Journal of
Applied Behavior Analysis

Journal of Applied Behavior Analysis 2020, **9999,** 1–14 NUMBER 9999 ()

An evaluation of synchronous reinforcement for increasing on-task behavior in preschool children

Sara C. Diaz de Villegas, Claudia L. Dozier, Rachel L. Jess and Elizabeth A. Foley

University of Kansas, USA

A synchronous-reinforcement schedule is a type of schedule of covariation in which the onset and offset of the reinforcer covaries with the onset and offset of behavior. This study was a proof-of-concept demonstration of the efficacy of synchronous reinforcement for on-task behavior (completing a preacademic skill) and an evaluation of preschoolers' preference for this schedule in comparison to a more traditional schedule of reinforcement. Specifically, we compared the effects of a synchronous-reinforcement schedule to one in which continuous access to stimuli was delivered at the end of the session and yoked to the duration of on-task behavior that occurred during the session (accumulated reinforcement). Results showed the synchronous-reinforcement schedule was more effective for increasing on-task behavior and preferred by most participants.

Key words: on-task behavior, pre-academic skill, preschoolers, reinforcement, schedules, synchronous reinforcement

Schedules of reinforcement specify the conditions under which a response or a set of responses produce a reinforcer, with different schedules of reinforcement producing different response patterns (Ferster & Skinner, 1957). Much research has been conducted evaluating and comparing the effects of common schedules of reinforcement (e.g., fixed ratio, variable ratio, fixed interval, variable interval), and research has shown consistent outcomes of these schedules with different organisms, behaviors, and reinforcers (Pierce & Cheney, 2013). A far less studied group of schedules termed "schedules of covariation" are schedules in which changes in a specific response class produce corresponding changes in a reinforcer (Biddiss & Irwin, 2010; Faith et al., 2001; Williams & Johnston, 1992). That is, some parameter of the behavior (e.g., rate, intensity, duration) determines some dimension of reinforcement (e.g., rate, magnitude, intensity, amplitude). Thus, schedules of covariation are continuous reinforcement schedules where the behavior and reinforcer fluctuate together.

A conjugate-reinforcement schedule is a schedule of covariation in which some parameter of behavior directly controls some dimension of reinforcement on a moment-to-moment basis (Lewis, 1973; Lindsley, 1962; MacAleese et al., 2015; Rapp, 2008). More specifically, the reinforcing consequence continuously covaries in proportion to changes in behavior (Rovee-Collier & Gekoski, 1979). For example, in racing a car, the force of pressing the accelerator (behavior) is directly proportional to the speed and movement of the car (reinforcement). Similarly, when playing the drums, the force used to strike the drumsticks against the drum set determines the intensity of the sound. Finally, the force of jumping on a trampoline determines the intensity of the sensation.

In addition to occurring naturally in our everyday environment, conjugate schedules have been

This study is based on a thesis submitted by the first author under the supervision of the second author in partial fulfillment of the requirements of the master's degree for the Department of Applied Behavioral Science at the University of Kansas. We would like to thank Drs. Pamela Neidert and Derek Reed for their comments on a previous version of the manuscript.

Address correspondence to: Claudia L. Dozier, Department of Applied Behavioral Science, University of Kansas, Lawrence, KS 66045. Email: cdozier@ku.edu

doi: 10.1002/jaba.696

used to study various behaviors and psychological phenomena. Lindsley (1957) initially developed the conjugate-reinforcement preparation as a tool to study adult sleep cycles. To do so, sleep deprived subjects wore a helmet with earphones that would play a tone. Subjects could press a hand-held device to reduce the volume of the tone that played continuously. Therefore, the subject's responding directly controlled the intensity of the tone. This preparation allowed Lindsley to study adult sleep patterns by evaluating the effects of sleep deprivation on sleep onset and duration (i.e., latency to response cessation and the duration of response cessation). After that initial use, Lindsley used a similar preparation to study anesthesia recovery (Lindsley et al., 1961) and the depth of a coma after electroshock therapy (Lindsley & Conran, 1958).

Since Lindsley's initial studies, the conjugate-reinforcement paradigm has been used to study (and change, in some cases) a variety of socially important behaviors and psychological phenomena such as (a) infant exploratory (e.g., Rovee & Rovee, 1969) and play behavior (e.g., panel pressing; Lipsitt et al., 1966), (b) the reinforcing efficacy of various stimuli including social reinforcers in infants and individuals with disabilities (e.g., Edwards & Peek, 1970; Lindsley, 1963; Lovitt, 1967; McKirdy & Rovee, 1978; Mira, 1969, 1970; Siqueland & DeLucia, 1969), (c) increasing work output (e.g., Greene & Hoats, 1969), (d) physical activity (e.g., Caouette & Reid, 1991; Lancioni et al., 2003), and (e) motor activity (e.g., Switzky & Haywood, 1973) in individuals with disabilities. For example, Greene and Hoats (1969) found that a conjugate schedule in which the clarity of the television (TV) picture, volume, and sound maintained as long as the subject was engaged in a target task. Results showed that avoiding TV distortion under the conjugate schedule was effective for behavior change. More recently, MacAleese et al. (2015) and Falligant et al. (2018) used a similar preparation to evaluate different parameters of conjugate reinforcement (e.g., response force and extinction-induced variability). That is, these researchers demonstrated the relevance and utility of these lesser known schedules. However, more research is needed to understand the mechanisms responsible for behavior change under this schedule, which represents an area with great clinical utility.

A less common schedule of covariation is the synchronous-reinforcement schedule in which the onset and offset of the reinforcer are perfectly synchronized with the onset and offset of the response (Ramey et al., 1972; Rovee-Collier & Gekoski, 1979; Weisberg & Rovee-Collier, 1998). Thus, the duration of the response directly controls the duration of access to the reinforcing stimulus (Ramey et al., 1972; Weisberg & Rovee-Collier, 1998). The synchronous schedule is similar to the conjugate schedule because in both schedules responding directly controls and covaries with the reinforcer. However, in papers that differentiate between the two schedules, it seems that they are differentiated by the timing of the response–reinforcer covariation (MacAleese, 2008; Rovee-Collier & Gekoski, 1979; Voltaire, Gewirtz, & Pelaez, 2005; Weisberg & Rovee-Collier, 1998). That is, in synchronous reinforcement, the behavior and reinforcer relation is all or nothing—if the behavior is happening, the reinforcer is delivered, whereas, if the behavior is not happening then the reinforcer is not delivered. In contrast, in conjugate reinforcement, some dimension of the behavior controls some dimension of the reinforcer—if the behavior is happening at a certain rate or intensity, then the reinforcer is delivered at that rate or intensity.

