Differential Reinforcement of Low Rates: A Systematic Review

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by

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The undersigned, approved by the dean of the Graduate School, have examined the thesis entitled

DIFFERENTIAL REINFORCEMENT OF LOW RATES: A SYSTEMATIC REVIEW

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a candidate for the degree of Master of Science, and hereby certify that, in their opinion, it is worthy of acceptance.

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ABSTRACT

Differential reinforcement of low rates (DRL) is a differential reinforcement variation used to reduce response rates of but not extinguish, a behavior. This review summarizes the applied literature on DRL variations used with children. Reviewed studies included DRL procedures that targeted on challenging behavior. Experimenters identified 21 studies through a systematic search process and evaluated several characteristics of each study including children treated, participants, DRL variations, target behaviors, functional analysis, design, number of sessions, settings, and percentage of improvement. Discussion includes prominent findings, implication and recommendations for future.

Keywords: differential reinforcement of low rates, full-session, spaced-responding, interval, autism spectrum disorder, intellectual disability

Introduction

Individuals diagnosed with Autism Spectrum Disorder (ASD) exhibit a range of behavioral characteristics (American Psychiatric Association, 2013). Among those are restricted and repetitive behaviors, defined as complex behavior with circumscribed interest, rigid and invariant routines, arranging and ordering, repetitive motions, and repetitive manipulations of objects (Turner, 1999). Different topographies of restricted and repetitive behavior include playing in a particular pattern, lining things up in patterns or rows, hand flapping, and object spinning.

Restricted and repetitive behavior in children with developmental disabilities often interfere with academic skill acquisition. Koegel and Covert (1972) demonstrated that RRBs interfere with academic skill acquisition. The experimenters evaluated the acquisition of discriminative behavior between three autistic children with high rates of self-stimulatory behavior when engaging in self-stim and when not not engaging in self-stim. The experimenters found that: (a) the participants could not discriminate while engaged in a self-stimulatory behavior; (b) reduction of self-stimulatory behavior allowed the participants to engage in accurate responding; (c) the participant's discrimination learning with the suppression condition corresponded with a reduction of self-stimulatory behavior. and may evoke challenging behavior when interrupted.

Previous research has also shown that interrupting restricted and repetitive behavior may evoke challenging behavior. For example, Leon et al. (2013) assessed the consequences of manipulating parts on a game board to see if problem behavior occurred. When experimenters manipulated the game board pieces outside of their initial location, the participant would engage in problem behavior to fix the stimuli.

Due to age-inappropriate forms of behavior, their influence with interactions between peers and adults, restrictive and repetitive behavior have been labeled as socially stigmatizing (Cunningham & Schreibman, 2008; Koegel & Covert, 1972; Lovaas et al., 1971). Currently, behavioral interventions are the most practical methods to diminish problem behavior associated with RRB in individuals with Autism Spectrum Disorder (National Autism Center, 2009). A third issue related to restricted and repetitive behavior is that it can be socially stigmatizing (Cunningham & Schreibman, 2008). Cunningham and Schreibman (2008) suggest that stereotypy is perceived as inappropriate because of duration, form, and intensity, and that it is uncomfortable for guardians who bring their children to public places. Because of this stigma, the children may engage in peer and adult interactions less, which has direct undesirable consequences for their development. In summary, they continued treatment for RRB is to be warranted.

Practitioners can choose from a wide range of procedures for decreasing or eliminating problem behaviors (e.g., extinction, reinforcement, and punishment). Although interventions based primarily on extinction or punishment are often effective, unwanted side effects may occur. Emotional and high rates of challenging behavior when behavior with a long history of reinforcement no longer reinforced. Punishment has often evoked escape, avoidance, and aggression (Poling & Ryan,1982). It also must be noted that you sometimes don't want to eliminate a target behavior as well. For example, Austin and Bevan (2011) evaluated a differential reinforcement procedure to reduce excessive children request for attention. In a classroom, it is appropriate for a student to request attention, however, we can reduce these behaviors if they are excessive. This allows the teacher to engage with other classmates.

