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Comparing Skill Acquisition Under Varying Onsets of Differential Reinforcement: A Preliminary Analysis

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Abstract

The purpose of the current study was to evaluate the effect of implementing differential reinforcement at different times relative to the onset of teaching new skills to learners with autism spectrum disorder. Specifically, we first determined the most efficient differential reinforcement arrangement for each participant. Using the most efficient arrangement, we evaluated if differential reinforcement from the immediate onset, early onset, or late onset is the most efficient for learners to acquire a new skill. Three children diagnosed with autism spectrum disorder who have a history of receiving intervention based on the principles of applied behavior analysis participated in this study. The immediate onset of differential reinforcement resulted in the most efficient instruction in 6 of 7 comparisons. The results are discussed in light of previous studies and suggestions for future research are provided.

Early intensive behavioral intervention targets acquisition of new skills that eventually occur without any assistance (i.e., unprompted correct responding). Differential reinforcement may promote unprompted correct responding. Differential reinforcement, in relation to skill acquisition, consists of arranging higher quality, larger magnitude, or denser schedules of reinforcement for unprompted correct responses, while delivering lower quality, smaller magnitude, or leaner schedules of reinforcement for prompted correct responses (Johnson, Vladescu, Kodak, & Sidener, **2017**). Although the use of differential reinforcement has been recommended by researchers (e.g., Grow & LeBlanc, **2013**) and early intervention manuals (e.g., Leaf & McEachin, **1999**; Lovaas, **2003**), only eight studies have evaluated differential reinforcement during skill acquisition programs with individuals with autism and other developmental disabilities (Boudreau, Vladescu, Kodak, Argott, & Kisamore, **2015**; Cividini-Motta & Ahearn, **2013**; Fiske et al., **2014**; Hausman, Ingvarsson, & Kahng, **2014**; Johnson et al., **2017**; Karsten & Carr, **2009**; Olenick & Pear, **1980**; Touchette & Howard, **1984**).

A subset of these studies evaluated the efficiency of one differential reinforcement arrangement (i.e., reinforcement quality or schedule) compared to nondifferential reinforcement (Hausman et al., **2014**; Karsten & Carr, **2009**; Olenick & Pear, **1980**; Touchette & Howard, **1984**). Across studies, differential reinforcement was more efficient than nondifferential reinforcement for seven out of nine participants. For the remaining two participants, differential reinforcement and nondifferential reinforcement were equally effective and efficient. Effective can be defined as mastery levels of responding being reached, whereas efficient can be defined mastery levels of responding being reached in fewer sessions, fewer trials, and less overall training time compared to the other arrangements.

The other subset of studies compared two or more differential reinforcement arrangements (Boudreau et al., **2015**; Cividini-Motta & Ahearn, **2013**; Fiske et al., **2014**). Across studies, nondifferential reinforcement was most efficient for three out of ten participants. For the remaining seven participants, differential reinforcement was more efficient than nondifferential reinforcement; however, the most efficient type of differential reinforcement varied across participants. Cividini-Motta and Ahearn (**2013**) compared differential quality and schedule reinforcement arrangements to nondifferential reinforcement and found the quality arrangement was most efficient for three participants, whereas the schedule arrangement was the most efficient for one participant. Fiske et al. (**2014**) compared differential schedule and magnitude of reinforcement arrangements to nondifferential reinforcement and found the schedule arrangement was most efficient for one participant and nondifferential reinforcement was most efficient for the remaining two participants. Boudreau et al. (**2015**) compared differential magnitude and quality reinforcement arrangements to nondifferential reinforcement and found the magnitude condition was the most efficient condition for one participant, the quality condition was most efficient for one participant, and the nondifferential reinforcement condition was the most efficient for one participant.

In summary, the quality arrangement was most efficient for four participants, the schedule arrangement was most efficient for two participants, and the magnitude arrangement was most efficient for one participant. This suggests that when differential reinforcement is the most effective, the most efficient differential reinforcement arrangement is learner specific.

To address this potential issue, Johnson et al. (**2017**) created an assessment to help clinicians and researchers identify the most efficient learner-specific reinforcement arrangement when teaching skills to learners with autism spectrum disorder (ASD). The experimenters compared three differential reinforcement arrangements (i.e., quality, magnitude, and schedule) when teaching auditory–visual conditional discriminations. The researchers attempted to validate their results across different skills (i.e., auditory–visual conditional discrimination, tacting, and intraverbals). The differential reinforcement assessment was predictive of the most efficient arrangement for the matched skill (i.e., auditory–visual conditional discrimination); however, the assessment did not predict the most efficient arrangement for the other skill types. These results suggest that the most efficient reinforcement arrangement may not only be learner specific, but also skill specific.

Research is also needed to clarify when differential reinforcement should be implemented during skill acquisition programming (e.g., implemented from the onset of teaching, implemented following various levels of unprompted correct responding). The majority of previous studies differentially reinforced unprompted and prompted correct responses from the onset of training (e.g., Olenick & Pear, **1980**) or differentially reinforced unprompted and prompted correct responses only after nondifferentially reinforcing these responses during trials conducted at a 0-s prompt delay (e.g., Fiske et al., **2014**; Touchette & Howard, **1984**). In contrast, Karsten and Carr (**2009**) implemented nondifferential reinforcement from the onset of instruction, then implemented differential reinforcement following the first instance of an unprompted correct response. Although differential reinforcement was not the explicit focus of their study, Richardson et al. (**2017**) arranged nondifferential reinforcement and then began differentially reinforcing less intrusive prompted responses once a 33% prompted correct response criterion was met for one session. Afterwards, once an unprompted correct response occurred for 33% or more of trials in a single session, the researchers differentially reinforced unprompted and prompted correct responses. In a second example where differential reinforcement was not the explicit focus of the study, Carroll, Kodak, and Fisher (**2013**) initially arranged nondifferential reinforcement, and then implemented differential reinforcement after unprompted correct responses occurred for 50% or more of trials for two consecutive sessions.

