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A translational comparison of contingency-based progressive delay procedures and their effects on contextually appropriate behavior

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Schedule thinning is an essential step in treating problem behavior, yet little research has been conducted to determine the method associated with sustained treatment effects. A frequently used method for thinning reinforcement is contingency-based progressive delay, which requires the individual to meet some criteria before the reinforcers are returned. The response requirement could be dependent on (a) contextually appropriate behavior (differential reinforcement of alternative behavior-based thinning) or (b) absence of problem behavior (differential reinforcement of other behavior-based thinning). A translational arrangement with college students was implemented to determine the effects of these 2 response requirements. Tolerance was observed regardless of thinning method and was indicated by low rates of responding to the analogue problem behavior; however, more contextually appropriate behavior occurred during differential reinforcement of alternative behavior-based thinning. These results support the use of response requirements for behaviors that are expected of the individual when reinforcement is not immediately forthcoming.

Key words: contextually appropriate behavior, contingency-based delay, schedule thinning, translational research

Function-based treatments are designed based on the results of functional assessment in which variables reinforcing problem behavior are identified. Functional communication training (FCT) is a widely used function-based treatment in which the individual is taught an appropriate communicative response to obtain the stimuli identified as reinforcing problem behavior (Tiger et al., 2008). Extinction is typically procedurally arranged for the problem behavior during FCT, meaning the reinforcer identified to be contributing to problem behavior is reserved only for targeted appropriate behavior. FCT was first used to successfully treat problem behavior by Carr and Durand (1985) and its efficacy has since been repeatedly demonstrated in single subject designs and consecutive case analyses (e.g., Hagopian et al., 1998; Rooker et al., 2013). Furthermore, FCT has met criteria to be designated as a well-established treatment for problem behavior (Kurtz et al., 2011).

Although there is a great amount of empirical support for the utility of FCT, continuous access to reinforcers for appropriate communication is by no means meant to be a sustainable goal. Once the target communicative response is successfully taught, it is often impractical to reinforce each functional communication response and schedule thinning is an essential step in creating effective and socially significant treatments. Schedule thinning is the systematic change in a schedule of reinforcement to decrease the rate or density of reinforcer delivery. Thus, to maintain and generalize treatment outcomes in the individual's home or school environment, schedule thinning is often the

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next step in this treatment process and is considered a crucial component of FCT treatments (Hagopian et al., 2004).

It is also essential for the researcher or clinician to maintain decreases in problem behavior throughout the progressive thinning of the reinforcement schedule. Maintained reductions have been noted as one of the most difficult challenges when thinning schedules of reinforcement (Hagopian et al., 2011). A large-scale study by Hagopian et al. (1998) investigated FCT treatments implemented with 21 individuals with problem behavior, focusing on the necessity and efficacy of extinction and punishment in these individual interventions. The investigators found that extinction was necessary to observe substantial reductions in problem behavior, and furthermore, that problem behavior increased during schedule thinning for five out of 12 participants experiencing schedule thinning. For these five participants, punishment procedures were necessary to reduce problem behavior by more than 90%. More recently, Greer et al. (2016) retrospectively analyzed the data of 20 participants admitted to an outpatient clinic who experienced FCT and schedule thinning. Although schedule thinning was largely successful for maintaining reductions in problem behavior, 60% of the participants still exhibited some problem behavior during schedule thinning with 25% of the participants requiring supplemental procedures to reduce problem behavior further.

Chained schedules involve a specific reinforcement thinning procedure in which an alternative response requirement is gradually increased before the reinforcer is delivered for the functional communication response. Chained schedules have historically been used in situations in which there is an additional aim to increase an alternative, contextually appropriate behavior (Hagopian et al., 2011). For example, if a child is engaging in problem behavior in the classroom, teachers may identify sitting at a table and completing work as the contextually appropriate behavior. In another example, if the problem behavior is occurring in the home, the caregiver may select interactive play with others as the contextually appropriate behavior. In recent literature, two variations of chained schedules have been developed, including one in which a contingency is specifically programmed for contextually appropriate behavior and one with no such contingency.

In the first arrangement, the reinforcers are provided following an increasing number of contextually appropriate behaviors emitted by the participant. This iteration is designated as differential reinforcement of alternative behavior (DRA) based thinning because the contingency requirement targets a specific alternative repertoire during the delay. The response requirement of the second iteration is dependent on the absence of problem behavior during the progressively increasing delays. It has been termed differential reinforcement of other behavior (DRO) based thinning because the participant can engage in any behavior other than that which is targeted for treatment for a programmed interval of time to regain access to the reinforcers. Thus, both iterations have been termed contingency-based progressive delays (CBPD; Ghaemmaghami et al., 2016) because reinforcement is dependent on behavior.

Hanley et al. (2014) evaluated CBPD procedures using both DRA- and DRO-based thinning simultaneously for three participants diagnosed with autism exhibiting problem behavior. After engaging in the functional communication response, response requirements during the comprehensive treatment evaluation involved following adult instructions (i.e., DRA-based) and simultaneously requiring the tolerance of less preferred activities for a certain period of time (i.e., DRO-based). The combination of CBPD thinning procedures resulted in decreased levels of problem behavior and increased compliance with instructions (contextually appropriate behavior) during periods of reduced access to reinforcers for all children. Furthermore, the caregivers reported the treatment package including CBPD to be highly acceptable.