Similar to the conjugate-reinforcement paradigm, the synchronous-reinforcement paradigm has also been used to study a variety of phenomena including (a) psychological phenomena in infants such as sensory feedback control (e.g., Smith et al., 1963) and motor movement (e.g., Siqueland, 1968; Siqueland & Lipsitt, 1966), (b) preference and reinforcing efficacy of social interaction (e.g., Pelaez-Nogueras et al., 1997; Pelaez-Nogueras et al., 1996) and other stimuli (e.g., Friedlander, 1966; Horowitz, 1974a, 1974b; Leuba & Friedlander, 1968) in infants, (c) increasing vocalizations in infants (e.g., Ramey et al., 1972), (d) preference and reinforcer efficacy of stimuli for adults with disabilities (e.g., Saunders et al., 2001; Saunders & Saunders, 2011; Saunders et al., 2003), and (e) increasing physical activity in adults (Biddiss & Irwin, 2010; Faith et al., 2001).

For example, Pelaez-Nogueras et al. (1996) evaluated infant preference for adult touch (i.e., smiling, vocalizing, and rhythmically rubbing both of the infant's legs and feet) using synchronous reinforcement. That is, the onset and offset of infant eye-contact responses directly controlled the onset and offset of adult touch. Results showed infants engaged in more eye-contact responses during the touch condition as compared to the no-touch condition, suggesting adult touch was reinforcing and may be used to influence infant behavior. In a follow-up study, Pelaez-Nogueras et al. (1997) compared two types of touch (i.e., stroking vs. tickling and poking) on infant eye-contact using a synchronous-reinforcement schedule. Results showed infants spent more time making eye contact during the stroking condition compared to the tickling and poking condition.

Similarly, Saunders and colleagues (Saunders et al., 2001; Saunders & Saunders, 2011; Saunders et al., 2003) used a synchronous-reinforcement schedule to determine preferences and reinforcers with individuals with profound intellectual and developmental disabilities. In their 2011 study, participants with profound disabilities used switches to activate and terminate leisure devices (e.g., auditory, tactile, and visual feedback). Results of the study demonstrated that synchronous reinforcement could be used to determine relative preference for potentially reinforcing stimuli. Additionally, these results provide an alternative method to determine preference and reinforcers for individuals who may be difficult to test using other preference assessment procedures.

In summary, previous research has used schedules of covariation to study various phenomena; however, few studies have evaluated the utility of these schedules for changing socially important behavior across populations, behaviors, and contexts. Furthermore, few studies, except for a few basic research studies (e.g., MacAleese et al., 2015; Williams & Johnston, 1992), have studied these schedules in their own right. Thus, little is known about the conditions under which they might be useful and the mechanism by which this type of schedule may be more effective than other schedules of reinforcement. Finally, few studies (e.g., Voltaire et al., 2005) have compared the effects of schedules of covariation with other schedules of reinforcement. Continued research on schedules of covariation is warranted given their ubiquity in our everyday lives (e.g., walking, crawling, singing, playing an instrument, playing sports). Additionally, Marr (1992, 2018) noted the importance of schedules of covariation to further our understanding of moment-to-moment processes that are instrumental in the development of complex patterns of behavior. Schedules of covariation, more specifically synchronous schedules, may offer a preparation by which researchers can evaluate dynamic processes of behavior and contribute to both basic and applied areas of research.

This study was a proof-of-concept demonstration of the effects of synchronous reinforcement on a behavior of applied significance: on-task behavior in preschool-age children. We compared the effects of the synchronous schedule with a control condition (accumulated reinforcement) in which the same contingency for on-task behavior was present; however, the reinforcer was delivered after the session (i.e., an asynchronous reinforcer presentation). A secondary purpose of the study was to determine participant preference for the two schedules of reinforcement.

Method

Participants, Setting, and Materials

Participants were eight typically developing children, ages 2 to 5, who attended a university-based preschool. Based on informal observations, all participants (a) followed multistep instructions (e.g., walk to your cubby, put your backpack away, and sit down), (b) remained seated for more than 5 min, and (c) held a writing utensil to trace shapes. Trained graduate students conducted sessions in rooms that contained a table, chairs, and relevant session materials. All sessions were conducted in a session block, and each session block consisted of two to three sessions that were conducted consecutively. Sessions were 5 min; and session blocks were conducted one to two times per day, 3 to 5 days per week.

During all sessions, target task materials (those that produced the reinforcer), an alternative task (those that did not produce the reinforcer), and a dry-erase marker were present. Target task materials included a stack of laminated shape-tracing worksheets (measuring 21.6 cm x 27.9 cm). The worksheets included three rows of shapes (e.g., circles, triangles, and squares) by three columns of shapes for a total of nine shapes on each worksheet. The alternative task materials included a stack of blank laminated sheets on which the participant could draw. Different colored stimuli were associated with different conditions to aid in discrimination across conditions. That is, we used different worksheet backgrounds, blank laminated sheet backgrounds, and different colored tablecloths. During both reinforcement conditions (see below), the experimenter presented a song board to participants. The song board was a white laminated poster board (measuring 55.8 cm x 71.1 cm) with 10 to 20 laminated picture icons (measuring 4.5 cm x 3 cm) that corresponded with 10 to 20 songs with VELCRO® strips affixed to the back, such that they could be attached to the poster board. During reinforcement sessions, the experimenter also had an iPod touch™ with a playlist containing the songs depicted on the song board.

Response Measurement, Interobserver Agreement, and Procedural Integrity

Trained observers collected data using handheld data-collection devices. The dependent variable was the duration of on-task behavior (shape tracing), which was scored if the participant was moving the marker steadily and approximately within the boundaries of the thick preprinted lines on the shape-tracing worksheet or turning over the worksheet page to access a new worksheet without pausing for more than 2 s. On-task behavior was not scored if more than 2 s passed with the participant lifting the marker away from the tracing worksheet, coloring anywhere outside or inside of the thick preprinted lines on the worksheet (e.g., shading the area between the lines with the marker, outlining the area around the thick lines, coloring the entire shape), or physically manipulating the marker in a manner that prevented tracing (e.g., rolling, tapping, or throwing the marker).