To our knowledge, no previous study has examined the influence of different onsets of differential reinforcement. This is an important area for research, as the onset of differential reinforcement may have implications for the acquisition of new skills. It is possible that an immediate or early onset of differential reinforcement may not be the most efficient method for all learners. Some learners may require frequent prompts even after the first instance of an unprompted correct response, and if this does not occur, it is possible that prompted correct responses could be extinguished if an effective reinforcer is not provided (Vladescu & Kodak, **2010**). Nondifferential reinforcement may also prove problematic because reinforcing prompted responses for too long may produce responding that is prompt dependent (Clark & Green, **2004**; Fisher, Kodak, & Moore, **2007**).

The onset of differential reinforcement may have a number of implications for clinicians and researchers providing services to learners with ASD. Therefore, the purpose of the current study was to evaluate the effect of implementing differential reinforcement at different times relative to the onset of teaching new skills to learners with ASD. We first determined the most efficient differential reinforcement arrangement for each participant. Using the most efficient arrangement, we next evaluated the effectiveness and efficiency of immediate onset, early onset, or late onset differential reinforcement.

METHOD

Participants

Three children diagnosed with ASD participated in this study. The Gilliam Autism Rating Scale-Third Edition (GARS-3; Gilliam, **2013**) was completed for each participant and each demonstrated behaviors characteristics of ASD. All participants had a history of receiving applied behavior analytic (ABA)-based services. All participants had a history with differential reinforcement that primarily focused on manipulation of reinforcement quality or schedule (i.e., participants received a token for unprompted correct responses and received praise or no reinforcement [extinction] for prompted correct responses, respectively).

Easton was a 9-year, 10-month-old male and had received ABA-based services since 20 months old. He received standard score of 62 (Qualitative description: Extremely Low) on the Expressive Vocabulary Test-Second Edition (EVT-2; Williams, **2007**) and a standard score of 45 (Extremely Low) on the Peabody Vocabulary Test-Fourth Edition (PPVT-4; Dunn & Dunn, **2007**). Easton scored in level two on the tact portion of the Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP; Sundberg, **2008**).

Gracie was a 9-year, 5-month-old female and had received ABA-based services since age 4. She received standard score of 46 (Extremely Low) and 81 (Moderately Low) on the EVT-2 and PPVT-4, respectively. Gracie scored in level 3 on the tact portion of the VB-MAPP.

Kyle was a 7-year, 8-month-old male and had received ABA-based services since approximately age 3. He received standard score of 89 (Moderately Low) and 88 (Moderately Low) on the EVT-2 and PPVT-4 respectively. Kyle scored in level 3 on the tact portion of the VB-MAPP.

Setting and Materials

The experimenter conducted sessions in a small room at a clinic for individuals with developmental disabilities or at the participants' homes. Materials included a table, chairs, putative reinforcers, a timer, data sheets, a pen, and a video camera. During the reinforcer assessment, materials for an arbitrary task were present. During the differential reinforcement assessment and onset of differential reinforcement evaluation, binders containing relevant stimuli to each condition were present. The stimuli binders contained one sheet for each trial in a session. Each trial sheet consisted of a white paper containing the discriminative stimulus (i.e., visual stimulus). The trial sheet was placed in a clear sheet protector with a blank piece of colored paper (based on the results of a preference assessment) on top of each trial sheet. The colored paper prevented the participant from viewing the visual stimulus prior to the start of the trial and provided the opportunity for a trial-initiation response. Condition-correlated colors were arranged to assist participants in discriminating the condition-specific contingencies.

Experimental Design, Measurement, and Interobserver Agreement

An adapted alternating treatment design was used (Sindelar, Rosenberg, & Wilson, **1985**) to compare conditions in the differential reinforcement assessment and onset of differential reinforcement evaluation. The experimenter recorded unprompted correct, unprompted incorrect, prompted correct, and prompted incorrect responses during each session. An unprompted correct response was defined as the participant tacting the visual stimulus prior to the delivery of a prompt. An unprompted incorrect response was defined as the participant emitting a response that did not correspond with the visual stimulus (i.e., error of commission) or not emitting any vocal response (i.e., error of omission). A prompted correct response was defined as the participant tacting the visual stimulus following the delivery of a prompt. A prompted incorrect response was defined as the participant engaging in an error of commission or omission following the delivery of a prompt. Only the percentage of unprompted correct responses are depicted in the figures and were calculated by dividing the number of unprompted correct responses in a session by the total number of trials, and then converting that number to a percentage.

The experimenter recorded session duration using a digital timer. The experimenter started the timer immediately prior to the delivery of the first antecedent stimulus (i.e., flipping the page and stating “What is it?” or “Who is it?”) on the first trial of the session. The experimenter stopped the timer immediately following the last trial of the session or when the last putative reinforcer was consumed or terminated.

To evaluate relative efficiency of training conditions, the experimenter calculated total training sessions, total training trials, and total training time per condition. Total training sessions were calculated by adding the total number of training sessions in a condition required to meet the mastery criterion. Total training trials were calculated by adding the total number of training trials in a condition required to meet the mastery criterion. Total training time was calculated by adding the total duration of each training session per condition required to meet the mastery criterion.

An independent observer scored participants'responding (unprompted correct responses, unprompted incorrect responses, prompted correct responses, and prompted incorrect responses) and session duration from video for a minimum of 33% of sessions across phases and conditions for interobserver agreement (IOA) purposes. Trial-by-trial IOA was calculated by dividing the number of trials with agreement by the total number of trials and converting that ratio into a percentage. An agreement in each trial was scored if the second observer recorded the exact same dependent variables as the primary observer within the trial. A disagreement was scored if the second observer recorded any different dependent variables as the primary observer within the trial. We calculated total duration IOA by dividing the shorter duration by the longer duration and converting that ratio into a percentage.

Mean IOA scores for Easton were 99% (range, 96%–100%), 99% (range, 92%–100%), and 99.7% (range, 96%–100%) across conditions in the differential reinforcement assessment, initial onset evaluation, and the onset evaluation replication, respectively. Mean IOA scores for Gracie were 99% (range, 92%–100%), 98% (range, 88%–100%), 99.6% (range, 96%–100%), and 98.7% (range, 92%–100%) across conditions in the differential reinforcement assessment, initial onset evaluation, the onset evaluation replication, and second onset evaluation replication respectively. Mean IOA scores for Kyle were 98% (range, 83%–100%), 99% (range, 92%–100%), and 99% (range, 92%–94%) across conditions in the differential reinforcement assessment, initial onset evaluation, and the onset evaluation replication, respectively.