Ghaemmaghami et al. (2016) further evaluated the importance of contingency requirements during reinforcement thinning by comparing tolerance in CBPD procedures to another form of schedule thinning in which the reinforcers were delivered after a delay regardless of problem behavior (i.e., time-based progressive delays). Of current relevance, the experimenters created an isolated comparison between DRA- and DRO-based reinforcement thinning for one participant (Will). After engaging in the functional communication response, Will was either required to complete a specified number of contextually appropriate behaviors (DRA-based thinning) before receiving reinforcement or wait a specified amount of time without engaging in problem behavior (DRO-based thinning) before receiving reinforcement. Only the DRA-based thinning procedure supported contextually appropriate behavior while maintaining the greatest reductions in problem behavior. These results indicated a possible difference in efficacy depending on the procedure used. This also suggested that DRA-based thinning may be sufficient without the need to be combined with a DRO-based component to create a more efficient treatment procedure. Therefore, it may be important to continue to comparatively evaluate the two CBPD procedures separately.

In a consecutive controlled case series of 25 participants, Jessel et al. (2018a) maintained this distinction between CBPD procedures and identified cases in which DRA-based, DRO-based, or the combination may be best applied. When caregivers reported difficulties with compliance during instructional periods (15 of 25 cases), the authors implemented the DRA-based thinning strategy. Some caregivers wanted a treatment for their child that maintained a level of independence with other activities, allowing the adult to complete household tasks while more passively supervising the child. The DRO-based thinning strategy was implemented for those participants (6 of 25 cases). Finally, some combination of requests from caregivers resulted in the implementation of the combination of CBPD procedures (4 of 25 cases). Although problem behavior was reduced by 90% from baseline levels, contextually appropriate behavior was not specifically targeted. In addition, only one set of CBPD procedures was prescribed for each participant based on the specific parental reports and no within-participant comparison was made. Therefore, it is difficult to determine the relative efficacy of DRA- or DRO-based thinning techniques based on the available literature.

The purpose of the present study was to expand the literature on schedule thinning by directly comparing the effects of DRA- and DRO-based thinning on problem and contextually appropriate behavior using a translational model. Translational research provides benefits in practicality and efficiency, by allowing researchers to obtain a large sample of participants and to answer relevant questions more rapidly than by conducting applied research. In addition, this method of research has proven to be an effective way to better understand behavioral principles related to appropriate treatment options for individuals with developmental disabilities and associated problem behavior before application to the intended population (e.g., Jessel et al., 2015; Mendres & Borerro, 2010).

Method

Participants

Fifty-six undergraduate students were recruited from general psychology courses. All students were granted mandatory research credits for their courses and were entered into a drawing for a cash prize. The participants' ages ranged from 18 to 22 years old. Students selected for participation were required to have previous experience with computers, be able to manipulate a computer mouse and keyboard independently, and be able to complete three-digit by two-digit multiplication. Inclusion in and exclusion from the experimental comparison depended on responding during Phase 1 and 2 and is detailed below.

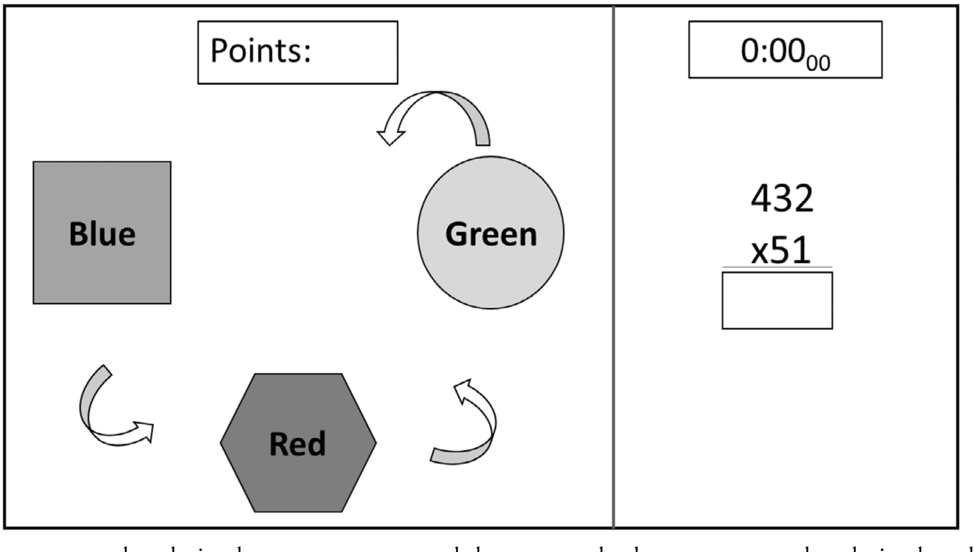
Apparatus and Setting

Participants were situated in a room at an urban university. Throughout the study, participants played a computer game. A sample screenshot of the program is displayed in Figure 1. For all conditions, on the left portion of the screen, three colored shapes (a blue square, a red hexagon, and a green circle) moved around and a point box displaying the number of points earned was presented at the top of the screen. In addition, three-digit by two-digit math problems, an answer submission bar, and a stopwatch were displayed on the right portion of the screen. All response options, including all shapes and math problems, were visible on the screen and available for responding or completion in all phases of the study and under all conditions. Participants could earn points by engaging in specific responses, including clicking on a colored shape, completing math problems, or waiting a specified amount of time. Whether or not a point was earned depended on the phase and condition of the study. After a predetermined variable ratio (VR) requirement, the shape disappeared and reappeared in a random location within the left portion of the screen; this occurred regardless of whether the VR satisfaction resulted in a point or the start of a schedule thinning interval. In addition, each time a point was earned, a "ding" sound played from the computer, the point box was illuminated, and the number in the point box increased by one.

