase 2, Pigeons 224 and 225 were given a single 5-min session of autoshaping (Brown & Jenkins, 1968) with the alternative key alone, after failing to acquire the alternative response after seven sessions. Table 4 shows the number of sessions in Phase 1 and Phase 2 for individual pigeons in both conditions.

Phase 3: Extinction or PR. We illuminated both target and alternative keys as in Phase 2. In the Extinction test, both the target and alternative keys arranged extinction. In the PR test, the target arranged extinction and the alternative arranged the PR schedule, which doubled the response requirement following every reinforcer (i.e., FR 5, FR 10, FR 20, FR 40, FR 80, etc.). Both types of test sessions continued until either 5 min had elapsed without a target or alternative response, or for a

Table 4

Counterbalanced order of conditions and keys for target and alternative responses for Experiment 2

Pigeon	Order of cycles 1st	 2nd	Response key Target	 Alternative
221	EXT	PR	Left Red	Right Green
222	EXT	PR	Right Red	Left Green
223	EXT	PR	Left Green	Right Red
224	PR	EXT	Right Red	Left Green
225	PR	EXT	Left Green	Right Red
226	PR	EXT	Right Green	Left Red

maximum duration of 45 min. We conducted five sessions of Phase 3 for both procedures. Following the first procedure, the pigeons began Phase 1 of the other procedure.

Results

Table 5 shows reinforcers per minute for target responding from the last five sessions of Phase 1 and from alternative responding from the last five sessions of Phase 2. Obtained reinforcers for alternative responding during Phase 3 of the PR condition varied across subjects. Mean number of obtained reinforcers across the five Phase 3 sessions of PR testing was 8, 6, 5, 4.4, 5.8, and 7.2 per minute for Pigeons 221-226, respectively. Figure 8 shows individual-pigeon responses per minute on the target and alternative keys across the three phases of the PR (left panel) and Extinction (right panel) procedures. The leftmost data points show mean target response rates from the last five sessions in Phase 1 for both procedures. Across pigeons, response and reinforcer rates did not differ reliably between Extinction and PR procedures.

Table 5

Number of sessions and mean obtained reinforcers per minute in last five sessions of Phase 1 and Phase 2 in Experiment 2

Pigeon	Procedure	Phase	Reinforcers/min	Sessions
221	PR	1	17.04	10
		2	24.44	6
	EXT	1	17.24	10
		2	20.92	6
222	PR	1	8.72	10
		2	20.32	6
	EXT	1	10.64	10
		2	3.92	7
223	PR	1	15.64	10
		2	21.60	6
	EXT	1	13.52	10
		2	6.56	7
224	PR	1	5.60	10
		2	0.64	8
	EXT	1	9.32	10
		2	16.32	6
225	PR	1	5.32	10
		2	1.52	8
	EXT	1	6.40	10
		2	15.48	6
226	PR	1	17.44	10
		2	14.80	7
	EXT	1	14.12	10
		2	25.56	6

The next series of data points in Figure 8 depict target and alternative responding across successive sessions in Phase 2. Alternative response rates increased more slowly in the first than second exposure to Phase 2 for all pigeons (see also Podlesnik & Kelley, 2014). Alternative response rates were greater than target response rates for all pigeons by the end of Phase 2 in both procedures.

The final series of data points in Figure 8 depict target and alternative responding across successive sessions in Phase 3. Alternative responding generally decreased from the end of Phase 2. An exception was 226 due to decreases in response rates in the final Phase-2 sessions before the PR test. Alternative response rates tended to be greater in the PR test than the Extinction test, with the first sessions for 222 and 224 being the exceptions. Target response rates varied between the PR and Extinction tests within and across pigeons. There was no systematic effect of the order of exposure to PR and Extinction tests, likely due to the return to Phase 1 between tests (see da Silva, Maxwell, & Lattal, 2008; Doughty, da Silva, & Lattal, 2007).

To directly compare resurgence of target responding between procedures in Phase 3, Figure 9 shows the difference in target response rates during Phase 3 from response rates during the last session of Phase 2. Response rates increased above Phase 2 levels for all pigeons for at least one session, with the exception of 226 during the PR test. Thus, resurgence assessed at the overall level occurred in most pigeons between the two conditions, defined as increases relative to the end of Phase 2 (see Podlesnik & Kelley, 2014; Sweeney & Shahan, 2013). Overall resurgence during the Extinction test was greater for four out of six pigeons, with 222 and 223 being opposite from the others.