Mean duration IOA scores for Easton were 99% (range, 94%–100%), 99% (range, 98%–100%), and 99.5% (range, 97%–100%) across conditions in the differential reinforcement assessment, initial onset evaluation, and the onset evaluation replication, respectively. Mean duration IOA scores for Gracie were 99% (range, 95%–100%), 99% (range, 93%–100%), 99.7% (range, 98%–100%), and 99.5% (97%–100%) across conditions in the differential reinforcement assessment, initial onset evaluation, the onset evaluation replication, and the second onset evaluation replication, respectively. Mean duration IOA scores for Kyle were 99% (range, 92%–100%), 98% (range, 94%–100%), and 99% (range, 94%–100%) across conditions in the differential reinforcement assessment, initial onset evaluation, and the onset evaluation replication, respectively.

Pre-Experimental Assessments

Preference assessments

The experimenter conducted separate shape and color preference assessments to identify condition-correlated stimuli for the conditions of the reinforcer assessments (shapes), differential reinforcement assessment (colors), and differential reinforcement onset (colors) comparisons using procedures similar to Heal, Hanley, and Layer (**2009**). We conducted paired-stimulus (Fisher et al., **1992**) and single-trial multiple-stimulus (Carr, Nicolson, & Higbee, **2000**) preference assessments to identify edibles to use during the reinforcer assessments, differential reinforcement assessment, and onset of differential reinforcement phases.

Edible amount and size assessments

Similar to Boudreau et al. (**2015**) and Johnson et al. (**2017**), we conducted assessments to determine the number of pieces of an edible item (hereafter referred to as the edible amount) delivered for unprompted and prompted correct responses (in corresponding conditions) and the size of the edible item provided after prompted correct responses in the differential reinforcement condition manipulating magnitude (hereafter referred to as the small edible).

Response assessment

Similar to Holth, Vandbakk, Finstad, Grønnerud, and Sørensen (**2009**), the experimenter conducted a response assessment to identify an arbitrary task that has an associated free-operant response that is not maintained by automatic reinforcement that could be used in the reinforcer assessments. The following responses were evaluated once each: touching a square on a table, moving a wooden block across a line on a table, putting a cloth ball into a vertical pipe, pressing a button, and attaching clothespins to a paper plate.

Reinforcer assessments

The experimenter conducted a free-operant assessment to compare the edible amount plus praise delivered on a fixed ratio (FR) 1 schedule to the edible amount plus praise delivered on an FR 3 schedule. An FR 3 schedule was selected based on schedules used in previous studies (e.g., Hausman et al., **2014**; Johnson et al., **2017**; Touchette & Howard, **1984**). Next, the experimenter conducted separate progressive-ratio assessments modified from Roane, Lerman, and Vorndran (**2001**)—praise compared to no consequence, praise compared to the edible amount plus praise, and the edible amount plus praise compared to the small edible plus praise.

Target Identification and Assignment

We identified a large pool of potential targets based on participants' individualized treatment goals and the New Jersey Core Curriculum Content Standards (State of New Jersey, **2014**). Each potential target was pretested three times. During each pretest trial, the experimenter established attending behavior, and then simultaneously presented the visual stimulus and said, “What is it?” or “Who is it?”. The experimenter waited up to 5 s for the participant to respond. No feedback or praise was given for unprompted correct or incorrect responses. The experimenter delivered a piece of an edible plus praise contingent on appropriate attending and sitting behaviors approximately every third intertrial interval. Potential targets were discarded if the participant engaged in an unprompted correct response during at least two presentations of the potential target (i.e., 66% of trials correct).

We identified 24 targets (six targets multiplied by four conditions) for each participant for the differential reinforcement assessment. Targets included pictures of celebrities (Easton and Gracie) and objects (Kyle). We identified 30 targets (six targets multiplied by five conditions) for each participant for the differential reinforcement onset evaluation. Targets for this evaluation included pictures of celebrities (Kyle and Gracie) and objects (Easton). We identified 30 targets (six targets multiplied by five conditions) for each participant for the differential reinforcement onset evaluation replication. During replication comparisons, two exemplars were identified for each target to increase the difficulty of the task. We assigned targets through a logical analysis by considering number of syllables in each target response, redundancy of phonemes across target name, physical similarity of target pictures, and zero correct responses to each potential target that occurred during the pretest (Wolery, Gast, & Ledford, **2014**). A list of detailed rules used to assign targets to conditions and target sets are available from the second author.

General Procedure

Prior to beginning each session in the differential reinforcement assessment and differential reinforcement onset evaluations, the experimenter required the participant to touch the cover of the stimulus binder and tact the condition-correlated color (i.e., differential observing response). If the participant did not touch and tact the cover of the stimulus binder within 3 s of its presentation, the experimenter modeled the response. Contingent on the participant touching and tacting the color, the experimenter turned the cover of the binder to expose the first trial sheet. Prior to each trial, the experimenter first established ready behavior (i.e., the participant sitting in the chair with body oriented towards the stimulus binder), then required the participant to touch the condition-specific colored piece of the paper covering the trial sheet. If the participant did not touch the trial sheet within 3 s of the trial sheet being presented, the experimenter modeled the response. Contingent on the participant touching the colored page, the experimenter turned the page to expose the visual stimulus. Immediately after the experimenter turned the page exposing the visual stimulus, the experimenter presented the auditory antecedent stimulus “What is it?” (for objects) or “Who is it?” (for people). Across conditions, a 3-s constant prompt delay procedure was used. If the participant did not respond within 3 s following the presentation of the auditory antecedent stimulus, the experimenter modeled the correct response. If the participant engaged in an unprompted incorrect response, the experimenter immediately modeled the correct response. We implemented condition-specific contingencies (described below) following unprompted and prompted correct responses. The experimenter presented the next trial following unprompted and prompted incorrect responses. The intertrial interval was approximately 3 s or until the participant consumed the edible.