Dependent Variables and Data Collection

The number of clicks on each colored shape, as well as math problems completed correctly, were recorded separately by the computer

Figure 1
Sample Screenshot of Computer Program



Note. Arrows are used to depict shape movement around the screen and color names are used to depict the color seen by the participants.

program. Because individuals referred for the assessment and treatment of problem behavior have a history of reinforcement with a previously reinforced response (i.e., problem behavior), a specific colored shape (i.e., the blue square) was assigned as the target response to be reinforced initially. Clicks on the target response were analogous to target problem behavior due to this initial reinforcement history. In addition, when treating problem behavior with FCT, an alternative response (i.e., the functional communication response) is reinforced while problem behavior is placed on extinction. Therefore, clicks on the alternative response (i.e., the red hexagon) were analogous to the alternative functional communication responses. Lastly, clicks to a third shape, the green circle, served as a control response; clicks to the green circle were never reinforced throughout the study. Math problems were the contextually appropriate behavior. The number of clicks to each shape, as well as the number of math problem completed correctly, were divided by the duration of the session and reported as responses per minute.

Experimental Design

In the preassessment phase, a probe reversal design was used to determine if the points functioned as reinforcers. Experimental control was demonstrated when higher rates of the target response were observed during the first and third probes (contingent reinforcement) in comparison to the second probe (no programmed reinforcement). In the treatment comparison, a multielement design was embedded within a multiple baseline design across participants. The independent variable of the multiple baseline design across two participants was schedule thinning, and the independent variable of the multielement design was the type of schedule thinning (DRA- or DRO-based thinning procedures). The multiple baseline was limited to a single staggered replication because including a third participant would have extended the duration of the appointments past that required for course credit.

Procedures

Participants signed up for two 1-hr appointments; Phase 1 and Phase 2 were conducted during the first appointment and Phase 3 was conducted during the second appointment. Participants could choose to schedule both appointments on the same day or on two separate days within a 4-day span of time. Prior to the start of the study and while obtaining consent, the participants were informed of the rules for earning three possible monetary rewards. The three participants who earned the highest number of points were given a monetary reward ($50.00 for first place, $25.00 for second place, and $10.00 for third place) after the completion of the study. Prior to starting the study, the first screen displayed in the computer game contained the following instructions:

> Thank you for your participation in this study. Your goal is to earn as many points as possible before the time is up. There are different ways to earn points. Clicking on one set of colored buttons or completing math problems could either add to your earnings or not affect your earnings. All of your earnings will be visible at the top of the screen. You are free to leave at any point during the study; however, credit for your participation will only be granted following the completion of the study in its entirety.

Phase 1: Preassessment

The preassessment phase was conducted to determine eligibility of participants. Participants were eligible to participate if it was demonstrated that point delivery functioned as a reinforcer. This was determined by analyzing clicks per minute of the target response when these clicks were and were not reinforced. For eligible participants, this preassessment phase was also used to establish responding to the target behavior (analogue problem behavior) using a VR2 schedule. The VR2 schedule was selected based on pilot data suggesting it could produce differentiated responding within the brief sessions (i.e., leaner schedules required extended time for the pilot participants to begin earning points consistently). In the preassessment condition, a white background was visible on the computer program. The visible stopwatch counted to a random time predetermined by the computer software and reset continuously throughout each session regardless of responding.

The preassessment included three 5-min sessions. In the first and third session, the target response was reinforced (on a VR2 schedule of reinforcement) and no reinforcement was programmed for clicks on any other shape or for completing math problems. The second session was identical to the first and third sessions with the exception of placing the target response on extinction (i.e., no points delivered for clicks on any shape). Any participant for whom experimental control (i.e., lower rates of clicks to the target response in the second session and higher rates of clicks to the target response in the first and third session) was not demonstrated was excluded from participation in the present study. Participants could also be excluded from the remainder of the study if they did not attend the second part of the study or if procedural integrity errors occurred (i.e., incorrect session was set up on the computer).

Phase 2: Reinforcement of Alternative Behavior

Phase 2 consisted of either four or six 3-min sessions. That is, the baseline (i.e., treatment prior to schedule thinning) was four sessions long for half of the participants and six sessions long for the other half. Participants were randomly assigned to receive either four or six sessions. In all sessions, the target response was placed on extinction and the alternative response was reinforced on a VR2 schedule of reinforcement. No reinforcement was provided for clicks to the control response or completion of math problems. The visible stopwatch again counted to a random time and reset throughout the sessions.

In this phase of the study, participants were excluded if no responding to the alternative response occurred in these sessions. Whereas the contingencies were the same in all sessions of Phase 2, the background visible on the screen alternated between different seasons. In Phase 3, these backgrounds were used to signal the programmed method of thinning reinforcement. The Summer background was correlated with the condition in which the participants experienced the DRA-based thinning and the Winter background was correlated with the DRO-based thinning procedures.

Phase 3: CBPD Comparison

In this phase, DRA-based thinning was compared to DRO-based thinning in a series of twelve 5-min sessions. Schedule thinning methods were similar to those used in the CBPD condition of the study by Ghaemmaghami et al. (2016). In the DRA-based condition, clicks to the alternative response (VR2) resulted in a message that appeared on the screen that read "Time to do math." The message appeared in the center of the screen but did not block any responses. In addition, the content of the message in both conditions matched those used in clinical evaluations of CBPD (e.g., Ghaemmaghami et al., 2016). In the DRA-based condition, while the message was displayed, the participant was required to complete a certain number of math problems before the point was delivered. After the math problem schedule was satisfied, a point was delivered, and the message disappeared. That is, to earn a point in the

DRA-based thinning condition, participants were required to click on the alternative response (VR2), then complete the math problems. Much like the previous phases, there were no contingencies arranged related to the stopwatch as it continued to reset at random intervals.