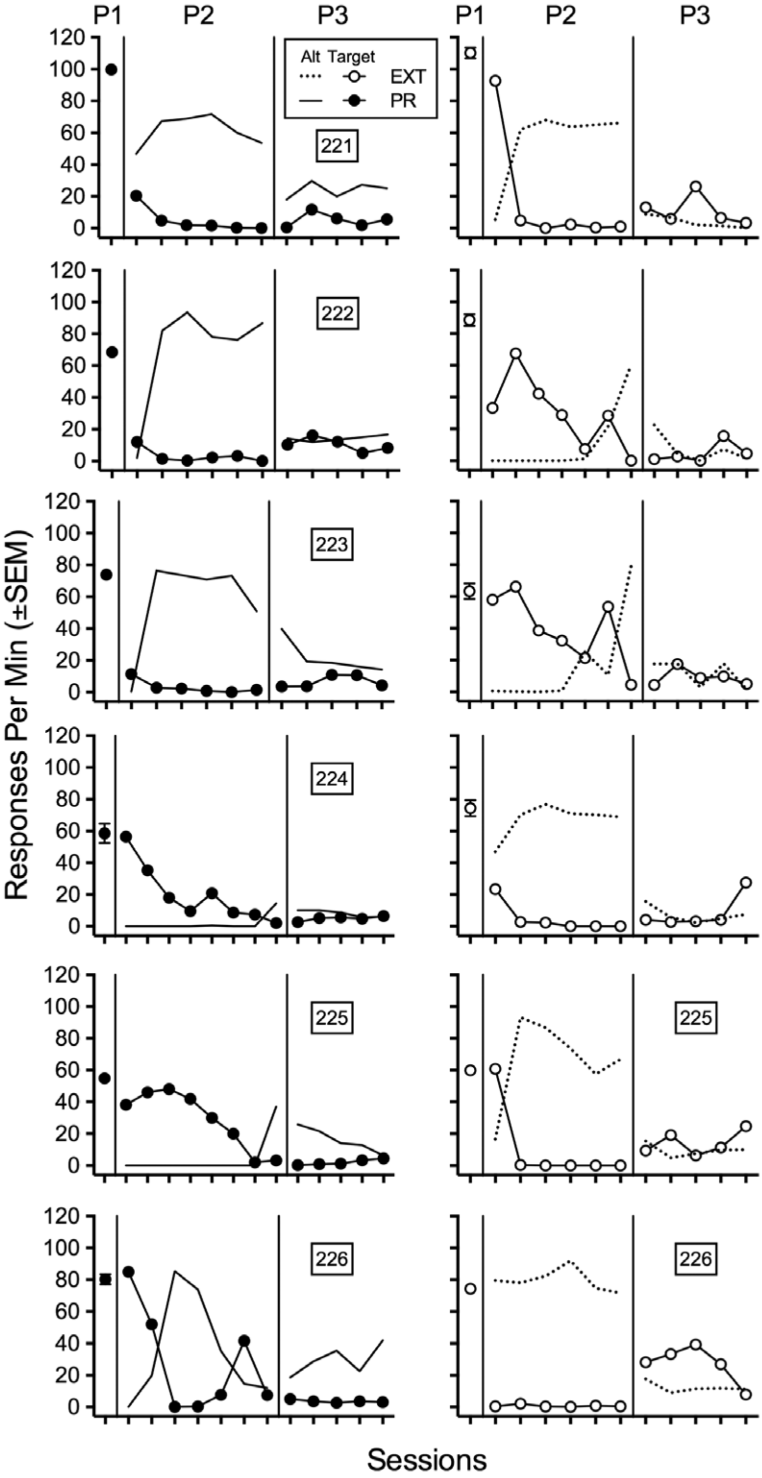

Fig. 8. Target and alternative responses per minute across Phase 1 (P1), Phase 2 (P2), and Phase 3 (P3) during the PR and Extinction tests in Experiment 2.

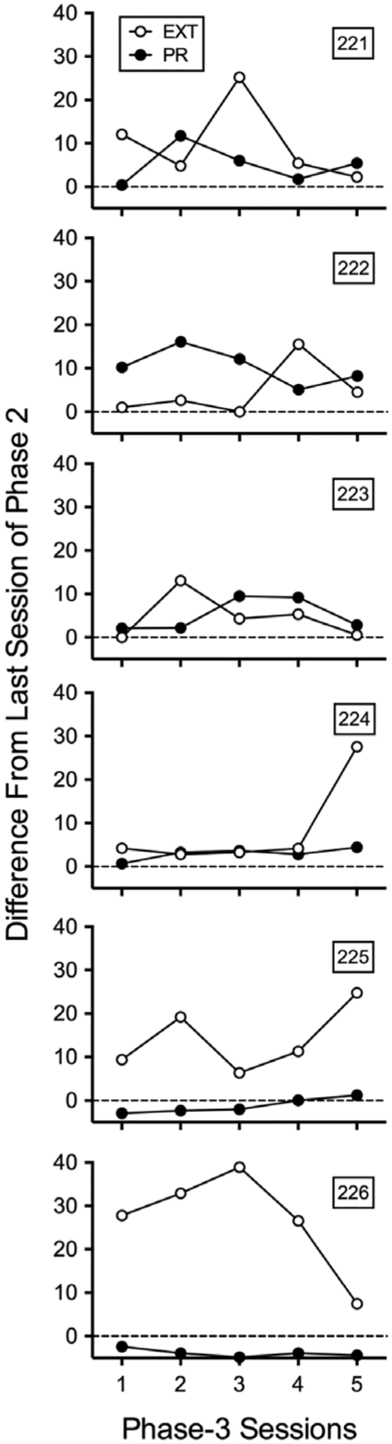

Fig. 9. Difference in response rate during PR- and Extinction-test sessions of Phase 3 relative to the last session of Phase 2 for target responding in Experiment 2.