Behavior analysts use differential reinforcement to diminish or eliminate problem behaviors to avoid these unwanted side effects and move away from interventions that incorporate punishment and extinction (Cooper et al., 2020). They also use DRL procedures when eliminating a target behavior entirely is not the goal. There are three different differential reinforcement procedures. The first type of differential reinforcement is a differential reinforcement of other behaviors (DRO). DRO is a behavioral, reinforcement-based procedure comprising the delivery of a consequence contingent on the absence of challenging behavior (Wong et al., 2014). For example, Allen et al. (1982) applied a DRO procedure to decrease third-grade students' disruptive classroom behaviors. The teachers set a timer to 5 minutes that continued to run as long as no disruptive behavior occurred. The experimenter reset the timer, and a new 5 min interval began if any student engaged in disruptive behavior during the interval. If the student did not engage in any disruptive behaviors during that 5 minutes, then they were provided reinforcement. The results demonstrated that the DRO procedure was effective in decreasing disruptive behavior in the classroom setting.

The next type of differential reinforcement procedure is differential reinforcement of alternative behavior (DRA), which denies the reinforcer for undesired behavior while concurrently reinforcing an alternative behavior (Roane et al., 1999). For example, LeGray et al. (2013) applied a DRA procedure to decrease disruptive behavior while simultaneously increasing children's appropriate behavior in center-based classrooms. The child earned the reinforcer for appropriate vocalizations, and inappropriate vocalizations were extinguished.

The last type of differential reinforcement procedure, designed to decrease but not eliminate challenging behavior, is differential reinforcement of low rates (DRL). Reinforcement contingencies, based on delivering reinforcement only when a target behavior does not exceed a predetermined amount in a set period (Ferster & Skinner, 1957). Deitz (1977) proposed three methods for programming DRL contingencies. The first proposed variant of DRL is the full-session DRL, which includes delivering a reinforcer if a behavior occurs fewer than a fixed number of times in a complete session. For example, Handen et al. (1984) evaluated a full-session DRL to reduce repetitive speech in a boy diagnosed with ASD using a changing criterion design. They gave the participant an allocated number of times he could engage in repetitive speech at each criteria level, and delivered reinforcement at the end of each day, if he had fewer than that amount. The procedure was effective in reducing repetitive speech to a final rate lower than baseline.

The second proposed DRL variant is interval DRL. A session is broken up into equal intervals, and reinforcement is provided when falls below the predetermined criterion for each interval (Deitz,1977). For example, Looney et al. (2018) used an interval DRL and self-monitoring to reduce repetitive body movements in children with Autism. During the interval DRL, they provided the child with a rule "If you have less than ten body movements, you can have chocolate"). Following this rule, the therapist would start a timer, and contingent on making less than ten body movements, the child would receive chocolate at the end of the interval.

The last proposed DRL variant is the spaced responding DRL. During the spaced responding DLR, reinforcement is provided for each response that is separated from the

previous response by a minimum amount of time (Deitz,1977). For example, Lennox et al. (1987) used a spaced-responding DRL reduce the rate of an eating response for children diagnosed with an intellectual disability. They implemented a 15-s spaced-responding interval, in which the child could only take a bite if it has been at least 15 seconds since the last bite ended.

The purpose of this systematic review is to examine previous studies utilizing DRL as an intervention method with children, identify trends and limitations in that literature, and make recommendations for future research.

Methods

Search Procedure

To identify relevant literature DRL procedures, researchers conducted a systematic literature review. First academic electronic databases: EBSCO host, PsychINFO, PubMed, and SpringerLink were searched. The search term combinations included: (a) "differential reinforcement of low rates" and "autis*", (b) "differential reinforcement of low rates and intellectual disabilities", (c) "interresponse time" and "autis*", (d) "interresponse time" and "intellectual disabilities".

Inclusion Criteria

The following criteria were used to identify studies that would be included in the literature review. Each paper had to: (a) be published in a peer-reviewed journal between 1957 and 2020; (b) incorporate a DRL variant to reduce a target behavior; (c) include a minimum of 16 sessions using the DRL variant; (d) use a single-subject design; (e) include a minimum of one human participant. We based the minimum of 16 sessions on previous research that has demonstrated there needs to be 16 sessions for treatments to

work (Flückiger et al., 2020). Following this, we reviewed the reference sections of each article located during the keyword search. Studies that were not written in English, or not peer-reviewed, and used nonhuman subjects were excluded from this review. The articles included in this review are summarized in Table 1.