In the DRO-based thinning condition, clicks to the alternative response (VR2) resulted in a message that appeared on the same portion of the screen as in the DRA-based condition that read “You can do math if you want.” After the passage of time without any clicks on the target response, the participant earned a point and the message disappeared. In these sessions, a variable, whole-interval resetting DRO was used. The DRO time period required to elapse without clicks to the target square was yoked with the average time period during which, in the DRA-based thinning condition, participants were engaged in completing math problems. The time of each DRO interval within a session was randomized around the mean time the participant was engaged in math problems in the DRA-based session immediately prior. That is, the mean duration of the randomized intervals was individually calculated for each DRO session. The stopwatch on the right portion of the screen counted toward the yoked variable time before resetting; because a resetting DRO was used, if the participant engaged in the analogue problem behavior (i.e., clicks on the target response) the stopwatch reset to zero. To earn a point in the DRO-based thinning condition, participants were required to click on the alternative response, then refrain from clicking on the target response for a period of time; completion of math problems had no impact on reinforcer deliveries.

The participants first experienced two DRA-based thinning sessions in which the math problem requirement was set at a mean of 2.5 math problems (Step 1). The computer program calculated this mean of responses by randomly rotating through numbers of a range 1 to 4 (Step 1) without replacement; once all numbers in the range were used, a novel order was randomized. The steps in schedule thinning progressed by multiplying the highest number in the range by two. Therefore, the participants subsequently experienced two sessions in which the math problem requirement increased to a programmed mean of 4.5 with a range of 1 to 8 (Step 2), and lastly, two sessions in which the requirement increased again to a mean of 8.5 with a range of 1 to 16 (Step 3). We used VR schedules of reinforcement because it represented the purposeful programming of unpredictable thinning requirements specified in the CBPD research (e.g., Ghaemmaghami et al., 2016). Thus, the range was progressively increased and the participants were presented with a varied and unknown amount of math problems to complete. Although the response required during DRA-based thinning is typically increased in an arithmetic sequence (e.g., 1, 2, 3, 4), a geometric sequence was used to expose the participants to larger differences in steps that could not be obtained otherwise within the brief amount of time. Each DRA-based thinning session was followed by a DRO-based thinning session in which the time required to pass without target responding was yoked with the DRA-based thinning session immediately prior.

Data Analysis

Data were analyzed for all participants who completed the entire study. Individual participant data (available upon request) were visually analyzed and categorized as differentiated or undifferentiated depending on the pattern of responding in math problem completion. Data sets from participants who consistently engaged in high rates of math problem completion in DRA-based thinning (i.e., condition in which point earning required math problem completion) and lower rates of math problem completion in DRO-based thinning (i.e., condition in which point earning was not contingent on math problem completion) were considered differentiated. A panel of three doctoral-level Board Certified Behavior Analyst®s (BCBA-D®s) with extensive experience visually analyzing single-case design graphs reviewed all participant data and categorized each as differentiated or undifferentiated; disagreements were discussed until a unanimous agreement was reached.

An analysis of optimal responding was also conducted for math completion during DRA-based reinforcement thinning. We calculated a value of optimal responding to determine the extent to which participants contacted the programmed reinforcer deliveries. During the DRA-based thinning condition, the participants had to engage in a new chain of responding to earn points (i.e., alternative response then completion of a certain number of math problems) and an optimal response rate would suggest that the participants were minimizing responding while maximizing reinforcement. Values were calculated for each participant by dividing the total number of math problems completed by the ratio requirement to earn reinforcement and dividing this quotient by the total number of reinforcers (i.e., points) earned. An optimal reinforcement value equal to 1 indicated optimal responding in that the participant completed the exact number of math problems needed to earn reinforcers. A value less than 1 indicated that the participant was responding suboptimally and completed more math problems than needed to earn reinforcers.

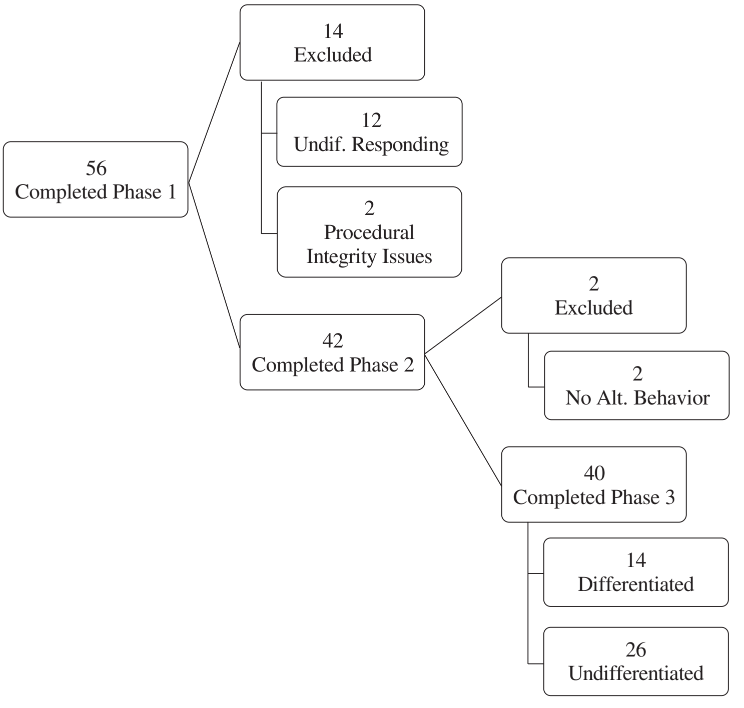
In addition, a 2 x 3 within-subjects repeated measures analysis of variance (ANOVA) was completed using version 25 of the SPSS software and the data from Phase 3. The two levels of treatment type were DRA- and DRO-based schedule thinning and the three levels of repeated measures were schedule thinning step (1, 2, or 3). Effects of these variables were evaluated for the two dependent variables most relevant to the purposes of the present study, including clicks on the target response and math problems completed correctly.