Figure 10 is presented in the same format as Figure 4 from Experiment 1. The left two panels show alternative and target response rates during the last session of Phase 2 (leftmost data point) and across the incrementing ratios of the PR condition for all five sessions of Phase 3. The right two panels show alternative and target response rates during the last session of Phase 2 (leftmost data point) and across simulated reinforcers during Extinction-test sessions. For both PR and Extinction tests, target response rates during the last session of Phase 2 remained at or near zero while alternative response rates consistently were greater.

During PR testing shown in Figure 10, alternative response rates generally increased and then decreased with increases in ratio requirement (see also Killeen et al., 2009) but 225's rates only decreased. Target response rates were low during Phase 2 but increased at some ratios for all pigeons—increases were minimal for 225. Thus, increasing the ratio requirement for alternative reinforcement produced resurgence of target responding for all pigeons compared to the final session of Phase 2. Nevertheless, the size of the effect and the ratios in which resurgence occurred during PR tests were not systematic across pigeons.

During Extinction testing shown in Figure 10, alternative response rates tended to increase and then decrease with increases in simulated ratio requirement for four of six pigeons but rates only decreased for 224 and 225. Target response rates increased relative to Phase 2 at some simulated ratios for all pigeons. Thus, introducing extinction produced resurgence of target responding for all pigeons. Nevertheless, the size of the effect during Extinction testing was not systematically related to the simulated ratio across pigeons.

In comparing PR and Extinction testing in Figure 10, alternative response rates generally decreased with increased actual or simulated ratio requirement but levels of alternative responding tended to be lower during Extinction tests. In addition, responding reached larger ratios with PR testing than during Extinction testing for four of six pigeons but 223 and 224 were opposite. With regard to target responding, there were no systematic differences in increases in response rates between PR and Extinction testing among the pigeons.