Inter-observer Agreement (IOA)

A coding sheet (Appendix A) we used to summarize each DRL study that met the inclusion criteria shown above. We did not include articles that did not meet eligibility criteria in this review. The coding sheet assessed (a) report characteristics, (b) participant characteristics, and (c) eligibility checklist. The primary author coded each of the articles included in this review. Two additional researchers were trained to independently code using the provided data sheets in Appendix A, and Appendix B. 100% of the included articles were reviewed by the last two researchers. A second researcher independently used the provider's search procedures and inclusion criteria as described above. The two reader's evaluations were compared, and we discussed the number of the agreements and disagreements. For each of the following articles that were not agreed on by each reader, we discussed the articles thoroughly and them thoroughly an agreement was made to include them for the literature review for 100% of the time.

Structure

The rest of the paper include three sections (a) description of articles, (b) summary of results and (c) discussion. The results section presents a summary of the studies identified in the search organized, as according to which DRL variant was used (1) full-session, (2) spaced-responding, and (3) interval. Following the brief review of DRL variants, the following variables are summarized across all studies: (a) children

treated (b) number of participants, (c) DRL variations, (d) target behaviors, (e) functional analysis, (f) design, (g) number of sessions, (h) settings, and (i) percentage of improvement. Target behaviors were categorized as prosocial behaviors, RRBs, and arbitrary responses (Computer programs). Prosocial behaviors for our study includes any behaviors that is not categorized under RRBs or an arbitrary response. RRBs include repetitive behaviors, motor and vocal stereotypy, and question asking. Arbitrary responses include any behavior that is simulated from a computer program. Percentage of improvement was calculated by subtracting the final mean value in treatment from the mean value in baseline and taking that number and divide that amount by the absolute value of the baseline mean value. Next, we multiplied that number by 100 to get percentage improvement (e.g., (Starting Value – Final Value) / |Starting Value|] x 100).

Results

The results are depicted in Figure 1, with the initial search yielding 40 different articles. Authors and researchers screened the title and abstract and removed duplicate articles to initially identify 16 relevant articles. A forward search of the 16 articles identified 5 additional articles for 21 articles.

Once we identified the studies, we reviewed full-session, spaced-responding, and interval DRL variants. First, discussed the most utilized DRL variant full-session, following by spaced-responding, and finally we analyzed the interval DRL, We provide a brief summary for all 21 articles including all relevant variables (e.g., percentage of improvement, setting, design, type of DRL variant, participants diagnosis).

Full Session

14 articles met criteria for using a full-session DRL. For example, Turner et al. (1990) evaluated a full-session DRL to measure the impact on verbal aggressions of a 21-year-old man using a multiple-baseline design in a therapy room setting. During the full-session DRL, the participant was provided with a contingency that if they engaged in more than five verbal aggressions, they would not receive reinforcement. The visual analysis showed there was an improvement in the reduction of challenging behavior.

Kostinas and colleagues (2001) evaluated a full-session DRL to reduce perseverative verbalizations with an adult diagnosed with intellectual disability using a reversal in a therapy room setting. During the full session, the participate could engage in 12 verbalizations or less in a session to receive reinforcement. If the participant exceeded 12 verbalizations, he was not provided reinforcement. The experimenters used a reversal design, and the results indicated 100% improvement in the reduction perseverative verbalizations.

Austin and Bevan (2011) evaluated the effects of a full-session DRL to diminish the total of requests for attention with three classroom participants diagnosed with ASD. During the full-session DRL, they provided each student with an index card with boxes that correlated to the amount of times they could engage in the target behavior. The student could engage in requesting attention up to 10 times, the number of boxes they had. The full-session DRL led to reduced repetitive demands for attention in this classroom setting by 96%.

Otalvara et al. (2020) replicated the effects of Austin and Bevin (2011) by evaluating the effect of full-session DRL on the response rate of repetitive question

asking with adults diagnosed with an intellectual disability. They also wanted to determine whether this reduction would increase task engagement. During Baseline, instructors answered each question asked by the participants. During the full-session DRL, they provided each student an index card with the allocated number of boxes they could engage in question asking, and if they had a minimum of one box remaining unsigned, that participant received one-on-one attention with a staff member. The experimenters found that a full-session DRL is successful in a work setting to decrease question asking, and that notecards helped signal a low number of requests for attention. A limitation to this study was that the subjects fell into a "ceiling effect" as the task engagement was already high, and it made it less likely that the experimenters would detect an percentage increase in work productivity.