Results

Participant exclusion/inclusion is presented in Figure 2. Fifty-six participants were recruited for the current study. After the preassessment (Phase 1), a total of 14 participants were excluded. Twelve participants were excluded because they did not qualify based on patterns of responding indicating that points did not serve as reinforcers. Two participants were excluded due to procedural integrity issues. Two additional participants were excluded following Phase 2 due to lack of responding to the alternative response. Forty participants in total completed the study in its entirety.

Figure 3 depicts the mean rate of responding across all responses (i.e., target, alternative, and control) and math problems completed correctly. For all participants, elevated rates of clicks on the target response and low rates of clicks on the alternative response were observed in the first session of Phase 1 when points were contingent on the target response. Lower rates of clicks on the target response were observed when all responses were placed on extinction in the second session within Phase 1. The highest rates of the target response were observed in the final session of Phase 1 when points were again available contingent on the target response. In addition, all participants engaged in the highest rates of clicks on the alternative response in Phase 2, when points were contingent on alternative responding. When schedule thinning was initiated in Phase 3, alternative responding decreased while target and control responding remained low in the DRA-based thinning condition. Furthermore, the rate of math completion was the only measure to substantially increase, supporting a predictable reallocation of alternative responding to math completion during the delayed access to reinforcement. In the DRO-based thinning

Figure 2
Summary of Participant Inclusion



Note. Undif. refers to undifferentiated. Alt. refers to alternative.

condition, alterative responding decreased as well. However, there was a more equal reallocation across all response alternatives (i.e., target, alternative, control, and math completion). Therefore, most participants engaged in some behavior during the delay but only the DRA-based thinning condition was associated with more math completion than any other response option.

Figure 4 depicts the categorization of differentiated and undifferentiated outcomes as well as the results of the analysis of optimal responding. Fourteen out of 40 participants (35%) exhibited differentiated completion of math problems (i.e., higher rates of math problem completion in DRA-based thinning and lower rates in DRO-based thinning) and 26 participants (65%) engaged in undifferentiated math problem completion. The mean optimal value during DRA-based thinning was higher among participants who exhibited differentiated responding to the math problems compared to participants with undifferentiated responding. This suggests that the responding of participants with undifferentiated data may not have been appropriately discriminated between the contingencies once reinforcement thinning began. Considering only the participants with comparable rates of optimal responding (n = 23), the percentage of participants with differentiated math completion increased to 61% (14 of 23) and the percentage of participants with undifferentiated math completion decreased to 39% (9 of 23). Therefore, those who responded optimally tended to complete more math problems in the DRA-based reinforcement thinning condition compared to the DRO-based thinning condition.

Figure 3
Mean Responses Across Experimental Phases

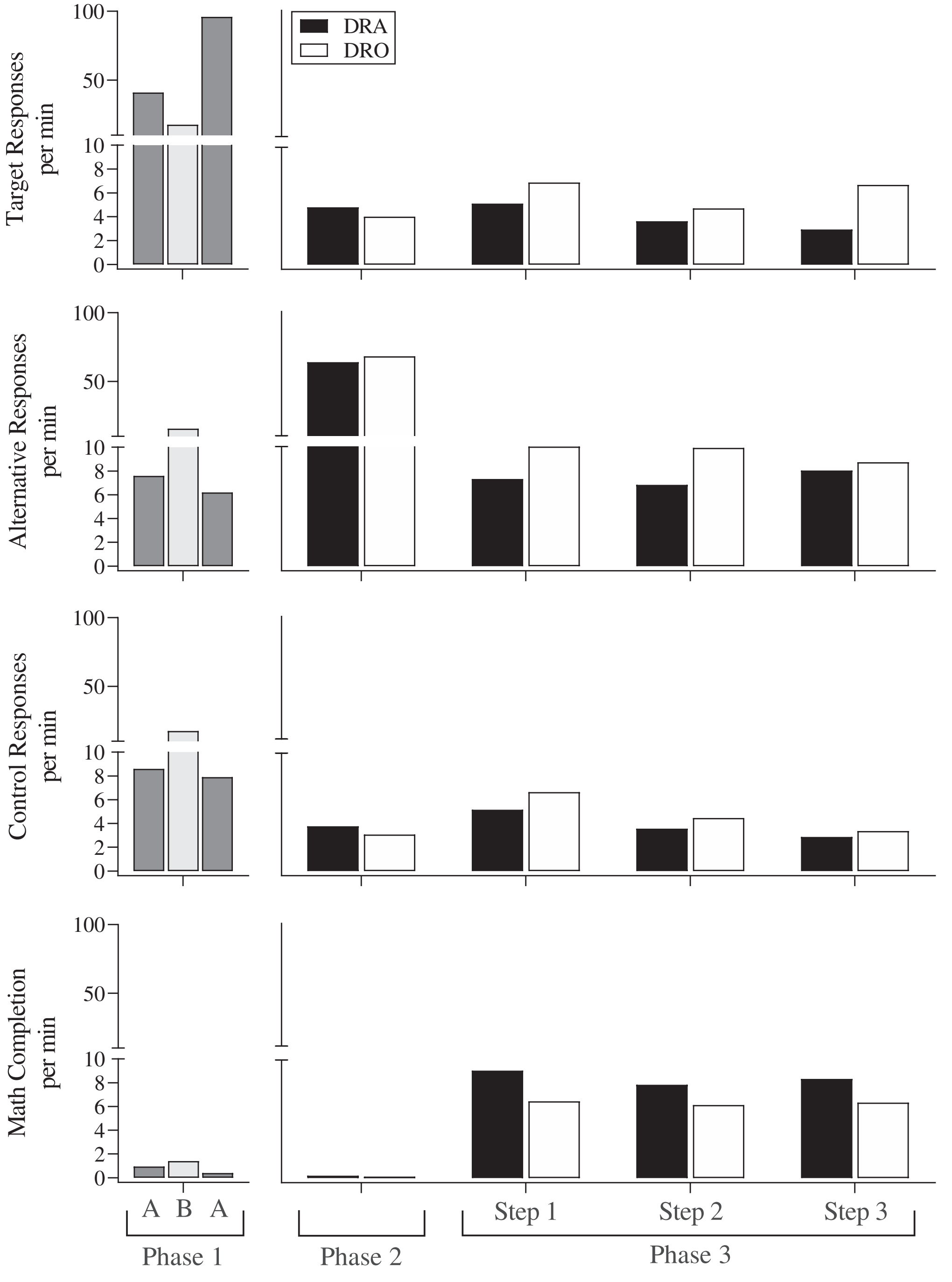
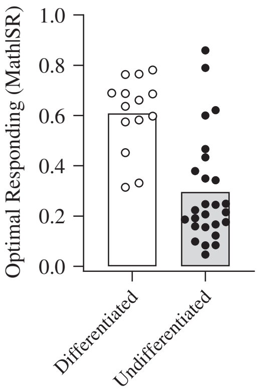