A second independent observer collected data during at least 50% of sessions for each participant. Interobserver agreement (IOA) was determined by using an exact agreement method to analyze second-by-second within-session responding. An agreement on a particular second was defined as both data collectors scoring the occurrence or nonoccurrence of the behavior on a given second. IOA was calculated by dividing the number of seconds in the session with an agreement by the total number of seconds and multiplying by 100. Mean IOA across participants was 95% (range, 93% to 98%).

We calculated procedural integrity, to determine whether the experimenter correctly implemented the programmed contingencies, for at least 50% of all reinforcement sessions (i.e., synchronous and accumulated reinforcement) for each participant across reinforcer conditions. For both reinforcement conditions, observers collected data on the duration of reinforcer delivery, which was defined as the period of onset and removal of the reinforcer. In addition, we calculated procedural integrity by comparing the outcomes of two measures (i.e., on-task duration and reinforcer delivery duration) by dividing the smaller duration by the larger duration and multiplying by 100. Mean procedural integrity across participants was 96% (range, 91% to 99%).

Determining Preferred Songs

Prior to the study, the experimenter asked (a) four doctoral-level graduate student supervisors who worked with the children in the preschool classrooms on a daily basis and (b) parents of the first three children who were recruited to list 10 preferred songs. From those lists, the experimenter determined the 10 most commonly reported songs to include on the song board during reinforcement sessions across children. However, during the latter part of the reinforcement phase for the first three participants, these participants began reporting that they wanted to listen to other songs than those on the song board. Therefore, for the subsequent five participants, we included the 10 songs that were included for the first three participants, as well as 10 additional songs that were verbally reported by individual children or their parents to be preferred. Furthermore, the subsequent five participants could request additional songs not shown on their individualized song board to be used during reinforcement phases.

General Procedures

During all sessions, the experimenter was seated across the table from the participant and presented the target task and the alternative task on the table in front of the participant (approximately 27 cm apart) with a dry-erase marker placed in between them. The experimenter presented a large stack of both sheets such that the participant would not run out of materials for either task. Prior to all sessions, a presession exposure procedure was conducted. The experimenter provided a brief rule stating the contingencies associated with the condition and provided exposure to the session contingencies programmed for on-task behavior (i.e., "This is the [color] condition. When you are tracing shapes, X [extinction or one of the reinforcement contingencies] will happen. When you draw on the drawing sheets, nothing will happen. You can switch between drawing and tracing whenever you would like").

Prior to the reinforcement phase, the experimenter familiarized participants with the songs associated with the different pictures on the song board by conducting three exposure sessions. During these exposure sessions, the experimenter pointed to each picture on the song board, told the participant the name of the song, and played a brief clip (10 s) of the song. After these three exposure sessions, the reinforcement phase began.

Prior to each reinforcement session, the experimenter displayed the song board and reminded the participant the name of each song while pointing to its corresponding picture. After this, the experimenter asked the participant to pick the songs they wanted to hear the most (typically three songs) prior to each reinforcement session. Whichever songs the participant picked (by touching the picture or saying the name of the song), those songs were played using the built-in speakers on the iPod touch™ in the order in which they were selected or requested during reinforcement sessions. To more closely resemble how these reinforcers were delivered in the child's everyday environment, attention from the experimenter (e.g., making statements about the song or discussing other contextual topics) was freely available while the song was playing.

Baseline

During baseline sessions, discriminative stimuli (i.e., task materials and tablecloth) were white. During presession exposure, the experimenter prompted the participant to trace for approximately 10 s and provided no programmed consequences. During the session, the experimenter did not deliver any programmed consequences for engaging in the target task or any other behavior.

Synchronous Reinforcement (SSR)

During synchronous-reinforcement sessions, discriminative stimuli (i.e., task materials and tablecloth) were blue. During presession exposure, the experimenter prompted the participant to trace for approximately 10 s and provided access to a preferred song and attention throughout that 10 s. During the session, the experimenter turned on the preferred songs and provided attention in the form of conversation while the participant was engaging in the task (based on the operational definition of on-task behavior). However, if the participant stopped engaging in the task for 2 s the experimenter paused the song and stopped providing attention in the form of conversation (e.g., preferred topics or activities) until the participant again began engaging in the task.

Accumulated Reinforcement (ACC)

During accumulated-reinforcement sessions, discriminative stimuli (i.e., task materials and tablecloth) were red. During presession exposure, the experimenter prompted the participant to trace for approximately 10 s and provided access to a preferred song and attention in the form of conversation at the end of the presession exposure for the duration of time spent engaging in the task (i.e., 10 s). During the session, the experimenter did not deliver any programmed consequences; however, at the end of the session they yoked the duration of access to the preferred songs and attention to the duration of task engagement (based on the operational definition of on-task behavior) during the session. Thus, the postsession duration was not fixed; it only lasted the duration of reinforcer access, which was yoked to the duration of on-task behavior during the session. To determine the duration of reinforcer access, the experimenter used a silent timer (e.g., iPod touch™ timer) that was not visible to the participant, to measure on-task behavior within the session. The experimenter measured on-task behavior using the same operational definition that data collectors used to collect data. That is, they started the timer when the participant was on-task and paused the timer when not on-task for more than 2 s.

Additional Discrimination Training (Graham)

Initial patterns of responding in the SSR versus ACC phase and comments made by Graham suggested his responding was not under the control of condition-specific stimuli. That is, at the start of sessions when the experimenter stated the rules that corresponded with the different conditions, Graham would often interrupt and say rules that differed from those associated with the contingencies. Therefore, the experimenter conducted several extended training sessions to enhance discrimination across conditions. During these sessions, the experimenter placed both of the color-correlated stimuli associated with the reinforcement conditions next to each other on the table in front of Graham and stated how each of the colors were different and had different rules associated with them. Next, the experimenter modeled tracing on the tracing sheets and drawing on the drawing sheets across both reinforcement conditions and a research assistant provided the consequences associated with each schedule to demonstrate how the contingencies were different across both conditions. Next, the experimenter had Graham state how each of the conditions were different and what would happen if he were to draw on the drawing sheets or trace on the tracing sheets. Finally, the experimenter prompted Graham to trace on the tracing sheets and draw on the drawing sheets for approximately 30 s each and provided the consequences associated with each reinforcement condition. These additional training sessions were 15 min and were conducted across 3 days, after which time Graham accurately stated the contingencies associated with each condition. Following this additional training, the experimenter resumed SSR and ACC sessions.