Bonner and Borrero (2017) evaluated full-session DRL contingency on the impact on severe problem behavior (SIB) in a therapy room setting using a reversal design with four participants diagnosed with ASD. During the full-session DRL if the participant met the contingency of not engaging in severe problem behavior for the allocated predetermined tolerance criterion, then they would receive reinforcement. The results show a 97% improvement in the reduction of severe problem behavior.

Deitz and Repp (1973) evaluated a later named full-session DRL on the reduction of classroom behavior with one participant diagnosed with intellectual disabilities using a reversal design in a classroom setting. During the full-session DRL, if the participant made three or fewer “talk-outs,” he would receive 5 min of reinforcement.

Laprime and Dittrich (2014) evaluated a full-session DRL using a changing criterion design on vocal stereotypy with a participant diagnosed with an autism spectrum

disorder. treatment package with response cost on vocal stereotypy with a participant diagnosed with an autism spectrum disorder. The results demonstrated that the full-session DRL, along with the treatment package comprising discrimination training and differential reinforcement with response cost, effectively reduced stereotypic behavior by 83%

Gadaire et al. (2017) evaluated a full-session DRL with five participants diagnosed with intellectual disabilities using a reversal, while in a playground setting. During the full-session DRL, participants would earn stickers that could be exchanged if they engaged in two or fewer positive comments. The results show an improvement relative to baseline.

Handen et al. (1984) evaluated a full-session DRL to reduce repetitive speech in a boy diagnosed with ASD using a changing criterion design. They gave the participant an allocated number of times he could engage in repetitive speech at each criteria level, and delivered reinforcement at the end of each day, if he had fewer than that amount. The procedure was effective in reducing repetitive speech to a final rate lower than baseline.

Shaw and Simms (2009) evaluated a full-session DRL using a changing criterion design with three participants diagnosed with an intellectual disability. The study was conducted in a classroom setting. During the full-session DRL, they provided each with trade-in rewards and reinforcers based on meeting the DRL contingency. The results demonstrated that the full-session DRL was successful in decreasing the frequency of targeted behaviors by 86%.

Becraft et al. (2017) evaluated a full-session and spaced-responding DRL variant and measure the impact on excessive bids for teacher's attention in a classroom setting

using a multi-element design. There were three typically developing participants. The results showed an improvement of 61% using full-session, and 66% improvement in the reduction of bids for attention.

14 out of the 21 articles incorporated a full-session DRL variation. 6 of the 14 (43%) articles included participants with a diagnosis of intellectual disability. The average number of participants that took part in these studies was 4. The most common challenging behaviors targeted for reduction were pro-social behaviors such as question asking, which was the targeted behavior for six out of the fourteen (43%) articles. 11 out of the 14 (79%) articles did not include a functional analysis and were evaluated using a reversal design. The average number of sessions for this variation was 69 sessions. 8 of the 14 (57%) studies took place in the classroom setting. Across all full-session articles, full-session yielded an improvement in the reduction of a variety of challenging behaviors by 82%.

Spaced-Responding

Singh et al. (1981) evaluated spaced responding DRL to reduce stereotypical responses in three participants with intellectual disabilities in a therapy room setting. They compared two conditions: baseline and spaced responding DRL using a reversal design. In baseline, they observed and recorded stereotypic responses (complex finger movements, repetitive body movements, rocking, mouthing) for ten days. In Spaced Responding Condition, a 12 second IRT contingency for stereotypic responding was in effect, in which the reinforcement was descriptive praise. There were three phases, 30 s,60 s,180 s, for five days. Responding DRL condition was reinstated with an IRT of 180 s. The experimenters observed the space responding DRL contingency with an IRT of 12

s immediately decreased the occurrence of stereotypical responding by 86% and increased social behavior occurrence compared to Baseline.

Lennox et al. (1987) evaluated the effects of a spaced-responding DRL on reducing rapid eating with three individuals diagnosed with intellectual disabilities. For the DRL contingency, they put a 15-s interval into place. If 15 s elapsed between one bite of food and another bite of food, the participant could take a bite. However, if the participant tried to engage in the eating response, the response was blocked, and the interval was reset. The overall interresponse time increased by 50% across all participants using the spaced-responding DRL variant.