Training continued until the participant demonstrated 100% unprompted correct responses across two consecutive sessions. Sessions in each condition continued until the mastery criterion was achieved or the total training time was at least 50% longer than the initial mastered condition's overall training time. Sessions consisted of 12 trials. Each target was presented an equal number of times during each session. The experimenter conducted three to nine sessions per day, two to five times per week, with a minimum of 5 min between sessions. Conditions were conducted in a random without replacement order.

Trial-initiation response training

The experimenter conducted trial-initiation response training to ensure participants would touch the condition-correlated colored sheet covering the trial sheet to initiate trials in the differential reinforcement assessment and onset of differential reinforcement evaluation. Stimuli that were used in these trials were previously mastered targets. The experimenter first instructed the participant to “touch the page.” If the participant did not touch the page within 5 s, the experimenter modeled the correct response by touching the colored sheet. Once the participant touched the sheet covering the trial sheet, either prompted or unprompted, the experimenter would continue with the trial. The edible amount plus praise was delivered for unprompted correct and unprompted incorrect responses to the stimuli. The instructor would no longer provide the instruction “touch the page” contingent on five consecutive unprompted trial-initiation responses. Training continued until the participant demonstrated five consecutive unprompted trial-initiation responses.

Differential reinforcement assessment

We conducted an assessment to identify the differential reinforcement arrangement to use in the differential reinforcement onset comparison for each participant. More specifically, the differential reinforcement condition that led to the most rapid skill acquisition (defined as requiring the least amount of total training time) for each participant was used in the onset of nondifferential reinforcement evaluation.

- *Baseline*. During baseline the cover of the stimulus binder and sheets covering each trial sheet in the stimulus binders remained white across conditions. The experimenter placed the binder in front of the participant. The experimenter delivered generic praise at the end of each trial (e.g., good working), regardless of the participant's response. No other consequences or prompts were provided.
- *Quality*. The experimenter delivered the edible amount plus praise following unprompted correct responses and praise only following prompted correct responses.
- *Magnitude*. The experimenter delivered the edible amount plus praise following unprompted correct responses and the small edible plus praise following prompted correct responses.
- *Schedule*. The experimenter delivered the edible amount plus praise following all unprompted correct responses (i.e., FR 1), and the edible amount plus praise every third prompted correct response (i.e., FR

3). No consequence was delivered on trials in which the participant engaged in a prompted correct response if the response did not meet the schedule requirement.
- *Control*. The condition followed the same procedures as baseline.

Differential reinforcement onset evaluation

We conducted a comparison to evaluate the effectiveness and efficiency of three unique onsets of differential reinforcement.

- *Baseline*. The procedures followed the same baseline procedures used in the differential reinforcement assessment.
- *Nondifferential reinforcement*. The experimenter delivered the edible amount plus praise for all unprompted and prompted correct responses.
- *Differential reinforcement immediate onset*. The experimenter delivered the edible amount plus praise for unprompted correct responses. A lower quality, smaller magnitude, or leaner schedule of reinforcement was provided for prompted correct responses. An immediate onset was used in the majority of past research regarding differential reinforcement (e.g., Olenick & Pear, 1980).
- *Differential reinforcement early onset*. The experimenter delivered the edible amount plus praise for all unprompted and prompted correct responses. Once a participant demonstrated unprompted correct responding during 33% or more of trials for two consecutive sessions, the experimenter implemented differential reinforcement during the subsequent session. That is, the experimenter delivered the edible amount plus praise following unprompted correct responses and a lower quality, smaller magnitude, or leaner schedule of reinforcement was provided for prompted correct responses. A 33% criterion was selected to closely resemble the Richardson et al. (2017) criterion; however, a change from nondifferential reinforcement to differential reinforcement was not made until two consecutive sessions to more closely resemble the criterion for the late onset condition in the present study.
- *Differential reinforcement late onset*. The experimenter delivered the edible amount plus praise for all unprompted and prompted correct responses. Once a participant demonstrated unprompted correct responding during 50% or more of trials for two consecutive sessions, the experimenter implemented differential reinforcement during the subsequent session. That is, the experimenter delivered the edible amount plus praise following unprompted correct responses, and a lower quality, smaller magnitude, or leaner schedule of reinforcement was provided for prompted correct responses (e.g., Carroll et al., 2013; Paden & Kodak, 2015; Toussaint, Kodak, & Vladescu, 2016).
- *Control*. Sessions followed the same procedures as baseline.

Procedural Integrity

An observer collected procedural integrity data from video for a minimum of 33% of sessions across all conditions. Procedural integrity was collected using a checklist of correct experimenter behavior and was calculated by dividing the total number of correct experimenter behaviors by the total number of correct and incorrect experimenter behaviors. Items in the checklist were condition specific and included: waiting for ready behavior, ensuring participant engaged in an observing response prior to delivering the discriminative stimulus, following corresponding prompt delay, providing condition specific reinforcement for participant response, providing a vocal model of the target if the participant did not respond or engaged in an unprompted incorrect response (only during treatment), terminate trial if participant engaged in a prompted incorrect response (only during treatment), record data after each trial.

Mean procedural integrity scores for Easton were 99.7% (range, 96%–100%), 99.9% (range, 98%–100%), and 100% across conditions in the differential reinforcement assessment, initial onset evaluation, and the onset evaluation replication, respectively. Mean procedural integrity scores for Gracie were 99.9% (range, 99%–100%), 99.9% (range, 99%–100%), 100%, and 100% across conditions in the differential reinforcement assessment, initial onset evaluation, the onset evaluation replication, and second onset evaluation replication, respectively. Mean procedural integrity scores for Kyle were 100%, 99.9% (range, 99%–100%), and 100% across conditions in the differential reinforcement assessment, initial onset evaluation, and the onset evaluation replication, respectively.