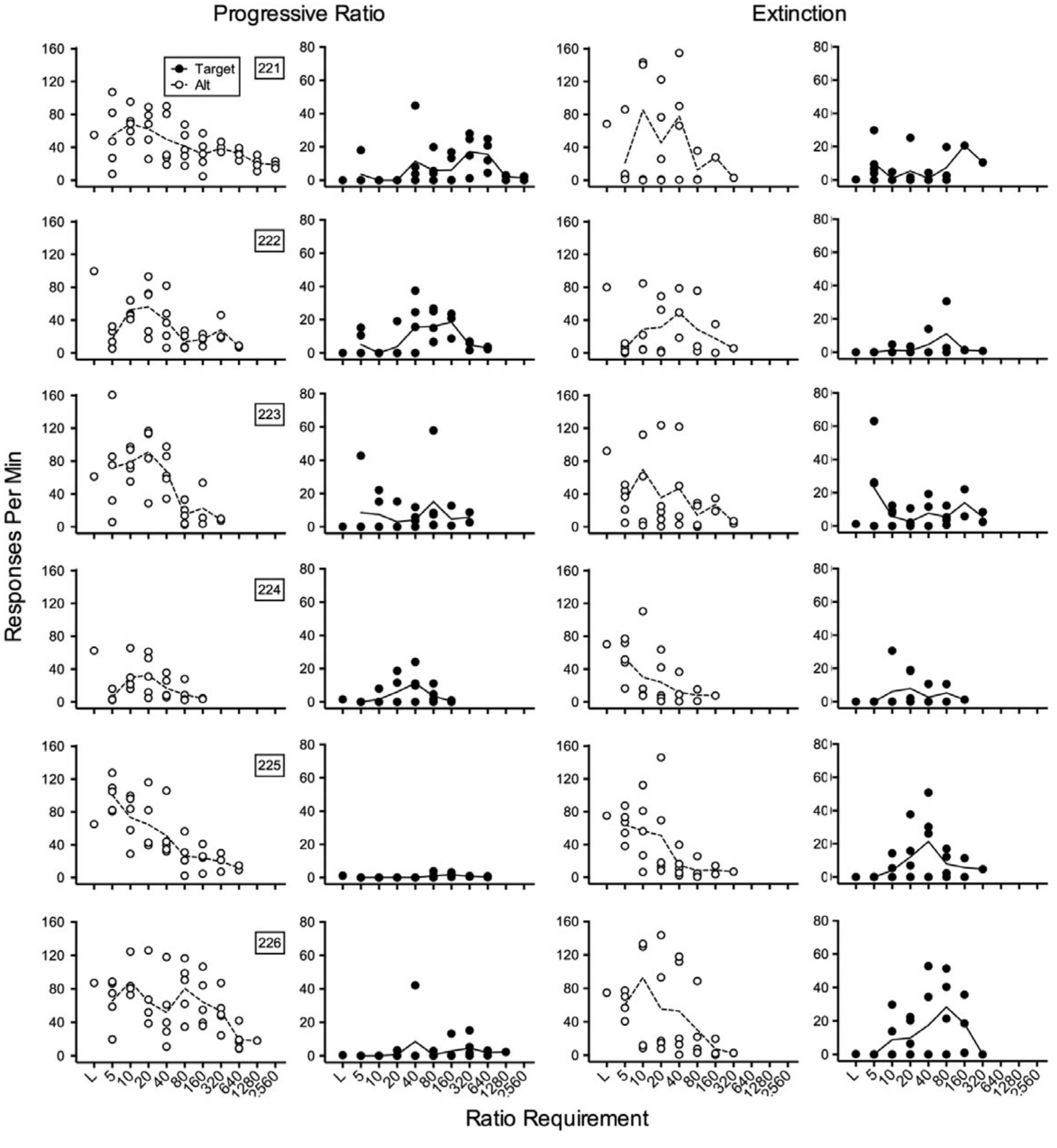

Fig. 10. Target and alternative responses per minute across the last session of Phase 2 (L) and across ratio requirements during PR-test sessions and simulated ratio requirements during Extinction-test sessions in Experiment 2. Lines in each panel indicate means. Note the open data points correspond with alternative responding and filled data points correspond with target responding among the columns.

Data in Figures 11 and 12 are presented identically as in Figures 5 and 6 from Experiment 1. They examine whether target responding during PR tests (Fig. 11) or Extinction tests (Fig. 12) correlates with alternative response rates (left columns) or alternative IRI (center and right columns) during test sessions. Data points plotted at 0.1 on the y-axis represent target responding at zero. The left columns show target response rates as a function of alternative response rates. The center columns show target response rates as a function of alternative IRI (Fig. 11) or simulated IRI (Fig. 12). The right columns show target response frequency as a