Figure 4
Values of Optimal Responding During the DRA-Based Thinning Condition



Note. Circles represent individual data for each participant. Bars represent the means across participants.

The repeated measures ANOVA of all participant data revealed a statistically significant difference in the average number of math problems completed in DRA and DRO-based thinning sessions with the higher amount of math problems completed correctly in the DRA-based thinning sessions ($F(1,39) = 5.48$, $p \leq .05$). No statistically significant difference was found between steps of schedule thinning for math problem completion. In addition, no statistically significant difference was found between the average clicks per minute on the target response in the DRA- and DRO-based thinning sessions. In the analysis of schedule thinning steps, no statistically significant difference was found in average clicks per minute on the target response between steps of schedule thinning.

Representative data for two participants engaging in differentiated responding are presented in Figure 5. In Phase 2, in which the alternative response was reinforced on a VR2 schedule of reinforcement, high rates of clicks to the alternative response, low rates of clicks to the target and control responses, and low math problem completion was observed. In Phase 3, both methods of schedule thinning were initially effective (i.e., in Step 1) at increasing math problem completion for P125, whereas there was a decreasing trend during DRO-based thinning for P104. By Step 2 of schedule thinning, more math problems were beginning to be completed during DRA-based thinning for both participants. In Step 3 of schedule thinning, zero rates of math problem completion were observed in DRO-based thinning and high levels of math problem completion were observed in DRA-based thinning. Clicks on the target and control responses remained low regardless of thinning condition.

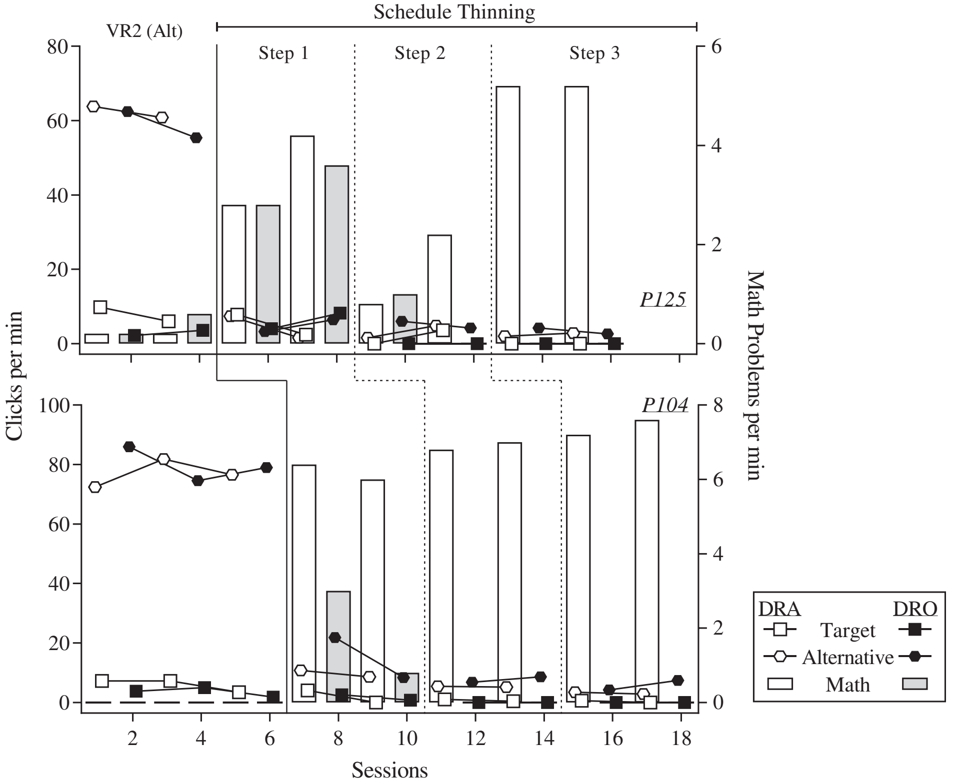
Representative data for two participants engaging in undifferentiated responding are presented in Figure 6. Similar to the data shown in Figure 5, high rates of clicks on the alternative response and low rates of clicks on the target response were observed in Phase 2. Throughout schedule thinning, high and comparable rates of math problem completion were observed in both DRA-based and DRO-based thinning sessions. Clicks on the target and control responses remained low regardless of thinning method.

Discussion

Regardless of the specific technique implemented, CBPD proved to be an efficacious method of schedule thinning as low rates of analogue problem behavior were observed throughout the comparison. Furthermore, math problem completion was overall higher in DRA-based thinning compared to DRO-based thinning. This suggests that DRA-based thinning procedures may maintain reductions in problem behavior as effectively as DRO-based procedures with the added benefit of strengthening a repertoire of contextually appropriate behavior.