A second observer collected procedural integrity data for 33% of procedural integrity sessions. We calculated trial-by-trial procedural integrity IOA by dividing the number of trials with agreement by the total number of trials and converting that ratio into a percentage. An agreement in each trial was scored if both independent observers scored a correct experimenter behavior or both observers scored an incorrect experimenter behavior. A disagreement in each trial was scored if an observer scored a correct experimenter behavior and the other observer scored an incorrect experimenter behavior. Agreement on treatment integrity scores was 100% for all participants.

RESULTS

During the free operant preference assessment, participants engaged in an average of 66 (range, 32–90) more cumulative responses when the edible amount plus praise was delivered on an FR 1 schedule compared to when the edible amount plus praise was delivered on an FR 3 schedule. During the progressive ratio assessments, when comparing the value of praise to no consequence, participants engaged in an average of 45 (range, 33–67) more cumulative responses in the praise condition when compared to the no consequence condition. When comparing the reinforcing efficacy of praise compared to the edible amount plus praise, participants engaged in an average of 237 (range, 81–413) more cumulative responses in the edible amount plus praise condition compared to the praise only condition. In the small edible plus praise versus the edible amount plus praise comparison, participants engaged in an average of 226 (range, 137–361) more responses in the edible amount plus praise condition than the small edible plus praise condition.

The results of the differential reinforcement assessment indicate that the differential reinforcement arrangement associated with the most efficient acquisition differed across participants. That is, the schedule manipulation was most efficient for Easton and Gracie, and the quality manipulation was most efficient for Kyle. During his comparison, Easton (Figure **1**, top panel) demonstrated mastery in the schedule, quality, and magnitude conditions in 10 (120 training trials, 43 min 18 s training time), 13 (156 training trials, 53 min 22 s), and 15 (180 training trials, 75 min 47 s) training sessions, respectively. Gracie (Figure **1**, middle panel) demonstrated mastery in the schedule, quality, and magnitude condition in 13 sessions (156 training trials, 71 min), 15 (180 training trials, 71 min 58 s), and 15 (180 training trials, 87 min 37 s) training sessions, respectively. Kyle (Figure **1**, bottom panel) demonstrated mastery in the quality, magnitude, and schedule conditions in 7 (84 training trials, 38 min 55 s), 7 (84 training trials, 46 min 26 s), and 11 (132 training trials, 85 min 47 s) training sessions, respectively.

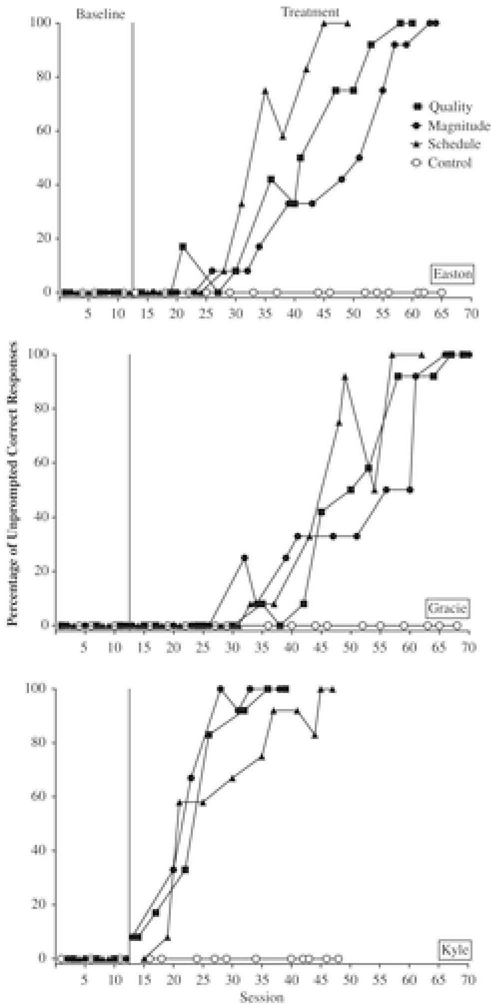

Figure 1 Percentage of unprompted correct responses across different differential reinforcement manipulations (i.e., quality, magnitude, schedule) for each participant.

We used the results of the differential reinforcement assessment to inform the differential reinforcement arrangement to be included in each participant's onset of differential reinforcement evaluation. That is, we arranged the quality manipulation to be in place for Kyle and the schedule manipulation to be in place for Easton and Gracie. The results of the onset of differential reinforcement evaluations indicated that the immediate onset condition led to the most efficient acquisition for two out of three participants (i.e., Easton and Kyle) in the initial onset evaluation, and led to the most effective skill acquisition for all participants in the replication.

During his initial onset of differential reinforcement comparison, Easton (Figure **2**, top panel; Figure **3**, top panel) demonstrated mastery in the immediate onset, early onset, nondifferential, and late onset conditions in 6 (72 training trials, 25 min 2 s training time), 10 (120 training trials, 50 min 26 s), 12 (144 training trials, 59 min 4 s), and 13 (156 training trials, 62 min 28 s) training sessions, respectively. Similarly, he demonstrated mastery in the immediate onset, early onset, late onset, and nondifferential conditions in 13 (156 training trials, 61 min), 16 (192 training trials, 97 min 31 s), 19 (228 training trials, 115 min 46 s), and 19 (228 training trials, 114 min 28 s) training sessions, respectively during his replication (Figure **2**, bottom panel).