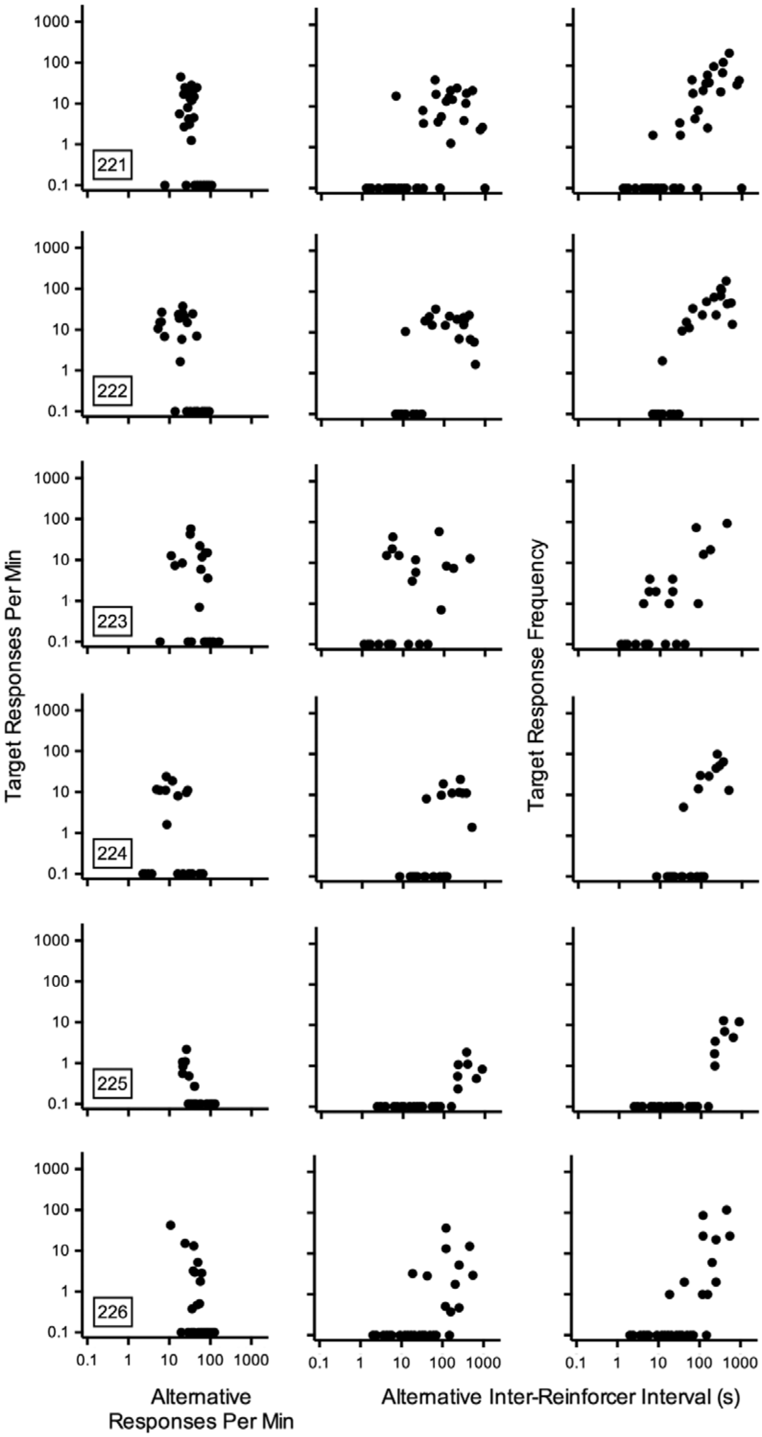

Fig. 11. The relation between target and alternative response rate (left column), between target responses per minute and alternative interreinforcer interval (middle column), and between target response frequency and alternative interreinforcer interval (right column) during PR-test sessions of Experiment 2. Note the logarithmic axes.

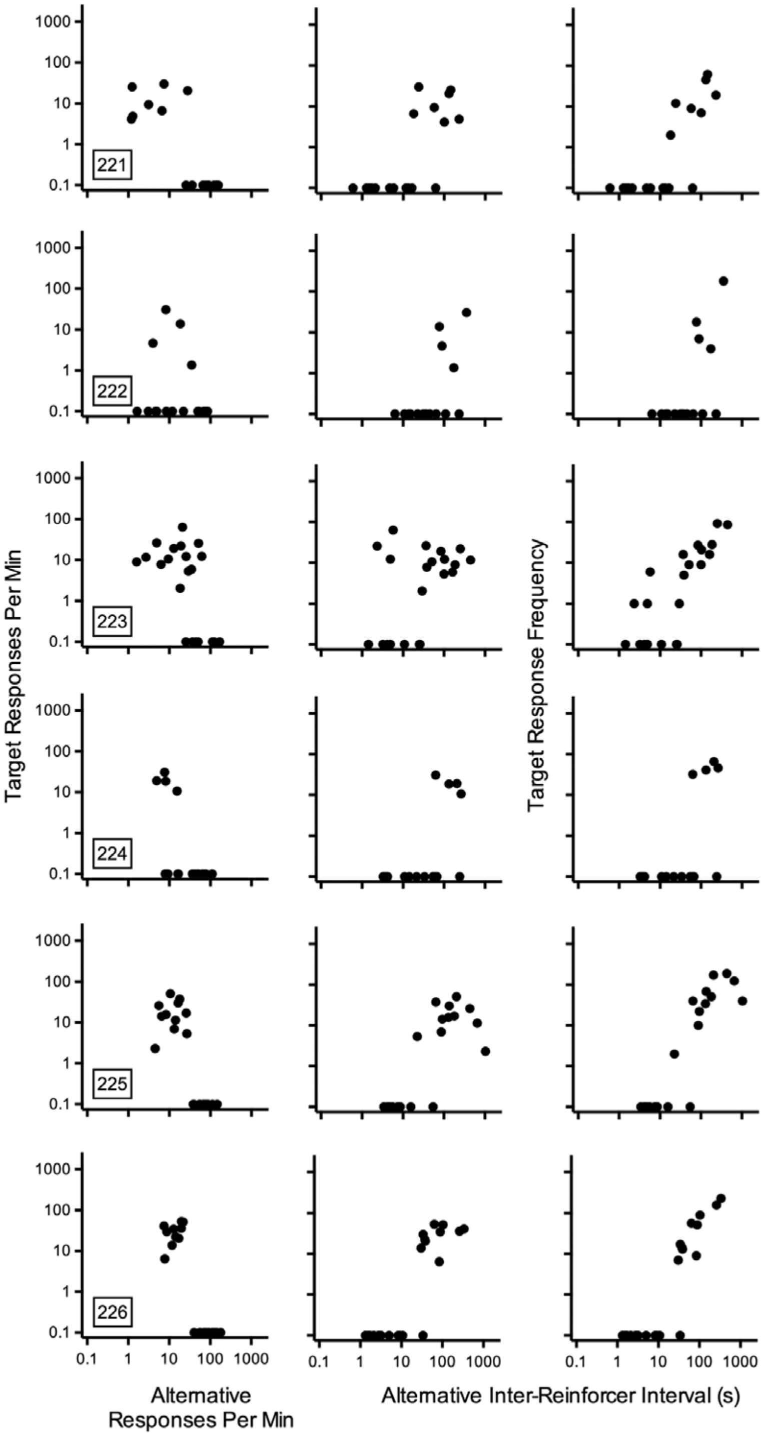

Fig. 12. The relation between target and alternative response rate (left column), between target responses per minute and simulated alternative interreinforcer interval (middle column), and between target response frequency and simulated alternative interreinforcer interval (right column) during Extinction-test sessions of Experiment 2. Note the logarithmic axes.