The success of DRA-based thinning may be attributed, at least in part, to the maintenance of a positive contingency when reinforcement

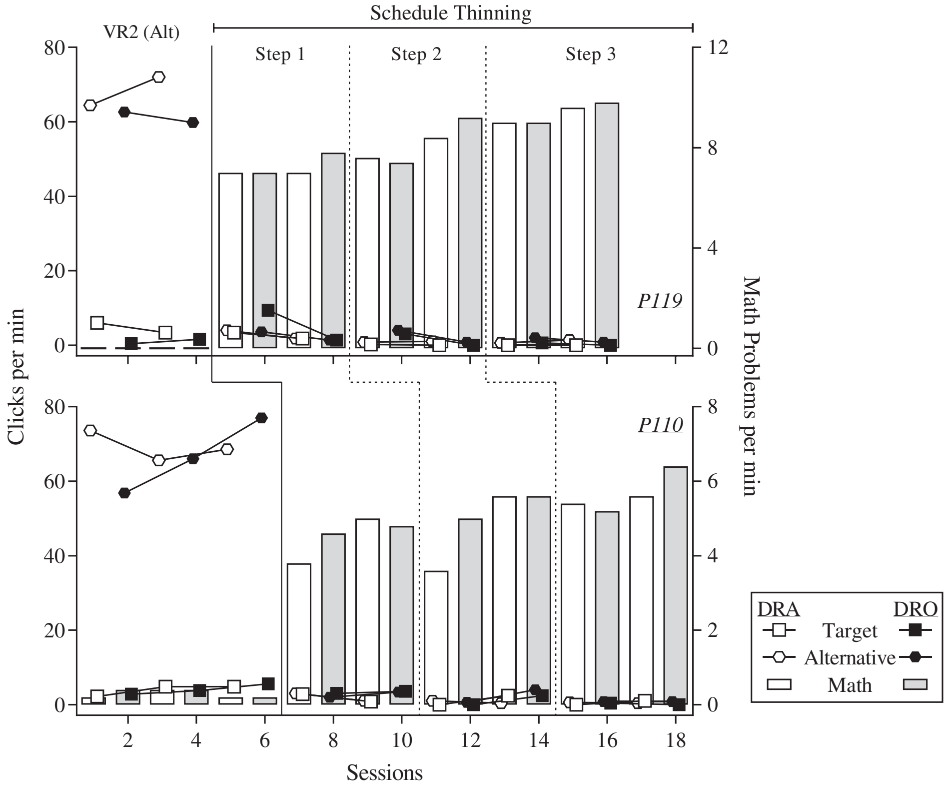
Figure 5
Sample Data of Participants with Differentiated Outcomes



was no longer provided for the alternative response. Luczynski and Hanley (2014) conducted a study comparing the effects of various schedules of reinforcement on the rate of mands for attention and participant preference for these schedules with five typically developing children. Luczynski and Hanley found that multiple schedules (alternating periods of continuous reinforcement and extinction) maintained the most efficient levels of responding in comparison to delayed reinforcement. Furthermore, the participants typically preferred the multiple schedule arrangement. The authors also calculated contingency strength values that indicated the multiple schedule arrangement was associated with stronger positive contingencies, which likely influenced the participants' preferences. Similarly, DRA-based thinning programs a strong positive contingency and essentially limits any experienced delay to reinforcement with the behavioral chain. Future researchers may consider comparing multiple schedules and DRA-based thinning. DRA-based thinning is likely to maintain a stronger positive contingency due to the extended periods of extinction experienced in a multiple schedule.

Although DRO-based thinning programs a negative contingency, the use of a specific CBPD procedure may be dependent on caregiver expectations when reinforcement is not available. For example, DRA-based thinning is possibly more suitable in classroom settings where a teacher is providing constant instructions to the student who is expected to complete tasks during the delay. On the other hand, caregivers may find DRO-based thinning

Figure 6
Sample Data of Participants with Undifferentiated Outcomes



more appropriate at home when they are not available to provide instruction and the individual is permitted to engage in an array of alternative activities when the functional reinforcers are restricted. However, the paucity of research in this area leaves these socially guided usages of the CBPD procedures in need of further validation. In addition, if the treatment is expected to maintain improvements in problem behavior under multiple and varying conditions, it may require some combination of both DRA- and DRO-based thinning to ensure the individual can tolerate a range of different types of delays experienced in various contexts.

For example, the caregivers of some of the participants from Jessel et al. (2018a) indicated difficulties during transitions and instruction. Following a functional analysis that supported the caregivers' concerns and a treatment process involving the acquisition of complex communication responses, schedule thinning began. The first stages of thinning involved DRA-based procedures with a progressively increasing number of tasks required to complete before the reinforcers were re-presented. Once the participant completed a specifically targeted number of tasks, the DRO-based procedures were introduced that included a progressively increasing duration of time without problem behavior. At the terminal goal of reinforcement schedule thinning, the participants tolerated both types of CBPDs.

It is important to note that moderately high rates of contextually appropriate behavior were observed in the DRO-based thinning condition of the current study and, in some cases, were comparable to levels of math completion in the DRA-based thinning condition. There are several possibilities for these outcomes. First, the completion of the math problems could have been adventitiously reinforced. Jessel et al. (2015) conducted a study with 13 college students earning points on a computer program. There were two available responses, one of which never produced the reinforcer, and the participants were exposed to three unsignaled probes (i.e., DRO, noncontingent reinforcement, extinction) interspersed with contingent reinforcement for the target response. All probes reduced target responding; however, the nonreinforced other behavior occurred at elevated rates only in the DRO probe. The authors found that the other behavior was likely to occur immediately before the reinforcer was delivered in the DRO interval and therefore, concluded that other behavior was adventitiously strengthened by the contiguous pairing. The math completion in the current study could have been similarly strengthened by points delivered on the DRO interval around the time the participants finished the problems; however, it is difficult to determine the relevance of adventitious reinforcement because contingency strength values were not calculated.