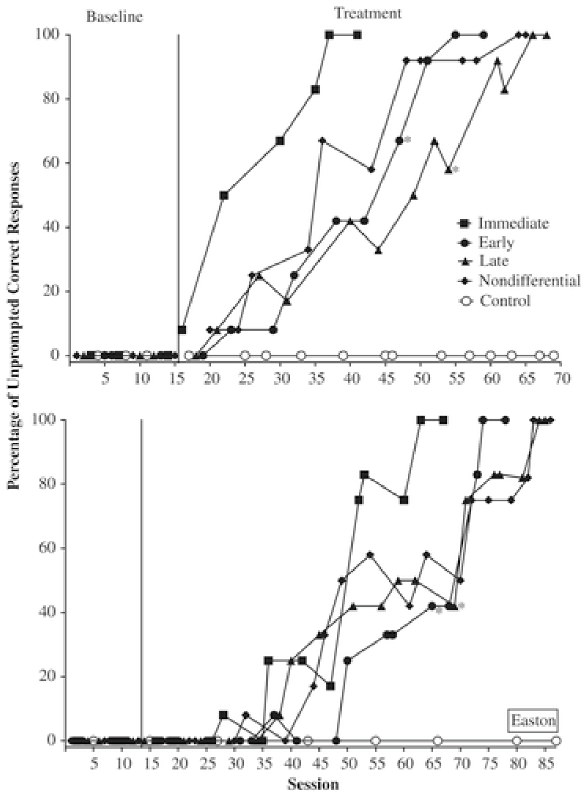

Figure 2 Percentage of unprompted correct responses across varying onsets of differential reinforcement, and nondifferential reinforcement for participant Easton in the initial onset evaluation (top panel) and the replication (bottom panel). The asterisk represents the session differential reinforcement was initiated in the early and late onset conditions.

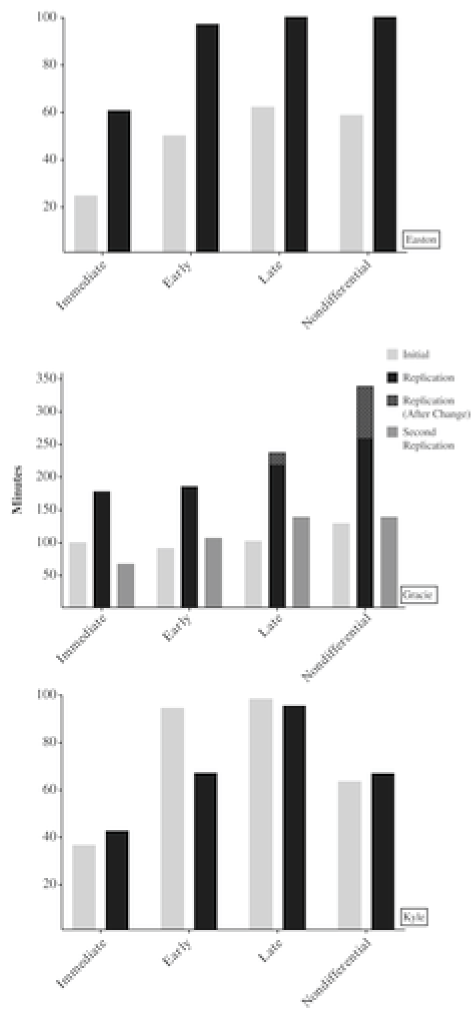

Figure 3 Total training time in minutes across all conditions in the onset evaluations for Easton, Kyle, and Gracie.

During her initial onset of differential reinforcement comparison, Gracie (Figure **4**, top panel; Figure **3**, middle panel) demonstrated mastery in the early onset, late onset, immediate onset, and nondifferential conditions in 12 (144 training trials, 92 min 7 s), 14 (168 training trials, 103 min 7 s), 15 (180 training trials, 100 min 59 s), and 15 (180 training trials, 130 min 14 s) training sessions, respectively. During the first replication, Gracie (Figure **3**, middle panel) demonstrated mastery in 21 (252 training trials, 186 min) and 23 (276 training trials, 178 min 26 s) training sessions in the early onset and immediate onset conditions, respectively. We continued training for an additional four sessions (approximately 25% more sessions than the initial mastered conditions overall training sessions) in the late onset and nondifferential conditions; however, no apparent increase in unprompted correct responding was observed. Thereafter, we implemented differential reinforcement in the late onset condition beginning with session 119. Immediately following this change, accurate responding increased until mastery levels of responding were demonstrated in both conditions. She demonstrated mastery in 32 (396 training trials, 278 min 45 s) and 34 (420 training trials, 259 min 45 s) training sessions in the late onset and nondifferential reinforcement conditions, respectively. During the second replication, Gracie (Figure **4**, bottom panel) demonstrated mastery in the immediate onset, early onset, late onset, and nondifferential reinforcement conditions in 11 (132 training trials, 68 min 13 s), 14 (168 training trials, 107 min 47 s), 17 (204 training trials, 140 min 25 s), and 17 (204 training trials, 140 min 25 s) training sessions, respectively.

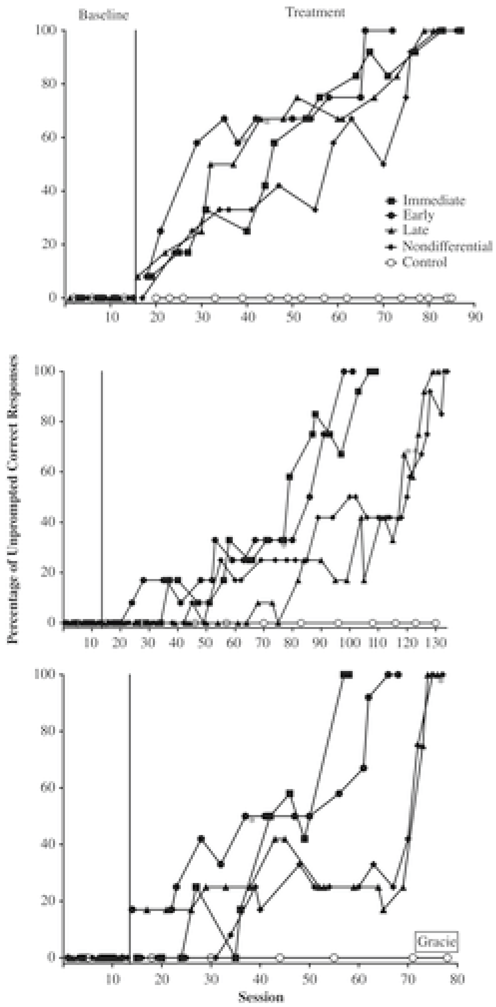

Figure 4 Percentage of unprompted correct responses across varying onsets of differential reinforcement, and nondifferential reinforcement for participant Gracie in the initial onset evaluation (top panel), the replication (middle panel) and the second replication (bottom panel). The asterisk represents the session differential reinforcement was initiated in the early and late onset conditions. **represents an unplanned change was made.