Jessel and Borrero (2014) compared a full-session contingency to a spaced-responding contingency on arbitrary responses while using a reversal design in a classroom setting with 16 typically developing participants. Both DRL variations used computer programs and had to engage with specific software for varied interval in a human operant arrangement. The results showed an improvement of 36% in the spaced-responding condition, and 63% in the full-session condition.

Becraft et al. (2018) compared a full-session contingency, to a spaced-responding contingency on arbitrary responses while also using a reversal design in a classroom setting with five participants who are typically developing. During both contingencies' computer software was set up, and the participants had to engage with the mouse and keyboard a specific number of times to receive reinforcement in the form of a point in the game. The results showed an improvement relative to baseline.

Angelesea et al. (2008) evaluated the effects of a vibrating pager for increasing the duration of meal consumption in three teenagers with autism who were observed to

eat too quickly using a reversal design. They taught only participants to take a bite during a spaced-responding interval. The results showed that the vibrating pager successfully increased mealtime's total duration by 58%, slowing consumption for all three participants.

Lennox et al. (1987) assessed several methods for diminishing the rate of eating responses with clients who have been diagnosed with intellectual disabilities using a multiple baseline across subject's design. A time based 15-s response interruption procedure was implemented, which resulted in little change in eating responses. Following the interruption procedure, a spaced-responding DRL 15-s procedure was implemented and decreased eating responses to target levels. The results demonstrated an improvement of 50% in the rate of eating responses.

Wright and Vollmer (2002) evaluated a spaced-responding variant and replicated and extended the treatment procedures described by Lennox et al. (1987) to reduce rapid eating in girls with intellectual disabilities who engaged in dangerously high food ingestion rates while using reversal design in a therapy room. The procedure included a spaced-responding DRL, response blocking, and prompts. Results showed that the treatment package was effective in reducing the rate of eating by 72%.

Piper et al. (2019) compared performances of a spaced-responding DRL contingency, and a full-session DRL contingency on arbitrary responses while using a reversal design in a classroom with four participants diagnosed with ASD. The results demonstrated that the spaced-responding variant yielded an increase of 73% improvement, and full-session yielded a 49% improvement in the reduction of arbitrary responses.

Overall, the literature search revealed that 8 out of the 21 (38%) articles incorporated a spaced-responding DRL variation. 3 of the 8 articles included participants diagnosed with intellectual disability, autism or typically developing. The average number of participants that took part in these studies was 5. The most common behaviors targeted were pro-social behaviors, which was the targeted behavior for 4 out of the 8 (50%) articles. No articles included a functional analysis, and seven out of the eight (88%) were evaluated using a reversal design. The average number of sessions was 49 sessions. 5 of the 8 (63%) studies took place in the classroom setting. The spaced-responding variation yielded an improvement of 63% in the reduction of behaviors.

Interval

Deitz and Repp (1974) introduced a new DRL variant called an interval DRL schedule. In an interval DRL, the total sessions is divided into smaller intervals and experimenters/therapist will deliver a reinforcer if fewer than a specified number of responses occurred. The investigators used a reversal design in a classroom setting to target out-of-seat behaviors using a criteria of two or fewer responses in an interval. They saw an improvement of 96% in the reduction of talk-outs.

Looney et al. (2018) evaluated the effects of a self-monitoring system and a DRL on decreasing repetitive body movements in children with autism. A trial-based functional analysis revealed that automatic reinforcement maintained repetitive body movements. The treatment comprised teaching the participant to use a self-monitoring system to monitor repetitive body movements. A stimulus control analysis revealed the self-monitoring system gained stimulus control over the body movements, meaning that they were more likely to occur in the system's absence than in its presence. The self-

monitoring system was implemented with a DRL contingency that included providing chocolate if fewer then 10 body movements occurring during a 1 minute interval , and they evaluated their combined effects using a reversal design, and the results showed that repetitive body movements decreased by 92% with implementing the treatment.

Deitz et al. (1978) evaluated interval DRL to reduce inappropriate classroom behavior of one male with a developmental disability. They compared two reinforcers using DRL treatments, with one comprising exchanging stars for free time contingent on brief intervals in which fewer than two responses occurred, and the other included minutes of access to a sand table was made contingent on two or fewer responses per interval occurred. The results showed that an interval DRL arrangement reduced inappropriate behavior by 89% in special classrooms.