Experimental Design

For all participants, we used a multielement design to compare the effects of the two reinforcement schedules. That is, after we determined baseline levels of on-task behavior for each participant, we rapidly alternated synchronous-reinforcement sessions and accumulated-reinforcement sessions. The order of conditions was quasirandom such that no more than two of the same conditions were conducted consecutively. For participants who engaged in similar levels of on-task behavior across conditions in the multielement phase of the study, we used a nonconcurrent multiple baseline design across participants to show experimental control (Konner, Kyara, and Ella).

Preference Assessment

Following the comparison of the different schedules of reinforcement, we conducted a preference assessment using a concurrent-chains arrangement (Hanley et al., 2005; Herrnstein, 1964) to determine participant preference for the different conditions. Prior to each session, the participant was presented with all three colored stimuli that were associated with each of the different conditions (baseline, synchronous reinforcement, and accumulated reinforcement) in a row on the table and reminded them of the contingencies associated with each set of materials. For example, the participant was reminded that the white materials meant that there were no songs or attention for tracing, the blue materials meant that they would listen to songs and talk with the experimenter while they were tracing, and red materials meant that they would listen to songs and talk with the experimenter after they traced. The placement of the different materials was switched each session (i.e., left, right, and middle). All participants had the opportunity to choose between all three experimental conditions (i.e., baseline, SSR, and ACC). After the experimenter reminded the participant of the contingencies associated with each set of materials, they asked the participant to pick their favorite by pointing to, touching, or naming a set of materials. The participant could only choose one set of materials associated with a specific condition per session. The experimenter then placed the materials selected on the table and conducted the chosen condition as described above. For example, if a participant selected the blue materials, the experimenter would remove the white and red materials from the table, set up the chosen blue materials on the table, and conduct the SSR condition as previously described. Trained observers collected data on the condition selected by participants and the duration of on-task behavior.

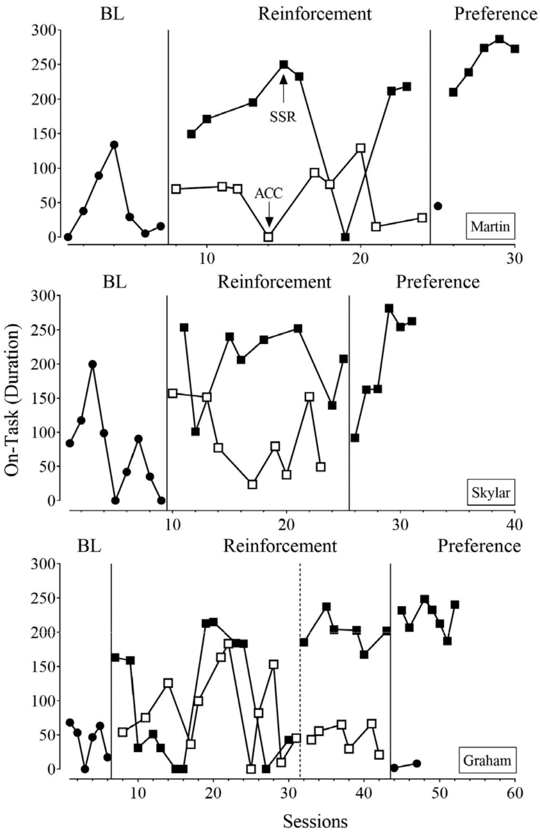
During the preference assessment, IOA was calculated for selection of a procedure using the total agreement method. An agreement was scored if both observers agreed which procedure was selected, and a disagreement was scored if there was a discrepancy between the two observers. Thus, IOA for selection for a particular session was either 100% (the two observers agreed) or 0% (the two observers disagreed). IOA was calculated for at least 30% of sessions for all participants, and mean agreement was 100% for all participants.

Results

Figures 1–3 depict the duration of on-task behavior for all eight participants. Figure 1

Figure 1

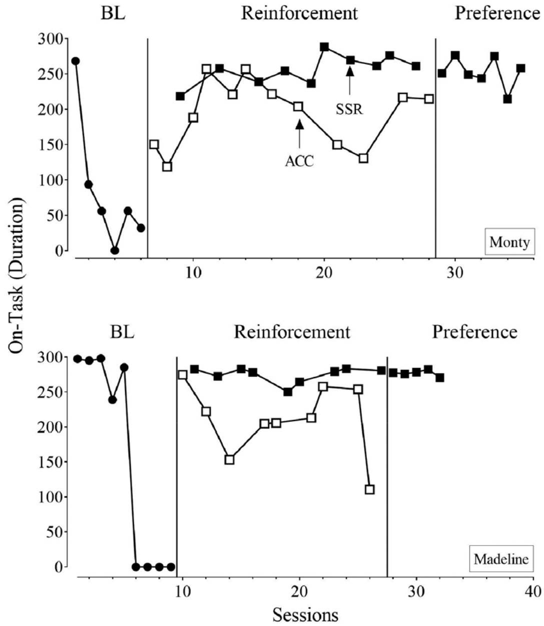
Data for Martin (top panel), Skylar (middle panel), and Graham (bottom panel)



Note. These data are depicted as duration of on-task behavior in seconds. The closed circles depict baseline sessions, closed squares denote SSR sessions, and open squares denote ACC sessions. The dotted phase line (bottom panel) denotes additional training sessions conducted with Graham to enhance discrimination across conditions.