During his initial onset of differential reinforcement comparison, Kyle (Figure **5**, top panel; Figure **2**, bottom panel) demonstrated mastery in the immediate onset, nondifferential, late onset, and early onset conditions in 7 (84 training trials, 36 min 52 s), 7 (84 training trials, 63 min 48 s), 13 (156 training trials, 98 min 39 s), and 14 (168 training trials, 94 min 47 s) training sessions, respectively. Somewhat similarly, Kyle (Figure **5**, bottom panel) demonstrated mastery in the immediate onset, nondifferential, early onset, and late onset conditions in 9 (108 training trials, 42 min 57 s), 10 (120 training trials, 67 min 14 s), 10 (120 training trials, 67 min 24 s), and 13 (156 training trials, 95 min 42 s) training sessions, respectively, during his replication.

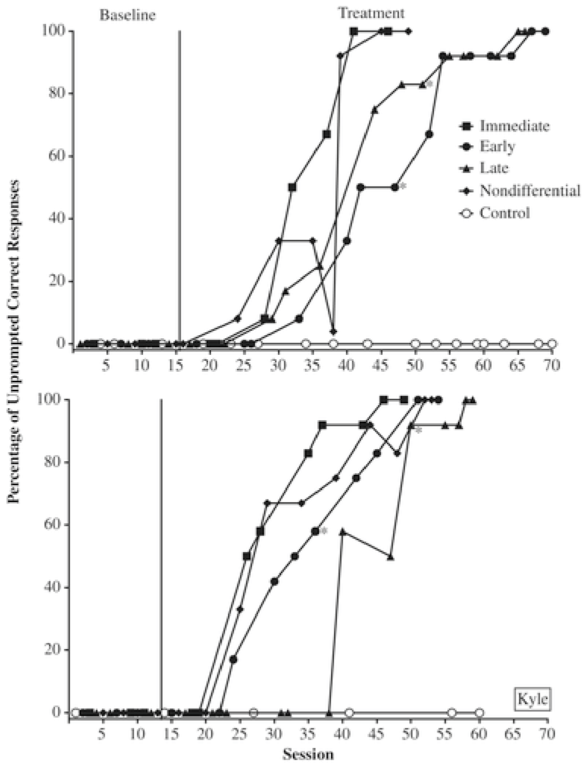

Figure 5 Percentage of unprompted correct responses across varying onsets of differential reinforcement, and nondifferential reinforcement for participant Kyle in the initial onset evaluation (top panel) and the replication (bottom panel). The asterisk represents the session differential reinforcement was initiated in the early and late onset conditions.

DISCUSSION

Previous research has demonstrated that differential reinforcement may increase instructional efficiency relative to nondifferential reinforcement (e.g., Hausman et al., **2014**; Karsten & Carr, **2009**), but the most efficient differential reinforcement arrangement may differ across individuals (e.g., Boudreau et al., **2015**) and tasks (Johnson et al., **2017**). However, no research has directly evaluated when during instruction to begin differentially reinforcing unprompted and prompted correct responses. The current study evaluated the effectiveness and efficiency of three different onsets of differential reinforcement for three participants with ASD. Across participants, the immediate onset of differential reinforcement resulted in the most efficient instruction in six of seven comparisons.

Similar to outcomes reported across previous studies (Boudreau et al., **2015**; Cividini-Motta & Ahearn, **2013**; Fiske et al., **2014**), we found some differences in the most efficient differential reinforcement arrangements across participants. More specifically, results from the differential reinforcement assessment indicated that although all differential reinforcement arrangements were effective, the schedule manipulation was the most efficient (i.e., based on fewest numbers of sessions to mastery, fewest trials to mastery, and the lowest overall training time) for Easton and Gracie. Kyle demonstrated mastery responding in the quality and schedule conditions in the same amount of training trials and sessions; however, the quality manipulation was associated with the lowest overall training time, therefore it was the most efficient arrangement. In some cases, substantial differences are evident in the amount of total training time required for participants to demonstrate mastery-level responding across the differential reinforcement arrangements. For example, across participants, the arrangement associated with the longest total training time required an average of 72% (range, 23% to 120%) more training time compared to the arrangement associated with the shortest total training time. These outcomes further support the need to identify learner-specific differential reinforcement arrangements to use during skill acquisition programming.

We did not conduct additional comparisons to establish the generality of the results of the differential reinforcement assessment because the primary goal of the current study was to evaluate different onsets of differential reinforcement, and previous research indicates that the optimal differential reinforcement arrangement may be similar when teaching a same skill (Johnson et al., **2017**). However, Johnson et al. (**2017**) demonstrated generality of the most efficient differential reinforcement arrangement in the context of auditory–visual conditional discriminations, but did not conduct additional comparisons to establish generality for other tasks types. This may be relevant because we taught tacts during all comparisons. Future studies are needed to further clarify whether differential reinforcement arrangements are indeed task specific.

To our knowledge, the current study is the first to directly evaluate the effectiveness and efficiency of differential reinforcement onsets during skill acquisition programming. For each participant, we conducted a minimum of two onset comparisons to evaluate the generality of the findings. Immediate onset was associated with the most efficient teaching in six of the seven comparisons. This outcome may not be surprising considering all participants had extensive histories of receiving intervention based on the principles of applied behavior analysis and this intervention included prompt/prompt-fading procedures and arranging differential reinforcement during skill acquisition programming. The participants' histories may be relevant as previous research (e.g., Coon & Miguel, **2012**; Kay et al., **2019**; Roncati, Souza, & Miguel, **2019**) has demonstrated the effect proximal history can have on subsequent responding. Related to the current evaluation, participants may have continued to emit prompted responses because of a history of differential reinforcement during skill acquisition programming, even though these responses did not produce a higher quality, larger magnitude, or denser schedule of reinforcement. Said another way, the participants' previous history may have established responding that persists under differential reinforcement arrangements. This may not be true of other learners without such extensive instructional histories or for learners whose behavior may require substantially more prompts prior to demonstrating unprompted correct responses. For these learners, prompted responses may be extinguished under differential reinforcement teaching arrangements (see Vladescu & Kodak, **2010**). Extinguishing prompted responses may be undesirable if unprompted responses are not yet under the desired stimulus control. Future research will be necessary to evaluate the generality of the current findings to learners with ASD who have different and similar histories to the participants included in the current evaluation.