function of alternative IRI (Fig. 11) or simulated IRI (Fig. 12). Figure 13 summarizes all correlations from Figures 11 and 12.

The left columns of Figures 11 and 12 allow us to assess whether response competition could account for resurgence (see Podlesnik & Kelley, 2014, 2015, for discussion) by showing whether resurgence of target response rates increased as alternative response rates decreased. Neither PR nor Extinction testing reveal a consistent negative relation between target and alternative response rates across pigeons. These findings suggest resurgence of target responding was not directly influenced through competition with alternative response rates. Nevertheless, nonzero target response rates tended to be shifted left along the x-axis, that is, when alternative response rates were lower (except 222 during Extinction testing). These findings suggest response competition might contribute to resurgence but not in such a robust way as to produce clear correlations between target and alternative response rates.

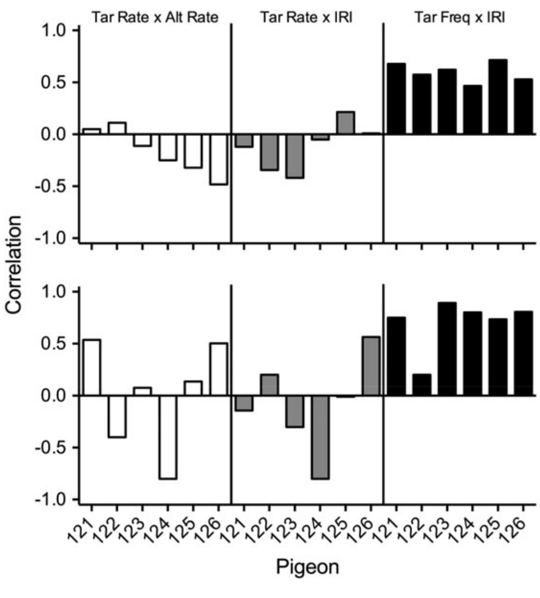

Fig. 13. Spearman's rank-order correlation coefficient during PR testing (top panel) and Extinction testing (bottom panel) across pigeons. White bars correspond to correlations between target responses per minute and alternative responses per minute, grey bars correspond to correlations between target responses per minute and IRI, black bars correspond to correlations between target response frequency and IRI.

The center columns of Figures 11 and 12 also show no clear positive relation between target response rates and alternative IRIs, suggesting the removal or omission of alternative reinforcers does not increase target response rates as assumed by Behavioral Momentum Theory (e.g., Shahan & Sweeney, 2011; Sweeney & Shahan, 2013). Two points need to be made. First, Figure 11 shows only simulated reinforcers from Extinction tests and IRIs are therefore not going to impact resurgence of target response rates. Second, the nonzero target response rates are shifted to the right of the zero-level data points in both Figures 11 and 12, suggesting a tendency for greater response rates at longer IRIs (Fig. 11) or with longer exposure to extinction contingencies (Fig. 12). Nevertheless, there is no clear correlation between target response rates and IRI.

The right columns of Figures 11 and 12 show a positive relation between frequency of target responses and alternative IRIs in Figure 11 and simulated IRIs in Figure 12. Therefore, longer durations between alternative reinforcers were correlated with more target responses in Figure 11 (see also Lieving & Lattal, 2003) and with longer exposure to extinction contingencies in Figure 12. In addition, nonzero target response frequencies are shifted to the right of zero-level data points in Figures 11 and 12, supporting the general correlation between target response frequency and obtained or simulated IRIs.

Finally, we assessed whether postreinforcement time was discriminated as a time of nonreinforcement for alternative responding, thereby inducing a return to target responding. The left side of Table 6 shows the percent of total time in PR-test sessions spent in the postreinforcement pause (PRP) defined as seconds between an alternative-food delivery and the first alternative response. Relatively little time was spent during PRPs, with no individual sessions exceeding 10% of the session. The right side of Table 6 shows the percent of target responses occurring during PRP relative to all target responses during PR-test sessions. Relatively few responses occurred during PRPs, with no individual sessions exceeding 10% of target responses within any session. Therefore, most resurgence of target responding during PR tests did not occur during PRPs but rather following reengagement of alternative responding.