A second explanation for the continued engagement in contextually appropriate behavior is possible automatic reinforcement for completing a relatively simple task when few other activities were available. We selected math problems that were well within the participants' repertoires to ensure that any lack of completion of the contextually appropriate behavior was due to a motivational deficit rather than a skill deficit. The continued, albeit low rates of, completion of math problems during Phase 1 does suggest some automatic value in completing math problems. Interestingly, Nederkoorn et al. (2016) found that undergraduate students completing mundane experimental tasks (in comparison to conditions that were neutral or sad) would go so far as to self-administer an electric shock. Therefore, the participants may have completed math problems simply because there was no alternative, more preferred, activities (e.g., cell phone use) to break the monotony of the computer program we designed when reinforcement was not forthcoming.

Third, all participants were provided with instructions signaling the availability of math problems during the delay. These instructions, provided to adults with advanced verbal skills, could have influenced allocation of responding for some during the DRO-based thinning condition. In a translational arrangement with college students, Hackenberg and Joker (1994) evaluated the effects of instructions on participant selection of point delivery. The authors began with an accurate statement identifying optimal performance to earning points; however, the conditions were slowly altered, making contact with contingencies (i.e., adapting to the diminishing points and switching to a more optimal alternative) more important than following the increasingly inaccurate instructions. The authors found evidence that all four participants were unlikely to be sensitive to most schedule changes and continued to follow the instructions at the expense of optimal point delivery. This suggests a possible similarity in some of the participants from the current study who continued to respond in the DRO-based thinning condition even though points were delivered regardless of math completion. This is especially likely considering that many of the participants who continued to complete math problems during the DRO-based thinning condition also were responding suboptimally during the DRA-based thinning condition and completing more math problems than necessary to earn points.

Fourth, DRA-based thinning sessions were always followed by a DRO-based thinning session. A limitation of this multielement design is that it provided participants with a very recent reinforcement history for math problem completion at the end of every DRA-based thinning session. Thus, the effects of the previously experienced DRA-based thinning condition could have interacted with the immediately succeeding DRO-based thinning condition, resulting in the continued completion of math problems. Although we are currently unable to pinpoint the source of variability in math completion during the DRO-based thinning condition beyond the speculations mentioned above, this variability provides researchers with some interesting avenues for future investigation.

For example, the possibility of interactive effects can be eliminated by conducting the study as a group design with one randomly selected group of individuals experiencing the DRA-based thinning procedures while the other individuals experience the DRO-based thinning procedures. If similar results were obtained, research of this kind would strengthen the conclusions in the current study, especially considering the limited experimental control demonstrated by several participants. The inclusion of data analyses such as calculating contingency strength within the group design would improve interpretations further if math completion continued to occur in both groups. Of course, if we are to assume that interactions are inevitable in this type of single-subject research design (Hains & Baer, 1989), researchers could attempt to capitalize on the interaction instead of trying to eliminate it. In other words, applied researchers could purposefully alternate the two thinning procedures to maintain acceptable levels of contextually appropriate behavior when contingencies are not specifically programmed to do so (i.e., DRO-based thinning). Using DRA-based thinning may be more cumbersome for clinicians because it requires the continuous supervision of the individual and audit of contextually appropriate behavior to ensure the criteria for the delivery of reinforcers are met. Therefore, it may be possible to slowly introduce DRO-based thinning while fading out the DRA-based procedures to reach an ultimate goal of independent work completion.

We are somewhat limited in interpreting similarities in these outcomes with previous CBPD studies due to DRA- and DRO-based thinning procedures often being combined into a single treatment package (e.g., Beaulieu et al., 2018; Hanley et al., 2014; Rose & Beaulieu, 2019) or evaluated individually without comparison (e.g., Boyle et al., 2020; Jessel et al., 2018b; Santiago et al., 2015). Ghaemmaghami et al. (2016) included the only other comparative evaluation of CBPD procedures with a single participant, Will, and found that although both reduced problem behavior, the DRA-based thinning procedure was more effective and improved contextually appropriate behavior. This suggests, along with the results of the current study, that the contingency that directly promotes alternative behavior could improve engagement when reinforcement is delayed; however, we are unable to provide decisive interpretations regarding the individualized differences among those who were not representative of these outcomes in the current study. Therefore, it may be possible to extend this research to more relevant participants and settings to improve our understanding of the individualized differences. Based on the generally positive effects observed in the current translational study, applied research of this kind is likely to be associated with minimal risk. Furthermore, conducting this comparison with the intended population may reduce the influence of the instructions. However, future researchers may want to continue to include measures of optimal responding to ensure that participants are sensitive to the schedule changes.

The translational nature of the current study limits the extension of the conclusions to the treatment of individuals who exhibit problem behavior. This is especially true considering that those who exhibit problem behavior tend to have long histories of reinforcement that were not replicated in our relatively brief study. However, the current model may provide researchers with a more efficient alternative when time and resources are not available to evaluate an entire reinforcement thinning process for an individual receiving clinical services. In a recent review of FCT treatments by Ghaemmaghami et al. (in press), only 294 of 744 (40%) applications of FCT included schedule-thinning procedures. It may be that schedule thinning is not being implemented in all studies due to their time-consuming nature and the difficulty in systematically increasing delay requirements. Thus, a translational model that requires only a couple of hours may be beneficial for comparing specific variations of reinforcement schedule thinning procedures before application to the intended population. In addition, translational models like this may prove useful in identifying the most practical and effective variations of schedule thinning, which in turn may promote more effective applications of FCT in clinical research and practice.

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