Relatedly, the nondifferential reinforcement of prompted responses may be undesirable if such an arrangement produces prompt dependency (Vladescu & Kodak, **2010**). Some evidence to support this possibility is apparent when evaluating the relative training required to achieve mastery-level responding during the onset evaluation. For example, across participants, the late onset condition *or* the nondifferential condition was associated with the longest training time in all comparisons. Moreover, in Gracie's first replication, she demonstrated stagnant unprompted correct responding in the late onset and nondifferential reinforcement conditions, and her unprompted correct responding increased quickly in both conditions only after we implemented differential reinforcement in the late onset condition. This outcome lends support to previous studies that have demonstrated differential reinforcement to be useful in remediating issues of prompt dependency (e.g., Cividini-Motta & Ahearn, **2013**).

During the onset evaluation, we arranged immediate, early, and late onsets. We selected these onsets because they have appeared in previous studies. For example, Olenick and Pear (**1980**) used an immediate onset arrangement, Richardson et al. (**2017**) used an early onset arrangement, and Carroll et al. (**2013**) used a late onset arrangement. It may be relevant to note that the immediate onset differs from the other onset conditions in that the transition to differential reinforcement is not made as a function of the level of unprompted correct responses emitted by the participant. The transition to differential reinforcement in the early and late onset conditions occurred based on responding, which could influence the degree to which a participant's responding contacts the differential reinforcement contingencies. For example, Gracie's responding did not contact the differential reinforcement contingency at all in the late onset condition in her second replication as her unprompted correct responding was at 100% when the transition occurred. This limited exposure to differential reinforcement may explain the similar training required in the late onset and nondifferential conditions and highlights the need for future studies to further evaluate criteria upon which to base the decision to transition to differential reinforcement. One alternative would be to transition from nondifferential to differential reinforcement after a specific amount of training has occurred. In addition, future studies should also examine the relative benefits and drawbacks of different onset options. For example, some learners may emit disruptive behavior following the transition from nondifferential to differential reinforcement because of extinction or ratio strain. Further, it may be important to evaluate other variables, such as student preference. If the conditions are equally efficient, the learners could be given the opportunity to select the condition under which new skills are taught.

Future research is needed to examine how the inclusion of trials conducted with a 0-s prompt delay may influence when to best implement differential reinforcement. For example, several studies (e.g., Fiske et al., **2014**; Touchette & Howard, **1984**) differentially reinforced unprompted and prompted correct responses only after nondifferentially reinforcing those responses during trials conducted at a 0-s prompt delay. It would be interesting to explore how responding would be affected if all correct responses were differentially reinforced at a 0-s prompt delay.

In some cases (e.g., Gracie's initial onset comparison), data from some conditions were undifferentiated until mastery levels of responding were achieved in the first condition or conditions. It is a possibility that differences in trials could be due to factors that were uncontrolled. We attempted to control for the differences in stimuli with careful assignment and the development of rules to ensure equivalence of stimuli difficulty in each set; however, it is possible the participants attended to certain features (e.g., eye color) that were left uncontrolled. Therefore, inconsistencies in the findings across participants where we saw this pattern of responding could have been due to differences among the stimuli across conditions.

Although we took steps to minimize the possibility of interaction effects by conducting sessions in a random order without replacement, assigning condition-correlated stimuli (colors), and requiring a minimum of 5 min to elapse between consecutive sessions, we may have observed multiple-treatment interference. That is, a participant's experience in a treatment session in one condition may have influenced their responding in the subsequent treatment session in another condition (Higgins Hains & Baer, **1989**). Future studies could further minimize the possibility of multiple-treatment interference by increasing the minimum time between sessions of different conditions (e.g., alternate sessions by day).

It is possible that the variation in the differential reinforcement arrangement used during the onset evaluation across participants (i.e., a schedule manipulation for Easton and Grace, a quality manipulation for Kyle) is a limitation to the study. That is, different results may have been obtained had the same differential reinforcement arrangement been in place across participants. Previous research has consistently demonstrated that the most efficient differential reinforcement is likely learner specific, thus we identified the participant-specific arrangement to employ during the onset evaluation rather than standardizing to a procedure that might not work optimally for some participants. Further, the procedural sequence we arranged might represent a model through which practitioners could evaluate the effect of differential reinforcement and its onset to facilitate acquisition of skills for learners with ASD. A learner's responding to differential reinforcement is likely influenced by a number of variables, and having a sequence of comparisons to identify the most efficient combination of differential reinforcement arrangement and the onset of differential reinforcement could be useful for practitioners' efficient provision of services.

It may be argued that some of the procedures employed in the present study may not be practical in applied settings. However, it could be counterargued that at least some of the pre-experimental assessments we conducted should be used regularly in clinical practice (e.g., the use of preference assessment to identify putative reinforcers); require little time (e.g., the edible amount and size assessments); or may be unnecessary in practical applications (e.g., the response and reinforcer assessments). Moreover, we arranged functional targets (as opposed to arbitrary targets, which have been incorporated into assessment comparisons in previous studies; see Johnson et al., **2017**; McGhan & Lerman, **2013**) be included in all sets during the comparisons, and in almost all cases, participants demonstrated mastery-level responding across conditions in the differential reinforcement and onset comparisons. Thus, the practicality of instructional assessments may be enhanced by the use of stimuli relevant to a learner's educational goals. Nonetheless, future researchers should determine whether practitioners find the procedures feasible and acceptable by including social validity measures.

In summary, the onset of differential reinforcement may be an important component to assess and evaluate for clinicians and researchers providing services to learners with ASD. Future research should seek to investigate whether the most efficient onset of differential reinforcement varies across skill types (e.g., auditory–visual conditional discrimination, intraverbals) by evaluating an assessment of generalization.

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