Table 6

Percent of time during postreinforcer pauses (PRP) relative to total session time and percent of target responses emitted during PRPs relative to total target responses

	Percent Time			Percent Responses		
	Mean	Min	Max	Mean	Min	Max
221	1.3	0.5	3.3	0.9	0.0	2.3
222	0.9	0.5	1.7	0.0	0.0	0.0
223	3.2	1.0	8.3	1.9	0.0	8.3
224	0.9	0.5	1.8	0.0	0.0	0.0
225	1.6	0.5	4.0	3.8	0.0	9.2
226	0.6	0.5	1.0	0.0	0.0	0.0

Note: The medians, minimums and maximums are calculated from the five sessions of PR tests for each pigeon.

Discussion

Experiment 2 systematically replicated Experiment 1 by examining resurgence in pigeons when exposing alternative responding to extinction or decreases in reinforcer availability with PR schedules. The conclusions from Experiment 2 generally were consistent with those suggested from Experiment 1. Resurgence of target response rates tended to be greater during the Extinction tests than during the PR tests for four of six pigeons. In addition, resurgence with PR schedules systematically replicates previous findings of resurgence when thinning alternative reinforcement across successive sessions (e.g., Sweeney & Shahan, 2013; Winterbauer & Bouton, 2012). Therefore, resurgence occurs not only in the presence of conditions arranging extinction of alternative responding but also when alternative reinforcement conditions worsen (see Lattal et al., 2017; Shahan & Craig, 2017, for reviews).

We examined within-session patterns of responding during resurgence tests in an attempt to assess the variables contributing to resurgence. Resurgence of target response frequency tended to be more consistently related to IRI during PR schedules than either the relations between target response rates and alternative response rates, or between target response rates and IRI (see Fig. 11). These findings support the notion that local periods of nonreinforcement contribute to resurgence (e.g., Lieving & Lattal, 2003) over interpretations based on response competition (Podlesnik & Kelley, 2014) or behavioral momentum (Shahan & Sweeney, 2011).

Despite the relations between response frequency and IRI during PR testing, caveats need to be mentioned. First, we observed similar patterns of responding in Figure 12 during Extinction tests when simulating alternative IRIs. Therefore, it is unclear whether patterns of resurgence related to IRI are due to time between reinforcer deliveries per se or simply duration of exposure to a sufficiently reduced rate of alternative reinforcement (which remains undefined). Furthermore, there were a number of instances of target responding occurring at certain IRIs while no target responding occurred at other comparable IRIs. It remains unclear what would produce responding during a given IRI duration in one instance but not during others of comparable duration. This perplexity of why resurgence sometimes occurs at one time but not under other comparable situations also applies to Extinction testing. Therefore, exactly what occasions the production of target responding during resurgence tests remains to be understood.

General Discussion

In both Experiment 1 with children and Experiment 2 with pigeons, we observed resurgence of target responding when arranging extinction and PR schedules for an alternative response. Resurgence tended to be greater overall during Extinction tests than during PR tests in both experiments. During PR tests, target response rates did not consistently correlate with either the alternative response requirement or response rate, suggesting neither response competition (Podlesnik & Kelley, 2014, 2015) nor Behavioral Momentum Theory (Nevin et al., 2017; Shahan & Sweeney, 2011) adequately accounted for resurgence in the present experiments. The clearest relation was that target response *frequency* tended to be most closely related to obtained IRIs during PR tests and simulated IRIs during Extinction tests (see Lieving & Lattal, 2003, for related findings). Overall, we can conclude longer exposure to nonreinforcement tended to increase resurgence until responding ceased entirely. Because we found similar effects with simulated reinforcers during Extinction tests in the absence of alternative reinforcers, exactly what variables initiated target responding over alternative responding at any given time remains unclear.

In addition to the difficulties accounting for the data from the present experiments, Behavioral Momentum Theory generally has been shown to be flawed in its approach to accounting for resurgence both during typical extinction tests and when thinning alternative reinforcement (see Nevin et al., 2017; Shahan & Craig, 2017, for reviews). Behavioral Momentum Theory predicts that any and all reinforcers obtained in the presence of a discriminative stimulus contribute to response strength of the target response. It is unclear how Behavioral Momentum Theory should quantify the progressive changes in alternative reinforcer availability with changes in ratio requirement within sessions. Currently, there is no formulation of Behavioral Momentum Theory to account for how such local changes in alternative reinforcer rate might affect resurgence.