Figure 2

Data for Monty (top panel) and Madeline (bottom panel)



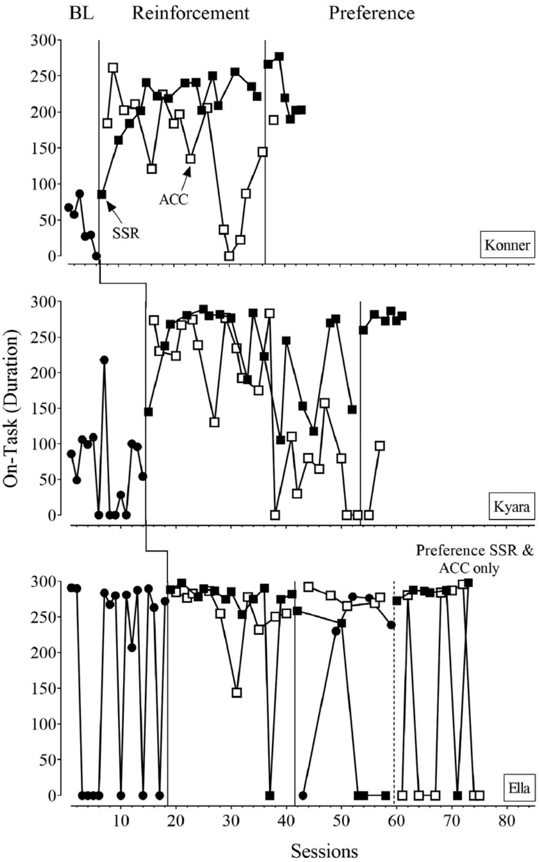
Note. These data are depicted as duration of on-task behavior in seconds. The closed circles depict baseline sessions, closed squares denote SSR sessions, and open squares denote ACC sessions.

depicts data for Martin (top panel), Skylar (middle panel), and Graham (bottom panel), individuals for whom the SSR condition was clearly superior to the ACC condition. During baseline, all three participants engaged in low levels (Martin and Graham) or decreasing levels (Skylar) of on-task behavior. During the reinforcement phase, Martin and Skylar showed an increase in levels of on-task behavior only in the SSR condition. Further, they both engaged in similar levels of on-task behavior in the ACC condition as compared to baseline. Initially, Graham engaged in overall higher but variable levels of on-task behavior in the SSR and ACC conditions as compared to baseline. However, after additional discrimination training, Graham showed an increased and stable level of on-task behavior only in the SSR condition. He engaged in similar levels of on-task behavior in the ACC condition as compared to baseline.

Figure 2 depicts data for Monty (top panel) and Madeline (bottom panel), individuals for whom the SSR condition was only slightly superior to the ACC condition. During baseline, both participants engaged in low levels (Monty) or decreasing levels (Madeline) of on-task behavior. During the reinforcement phase, both participants engaged in higher levels of on-task behavior during both SSR and ACC

Figure 3

Data for Konner (top panel), Kyara (middle panel), and Ella (bottom panel)



Note. These data are depicted as duration of on-task behavior in seconds. The closed circles depict baseline sessions, closed squares denote SSR sessions, and open squares denote ACC sessions. The dotted phase line (bottom panel) denotes a modification in the preference condition conducted with Ella.

conditions as compared to baseline; however, on-task behavior was consistently higher in the SSR condition.

Figure 3 depicts data for Konner (top panel), Kyara (middle panel), and Ella (bottom panel), individuals for whom levels of responding were similar across conditions, at least initially, during the reinforcement phase. A multiple baseline design across participants embedded within a multielement design was used to show experimental control with these participants. During baseline, participants engaged in low levels (Konner and Kyara) or variable levels (Ella) of on-task behavior. During the reinforcement phase, Konner and Kyara initially engaged in higher levels of on-task behavior during both the SSR and ACC condition as compared to baseline. However, over time, SSR showed to be more effective for producing maintained high levels of on-task behavior. Ella engaged in more consistently high levels during both SSR and ACC conditions as compared to baseline.

During the preference phase, seven of eight participants (Martin, Skyler, Graham, Monty, Madeline, Konner, and Kyara) consistently chose the SSR condition and engaged in high levels of on-task behavior during those sessions. Ella displayed a different pattern of responding. She chose all three conditions, suggesting she did not have a clear preference. However, only in sessions in which she chose the SSR or ACC conditions did she engage in high levels of on-task behavior. Given the purpose of the preference phase was to assess relative preference between the two schedules of reinforcement, the experimenter removed the baseline condition materials and only presented the SSR and ACC condition materials in subsequent sessions. Following this modification, Ella chose both SSR and ACC conditions; however, she engaged in higher and more consistent on-task behavior during SSR sessions.

Discussion

The current study was a proof-of-concept demonstration of the effects of a synchronous-reinforcement schedule (SSR) in comparison to an accumulated-reinforcement schedule (ACC) for increasing on-task behavior in young children. Additionally, we evaluated participant preference for both schedules of reinforcement. Although ACC was effective for increasing on-task behavior over baseline levels for several participants, at least initially, SSR was more effective at increasing on-task behavior for seven out of eight participants. For Ella, the results were similar across conditions. Furthermore, all participants but Ella preferred SSR over ACC. Ella selected both SSR and ACC during the preference phase, suggesting no clear preference for one over the other. Overall, these results showed that SSR was more effective and more preferred for increasing on-task behavior in preschoolers using the current preparation.

Although the duration of reinforcement was based on response duration in both schedules, for seven out of eight participants SSR was more effective and preferred than ACC. There are several possible reasons for these results. First, access to reinforcement was immediate in the SSR condition and delayed in the ACC condition (i.e., after the session ended). Therefore, patterns of responding observed under SSR and ACC schedules may be similar to those observed under other immediate and delayed schedule arrangements (Lattal, 2010). Second, it is possible that moment-to-moment changes in reinforcer access during the SSR condition influenced responding (Saunders et al., 2001; Saunders & Saunders, 2011; Switsky & Haywood, 1973). That is, with the SSR schedule, the duration of participant on-task behavior was perfectly synchronized with the duration of access to the reinforcer, which may have provided a more sensitive reinforcement contingency for behavior change. Third, it is possible that the removal of music and conversation during the SSR condition functioned as negative punishment resulting in more effective behavior change (Greene & Hoats, 1969; MacAleese et al., 2015; Switsky & Haywood, 1973). That is, during the SSR condition, if the participant was off-task (i.e., not tracing or tracing incorrectly) for more than 2 s, then the experimenter paused the song and stopped providing attention until the participant again was on-task. Fourth, it is possible that the work task (tracing) was less aversive during the SSR condition because of the ongoing availability of reinforcers during the work task. In fact, previous research suggests access to preferred items and activities during work tasks may make a task less aversive and more preferred (Carr et al., 1980; Lalli et al., 1999; Lomas et al., 2010; Wallace et al., 2012).

Finally, it is also possible the results were influenced by the design of the ACC condition. That is, the extent to which the ACC condition functioned as a true control for the SSR condition is unknown. Previous research evaluating ACC reinforcer arrangements (e.g., DeLeon et al., 2014) often includes the delivery of tokens (Hackenberg, 2009) to signal the accumulation of reinforcement and provide immediate feedback about within-session performance. The procedures in the current study were inconsistent with previous research using ACC with tokens, which may have weakened our experimental arrangement and limited our findings. Furthermore, the presence of the reinforcer within the session during the SSR condition may have established better stimulus control as compared to the ACC condition. Future research should involve controlling for this by including a signal such as tokens to increase the saliency between the response–reinforcer relations and equate the differences in reinforcer magnitude across the SSR and ACC conditions.