A different theoretical approach to understanding resurgence is Bouton and colleagues' Context Theory (see Trask, Schepers, & Bouton, 2015, for a review). Specifically, resurgence is described as an instance of a phenomenon called *renewal*, which forms a general theoretical foundation for understanding all treatment-relapse effects. After reinforcing target responding in one context (A) and extinguishing in another (B), the most common tests for renewal of extinguished target responding occur when returning to the original context (ABA renewal) or transitioning to another novel context (ABC renewal). According to Context Theory, resurgence is a case of ABC renewal (Winterbauer & Bouton, 2012). In Phase 1, reinforcement of target responding comprises one context (A). In Phase 2, extinguishing target responding and reinforcing alternative responding comprises a novel context (B). Finally, resurgence occurs because removing alternative reinforcers in Phase 3 arranges yet another novel context (C). Context Theory attributes resurgence when thinning alternative reinforcement schedules to gradually changing the context from B to C (see Winterbauer & Bouton, 2012). A similar approach would be used to account for resurgence with PR schedules in the present research. Although Context Theory presents an intuitive account of resurgence, the theory has been criticized for being unfalsifiable (see Podlesnik & Kelley, 2015; Shahan & Craig, 2017). In addition, as with Behavioral Momentum Theory, Context Theory also remains unable to define the variables producing instances of resurgence (see Winterbauer & Bouton, 2012). Specifically, Context Theory does not provide an explanation as to why resurgence of target responding in the present research occurred with some IRIs but not with others of similar or even longer durations (see Figs. 11 and 12).

A final theoretical framework relevant to understanding resurgence proposed by Shahan and Craig (2017) is Resurgence as Choice (RaC). The quantitative model is based in research and theory on choice in concurrent schedules (e.g., Baum, 1974; Baum & Rachlin, 1969; Herrnstein, 1970). Thus, resurgence is a particular allocation of behavior based on relative value between the target and alternative options. However, this model has yet to be formally evaluated beyond effectively simulating a range of resurgence effects. As with Behavioral Momentum Theory and Context Theory, the relevance of Resurgence as Choice also largely has been isolated to accounting for resurgence effects spanning relatively long time periods (i.e., sessions). Therefore, the extent to which the theory can address momentary changes in the allocation of behavior, as with resurgence with PR schedules examined in the present research, awaits further development.

We compared resurgence during the experimental PR tests with more typical resurgence testing during extinction of alternative responding. This allowed a comparison of progressively removing alternative reinforcers in Phase 3 with the standard resurgence assessment in which no reinforcers are delivered. Future research, however, might examine other comparisons. For example, the rate and distribution of alternative reinforcers during experimental conditions could be better controlled by using progressive-interval schedules than PR schedules (see Lattal, Reilly, & Kohn, 1998). Additional control conditions could arrange response-independent presentations of the reinforcing event yoked to the delivery of reinforcers delivered response- dependently according to the progressive schedule. Such conditions would assess the role of the presence versus absence of the contingency in comparison to the presence versus absence of reinforcer delivery assessed in the present study. Additional research examining alternative approaches to progressively removing reinforcer deliveries could provide additional insight into the processes contributing to resurgence.

A limitation of the present research common to many studies of resurgence was the absence of an unreinforced control response. A number of studies arranged unreinforced control responses throughout all phases to examine whether increases in responding during resurgence testing in Phase 3 are specific to the previously reinforced target response (i.e., resurgence) or due to more general increases in variability (e.g., Bolivar, Cox, Barlow, & Dallery, 2017; Sweeney & Shahan, 2016). To our knowledge, all studies employing control responses with nonhuman animals reveal little to no increases in control responding during resurgence tests (e.g., Craig & Shahan, 2016; Kuroda et al., 2017a,b). In Experiment 1, we similarly found that other responses functionally equivalent to target and alternative responding and emotional responses tended to be lower than resurgence of target responding (see also Liggett et al., 2018). Nevertheless, recent studies with university students as participants revealed no reliable difference in target and control responses during resurgence tests (e.g., Bolivar et al., 2017; Sweeney & Shahan, 2016). Maintaining control responses in studies of resurgence is important for ensuring increases in target responses are due to a reinforcement history rather than general increases in variability.

Overall, we found resurgence tended to be greater when eliminating alternative reinforcement compared to systematically reducing the availability of alternative reinforcement within sessions with PR schedules. These findings replicate others, revealing less overall resurgence when reducing availability of alternative reinforcement abruptly (e.g., Lieving & Lattal, 2003) or gradually across experimental sessions (e.g., Sweeney & Shahan, 2013; Winterbauer & Bouton, 2012). These findings also replicate Lieving and Lattal's observation that longer IRIs tended to result in more target responses, indicating resurgence resulting from momentary absence of alternative reinforcement. However, there were numerous IRIs of similar duration with and without accompanying increases in target responding. Therefore, the momentary variables influencing instances of resurgence remain to be determined. Assessments employing both animals and human participants are well suited to demonstrating the generality of effects (see also Kelley, Liddon, Ribeiro, Greif, & Podlesnik, 2015; Kelley, Nadler, Rey, Cowie, & Podlesnik, 2017; Nevin et al., 2016) while providing a platform from which to devise methods to mitigate resurgence of problem behavior resulting from omissions of alternative reinforcement during DRA treatments.

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