There are several methodological limitations worth mentioning. First, multiple rules were provided to participants to aid in discrimination between conditions and it is unknown to what extent the rules played in differential responding. As mentioned, one of our participants, Graham, created self-generated rules that influenced his responding, which was only corrected after providing him with additional exposure to the rules and contingencies. Future research should involve determining the influence of these schedules with individuals who have less sophisticated listener behavior to determine whether similar results would be obtained. Second, although SSR and ACC sessions were both 5 min, the duration of time participants were in the session room was different across conditions. That is, during all SSR sessions, participants left the session room after sessions because access to reinforcement was delivered within session. However, during ACC sessions, reinforcer access was provided after session and the duration of postsession reinforcement was based on the duration of on-task behavior during session. Therefore, participants did not leave the session room until after their 5-min session plus reinforcer access time. Thus, from a molar perspective, the longer "session" duration in ACC may have influenced responding. However, this is unlikely because in the preference phase most participants did not choose BL or ACC and then not respond, which would indicate that they wanted to leave the session room. Third, attention was not purely synchronized with on-task behavior because attention was delivered in the form of a conversation, which naturally involved responding and listening to the participant. Future research should involve controlling for this by delivering a different topography of attention (i.e., praise statements or general comments), which might not involve pauses between the speaker and listener. Fourth, differences in reinforcer magnitude across SSR and ACC conditions may have confounded the results obtained during the preference assessment. Researchers might address this limitation by equating reinforcer densities across SSR and ACC and then assessing preference. Additionally, researchers could also include forced-choice exposure sessions to both conditions to equate the history of reinforcement across both conditions. However, it is likely that SSR would still result in being more preferred as compared to ACC due to the immediacy of the reinforcer delivery. More research is warranted to determine the utility and relevance of using procedures similar to those described in the current study as a way to assess preference for contingencies (Taber-Doughty, 2005).

Although results of the current study are promising and suggest SSR schedules of reinforcement have wide-ranging applicability for behavior change, a couple of practical considerations need to be mentioned. In particular, SSR schedules may not be amenable to all response–reinforcer arrangements. That is, some responses may be disrupted by the presentation of a reinforcer in the context of completing those tasks (depending on the nature of the task and the reward). In some cases, reinforcer consumption may be incompatible with moment-to-moment compliance. For more basic behaviors, such as those in this study, the use of a reinforcer that required motor movements for consumption (e.g., eating food) and reorientation to the task following consumption likely would affect the response rate. For more complex behavior, such as reading comprehension, the delivery of a reinforcer such as that used in this study may be disruptive and interfere with the occurrence of the target response.

In addition, synchronous schedules, depending on the reinforcer used, may be disruptive to peers in close proximity and may be very effortful to implement. That is, it may not be feasible for teachers, caregivers, or staff to continuously observe the responding of an individual and synchronize the delivery of access to reinforcers with the target behavior. To address this limitation, researchers may consider automating the delivery and removal of reinforcing stimuli using procedures similar to those described by Lindsley (1962). Researchers could also automate reinforcement delivery with technology and video games (e.g., Kinect, TV; Biddiss & Irwin, 2010; Faith et al., 2001).

In addition to future research directly related to the procedures used in this study, there are various avenues for future studies on schedules of covariation including the evaluation of combined schedules (e.g., combining conjugate and synchronous schedules). Researchers could replicate and extend the current study to other populations (e.g., school-age children, adults, and elderly individuals) and behaviors (e.g., problem behavior, transition behavior, hygiene and self-help skills, physical activity, and preacademic skills). Additionally, researchers should evaluate the degree to which behavior maintains under SSR. For example, continuous schedules are not likely to occur over time, and thus it is important to assess the durability of schedules of reinforcement when they are thinned or when errors in treatment integrity occur. This would provide meaningful information on the practical utility of schedules of covariation. Another avenue for future research is to determine the influence of SSR on group behavior. For example, researchers could evaluate the utility of SSR as a classroom management procedure to increase the on-task behavior of a group of individuals. Another consideration may be extending this line of work by comparing schedules of covariation with other common schedules (ratio and interval schedules) to determine their efficacy and conditions under which they are most likely to be effective. Comparing these different schedules might allow us to determine the influence of duration of reinforcement, uninterrupted and continuous access to reinforcers, covariation in response and reinforcer, uninterrupted and continuous work, and combinations of factors on the efficacy and preference for these schedules. In the future, researchers could replicate and extend the current study by comparing SSR and ACC and denote correct and/or incorrect responding with a green and red light or some other stimulus change. This may allow researchers to determine if moment-to-moment reinforcement is necessary or if the important mechanism is feedback for correct/incorrect responding. Furthermore, it would be interesting to compare the effects of synchronous and conjugate schedules to determine the mechanisms responsible for behavior change. That is, researchers could isolate relevant variables such as reinforcer delivery that may be responsible for behavior change. For example, it is unknown whether a conjugate-reinforcement schedule is effective due to the moment-to-moment changes in the reinforcer delivery and covariation of some dimension of behavior *and* the change in some relevant dimension of reinforcement. Thus, a comparison of these schedules may allow us to rule this out.

The current study served as a proof-of-concept demonstration of the effects of a synchronous-reinforcement schedule compared to an accumulated-reinforcement schedule for increasing on-task behavior in young children. Results showed the synchronous schedule was more effective and more preferred for most participants. These findings provide support for evaluating the utility of an SSR schedule, and more broadly schedules of covariation, for changing socially important behaviors. Given the ubiquity of schedules of covariation in the everyday environment, more research is warranted to gain a better understanding of these schedules and how they influence behavior.

REFERENCES

Biddiss, E., & Irwin, J. (2010). Active video games to promote physical activity in children and youth. *Archives of Pediatrics & Adolescent Medicine*, *164*, 664–672. https://doi.org/10.1001/archpediatrics.2010.104

Caouette, M., & Reid, G. (1991). Influence of auditory stimulation on the physical work output of adults who are severely retarded. *Education and Training in Mental Retardation*, *26*, 43-52. Retrieved from PsychINFO database.

Carr, E. G., Newsom, C. D., & Binkoff, J. A. (1980). Escape as a factor in the aggressive behavior of two retarded children. *Journal of Applied Behavior Analysis*, *13*, 101–117. https://doi.org/10.1901/jaba.1980.13-101

DeLeon, I. G., Chase, J. A., Frank-Crawford, M. A., Carreau-Webster, A. B., Triggs, M. M., Bullock, C. E., & Jennett, H. K. (2014). Distributed and accumulated reinforcement arrangements: Evaluations of efficacy and preference. *Journal of Applied Behavior Analysis*, *47*, 293–313. https://doi.org/10.1002/jaba.116

Edwards, J. S., & Peek, V. (1970). Conjugate reinforcement of radio listening. *Psychological Reports*, *26*, 787–790. https://doi.org/10.2466/pr0.1970.26.3.787

Faith, M. S., Berman, N., Heo, M., Pietrobelli, A., Gallagher, D., Epstein, L. H., … Allison, D. B. (2001). Effects of contingent television on physical activity and television viewing in obese children. *Pediatrics*, *107*, 1043–1048. https://doi.org/10.1542/peds.107.5.1043

Falligant, J. M., Rapp, J. T., Brogan, K. M., & Pinkston, J. W. (2018). Response force in conjugate schedules of reinforcement. *The Psychological Record*, *68*, 525–536. https://doi.org/10.1007/s40732-018-0298-8

Ferster, C.B., & Skinner, B. F. (1957). Schedules of reinforcement. B.F. Skinner Foundation.

Friedlander, B. Z. (1966). Three manipulanda for the study of human infants' operant play. *Journal of the Experimental Analysis of Behavior*, *9*, 47–49. https://doi.org/10.1901/jeab.1966.9-47

Greene, R. J., & Hoats, D. L. (1969). Reinforcing capabilities of television distortion. *Journal of Applied Behavior Analysis*, *2*, 139–141. https://doi.org/10.1901/jaba.1969.2-139

Hackenberg, T. D. (2009). Token reinforcement: A review and analysis. *Journal of the Experimental Analysis of Behavior*, *91*, 257–286. https://doi.org/10.1901/jeab.2009.91-257

Hanley, G. P., Piazza, C. C., Fisher, W. W., & Maglieri, K. A. (2005). On the effectiveness and preference for punishment and extinction components of function-based interventions. *Journal of Applied Behavior Analysis*, *38*, 51–65. https://doi.org/10.1901/jaba.2005.6-04

Herrnstein, R. J. (1964). Secondary reinforcement and rate of primary reinforcement. *Journal of the Experimental Analysis of Behavior*, *7*, 27–36. https://doi.org/10.1901/jeab.1964.7-27

Horowitz, F. D. (1974a). Discussion and conclusions. *Monographs of the Society for Research in Child Development*, *39*, 105–115. https://doi.org/10.2307/1165976

Horowitz, F. D. (1974b). Infant attention and discrimination: Methodological and substantive issues. *Monographs of the Society for Research in Child Development*, *39*, 1–15. https://doi.org/10.2307/1165968

Lalli, J. S., Vollmer, T. R., Progar, P. R., Wright, C., Borrero, J., Daniel, D., … May, W. (1999). Competition between positive and negative reinforcement in the treatment of escape behavior. *Journal of Applied Behavior Analysis*, *32*, 285–296. https://doi.org/10.1901/jaba.1999.32-285

Lancioni, G. E., Singh, N. N., O'Reilly, M. F., Oliva, D., Campodonico, F., & Groeneweg, J. (2003). Assessing the effects of automatically delivered stimulation on the use of simple exercise tools by students with multiple disabilities. *Research in Developmental Disabilities*, *24*, 475–483. https://doi.org/10.1016/j.ridd.2003.03.002

Lattal, K. A. (2010). Delayed reinforcement of operant behavior. *Journal of the Experimental Analysis of Behavior*, *93*, 129–139. https://doi.org/10.1901/jeab.2010.93-129

Leuba, C., & Friedlander, B. Z. (1968). Effects of controlled audio-visual reinforcement on infants' manipulative play in the home. *Journal of Experimental Child Psychology*, *6*, 87–99. https://doi.org/10.1016/0022-0965(68)90074-X

Lewis, R. F. (1973). Conjugate reinforcement. Presented at the Association for Educational Communication and Technology Annual Conference, Las Vegas, NV, April, 1973.

Lindsley, O. R. (1957). Operant behavior during sleep: a measure of depth of sleep. *Science*, *126*, 1290–1291. https://doi.org/10.1126/science.126.3286.1290

Lindsley, O. R. (1962). A behavioral measure of television viewing. *Journal of Advertising Research*, *2*, 1–12.

Lindsley, O. R. (1963). Experimental analysis of social reinforcement: Terms and methods. *American Journal of Orthopsychiatry*, *33*, 624–633. https://doi.org/10.1111/j.1939-0025.1963.tb01010.x

Lindsley, O. R., & Conran, P. (1958/1962). Operant behavior during EST: a measure of depth of a coma. *Diseases of the Nervous System*, *23*, 2–4.

Lindsley, O. R., Hobika, J. H., & Etsten, B. E. (1961). Operant behavior during anesthesia recovery: A continuous and objective method. *Anesthesiology*, *22*, 937–946. https://doi.org/10.1097/00000542-196111000-00012

Lipsitt, L. P., Penderson, L. J., & DeLucia, C. A. (1966). Conjugate reinforcement of operant responding in infants. *Psychonomic Science*, *4*, 67–68. https://doi.org/10.3758/BF03342180

Lomas, J. E., Fisher, W. W., & Kelley, M. E. (2010). The effects of variable-time delivery of food items and praise on problem behavior reinforced by escape. *Journal of Applied Behavior Analysis*, *43*, 425–435. https://doi.org/10.1901/jaba.2010.43-425

Lovitt, T. C. (1967). Use of conjugate reinforcement to evaluate the relative reinforcing effects of various narrative forms. *Journal of Experimental Child Psychology*, *5*, 164–171. https://doi.org/10.1016/0022-0965(67)90004-5

MacAleese, K. R. (2008). *Examining conjugate reinforcement* (Doctoral dissertation). Retrieved from ProQuest Dissertations & Theses Global. (Order Number 3342622).

MacAleese, K., Ghezzi, P. M., & Rapp, J. T. (2015). Revisiting conjugate schedules. *Journal of the Experimental Analysis of Behavior*, *104*, 63–73. https://doi.org/10.1002/jeab.160

Marr, M. J. (1992). Behavior dynamics: One perspective. *Journal of the Experimental Analysis of Behavior*, *57*, 249–266. https://doi.org/10.1901/jeab.1992.57-249

Marr, M. J. (2018). Bounded in a nutshell: The uncertain future of EAB. *Behavior Analysis: Research and Practice*, *18*, 388–397. https://doi.org/10.1037/bar0000121

McKirdy, L. S., & Rovee, C. K. (1978). The efficacy of auditory and visual conjugate reinforcers in infant conditioning. *Journal of Experimental Child Psychology*, *25*, 80–89. https://doi.org/10.1016/0022-0965(78)90040-1

Mira, M. P. (1969). Effects of response force on conjugate rates. *Behavior Research and Therapy*, *7*, 331–333. https://doi.org/10.1016/0005-7967(69)90017-5

Mira, M. P. (1970). Direct measurement of the listening of hearing-impaired children. *Journal of Speech and Hearing Research*, *13*, 65–73. https://doi.org/10.1044/jshr.1301.65

Pelaez-Nogueras, M., Field, T., Gewirtz, J. L., Cigales, M., Gonzalez, A., Sanchez, A., & Richardson, S. C. (1997). The effect of systematic stroking versus tickling and poking on infant behavior. *Journal of Applied Developmental Psychology*, *18*, 169–178. https://doi.org/10.1016/S0193-3979(97)90034-4

Pelaez-Nogueras, M., Gewirtz, J. L., Field, T., Cigales, M., Malphurs, J., Clasky, S., & Sanchez, A. (1996). Infants' preference for touch stimulation in face-to-face interactions. *Journal of Applied Developmental Psychology*, *17*, 199–213. https://doi.org/10.1016/S0193-3973(96)90025-8

Pierce, W. D., & Cheney, C. D. (2013). *Behavior analysis and Learning*. Psychology Press.

Ramey, C. T., Hieger, L., & Klisz, D. (1972). Synchronous reinforcement of vocal responses in failure-to-thrive infants. *Child Development*, *43*, 1449–1455. https://doi.org/10.2307/1127533

Rapp, J. T. (2008). Conjugate reinforcement: A brief review and suggestions for applications to the assessment of automatically reinforced behavior. *Behavioral Interventions*, *23*, 113–136. https://doi.org/10.1002/bin.259

Rovee, C. K., & Rovee, D. T. (1969). Conjugate reinforcement of infant exploratory behavior. *Journal of Experimental Child Psychology*, *8*, 33–39. https://doi.org/10.1016/0022-0965(69)90025-3

Rovee-Collier, C. K., & Gekoski, M. J. (1979). The economics of infancy: A review of conjugate reinforcement. *Advances in Child Development and Behavior*, *13*, 195–255. https://doi.org/10.1016/S0065-2407(08)60348-1

Saunders, M. D., Questad, K. A., Kedziorski, T. L., Boase, B. C., Patterson, E. A., & Cullinan, T. B. (2001). Unprompted mechanical switch use in individuals with severe multiple disabilities: An evaluation of the effects of body position. *Journal of Developmental and Physical Disabilities*, *13*, 27–39. https://doi.org/10.1023/A:1026505332347

Saunders, M. D., & Saunders, R. R. (2011). Innovation of a reinforcer preference assessment with the difficult to test. *Research in Developmental Disabilities*, *32*, 1572–1579. https://doi.org/10.1016/j.ridd.2011.01.049

Saunders, M. D., Timler, G. R., Cullinan, T. B., Pilkey, S., Questad, K. A., & Saunders, R. R. (2003). Evidence of contingency awareness in people with profound multiple impairments: Response duration versus response rate indicators. *Research in Developmental Disabilities*, *24*, 231–245. https://doi.org/10.1016/S0891-4222(03)00040-4

Siqueland, E. R. (1968). Reinforcement patterns and extinction in human newborns. *Journal of Experimental Child Psychology*, *6*, 431–442. https://doi.org/10.1016/0022-0965(68)90124-0

Siqueland, E. R., & DeLucia, C. A. (1969). Visual reinforcement of nonnutritive sucking in human infants. *Science*, *165*, 1144–1146. https://doi.org/10.1126/science.165.3893.1144

Siqueland, E. R., & Lipsitt, L. P. (1966). Conditioned head-turning in human newborns. *Journal of Experimental Child Psychology*, *3*, 356–376. https://doi.org/10.1016/0022-0965(66)90080-4

Smith, K. U., Zwerg, C., & Smith, N. J. (1963). Sensory-feedback analysis of infant control of the behavioral environment. *Perceptual and Motor Skills*, *16*, 725–732. https://doi.org/10.2466/pms.1963.16.3.725

Switzsky, H. N., & Haywood, C. (1973). Conjugate control of motor activity in mentally retarded persons. *American Journal of Mental Deficiency*, *77*, 567–570.

Taber-Doughty, T. (2005). Considering student choice when selecting instructional strategies: A comparison of three prompting systems. *Research in Developmental Disabilities*, *26*, 411–432. https://doi.org/10.1016/j.ridd.2004.07.006

Voltaire, M., Gewirtz, J. L., & Pelaez, M. (2005). Infant responding compared under conjugate- and continuous-reinforcement schedules. *Behavioral Development Bulletin*, *1*, 71–79. https://doi.org/10.1036/h0100564

Wallace, M. D., Iwata, B. A., Hanley, G. P., Thompson, R. H., & Roscoe, E. M. (2012). Noncontingent reinforcement: A further examination of schedule effects during treatment. *Journal of Applied Behavior Analysis*, *45*, 709–719. https://doi.org/10.1901/jaba.2012.45-709

Weisberg, P., & Rovee-Collier, C. (1998). Behavioral process of infants and young children. In K. A. Lattal & M. Perone (Eds.), *Handbook of research methods in human operant behavior* (pp. 325–370). Plenum.

Williams, D. C., & Johnston, J. M. (1992). Continuous versus discrete dimensions of reinforcement schedules: an integrative analysis. *Journal of the Experimental Analysis of Behavior*, *58*, 205–228. https://doi.org/10.1901/jeab.1992.58-205

Received June 12, 2019
Final acceptance December 10, 2019
Action Editor, Griffin Rooker