3 out of the 21 (14%) articles incorporated an interval DRL variant. All 3 articles had participants with different diagnoses (no autism, Autism, and intellectual disabilities). The most targeted behavior was pro-social behaviors being in 2 of the 3 (66%) articles. Only 1 article included a functional analysis. 3 articles used a reversal design. The average number of sessions for this variation was 41 sessions. 2 of the 3 articles were conducted in a classroom, and one was conducted in a therapy room. Finally, the interval reduced the behaviors by 92%.

Overview of Studies

63 people between the ages of 4 and 47 took part in the studies. The diagnoses of these people are different, with 16 of 63 (25%) participants being diagnosed with autism, 26 of 63 (41%) participants being typically developing, and 21 of 63 (33%) participants being diagnosed with an intellectual disability. The most common DRL variation was the

full-session DRL implemented in 14 of the 21 articles. The second most frequently employed variant was the spaced-responding DRL used in 8 of the 21 articles. The last DRL variant used was the interval DRL, used 3 of the 21 collected studies. 4 of 21 studies included more than 1 DRL variant.

They targeted 13 different topography of behaviors throughout the studies. Pro-social behaviors were targeted in 13 of the 21 (62%%) of the collection of studies, followed by RRBs in 5 of the 21 (24%) and Arbitrary Responses being included in 3 of the 21 studies (14%).

17 out of the 21 studies (81%) did not conduct a functional behavior assessment (FBA) or conduct initial components of an FBA (e.g., indirect assessment) before beginning the intervention. 4 out of the 21 (19%) used a functional analysis. Of those who conducted an FBA, 2 of the 4 (50%) of those incorporated the DRL as part of a treatment package that used various procedures (e.g., extinction, punishment) to reduce the target behavior.

16 out of the 21 studies used a reversal design. The changing criterion design was used in 3 of the 21. Multi-element and multiple-baseline designs were used in one article each. The total number of sessions addressed in these studies were 1,292. The average number of sessions per article was 64. There was an outlier that included weeks and days for their study, and we could not allocate them to one of our categorizations (Handen et al., 1984; Turner et al. 1990).

Treatments occurred in a variety of settings; 11 of the 21 (52%) were conducted in a classroom, 9 of the 21 studies (43%) used a therapy room, and one occurred outside on a playground (5%).

The three DRL variations yielded varied results in regards to range of percentage of improvement. Most of the collected studies included the Full-Session DRL, resulted in an average of 82% improvement. Spaced-responding DRL yielded a 63% improvement. Interval DRL variant yielded a 92% improvement.

Discussion

The purpose of this literature review was to evaluate the research on DRLs in applied settings. This review of 21 articles revealed DRL's utility with children and adults with both typically and children and with intellectual disabilities and ASD.

Percentage of Improvement / Limitations

Overall, all DRL variations reduced all targeted behaviors. We made an interesting discovery while examining the DRL literature. We discovered that the interval DRL yielded a higher percentage of reduction compared to both full-session and spaced-responding. The authors believe this increased percentage is because of the interval DRL only having three articles, relative to the full-session and spaced-responding, used in most articles. It is important that we discuss the percentage of improvement for each DRL variant. The DRL was intentionally designed to reduce but not eliminate a behavior, however the interval and full-session DRL were shown to drop the target behavior down to near zero rates. For most prosocial behaviors, it is socially acceptable to reduce but not eliminate behaviors (e.g., requesting attention, question asking). These prosocial behaviors are relevant behaviors that we don't want to occur at a high rate, however we want them to occur at a relevant acceptable rate. Future research should continue to evaluate prosocial behaviors, and RRBs and analyze whether DRL variants are more effective then using punishment, and extinction in classrooms and applied settings.

However, further analyzing these articles leads to the additional discovery that there have been some inconsistencies with the DRL variation terminology.

Terminology

The way we speak about behavioral occurrences has been a long priority in behavior analysis (Schlinger et al., 1991). Careful use of the discipline's technical terms is essential for effective scientific communication and more precise conceptual analysis. Since 1977, several DRL procedures, including full-session, interval, and spaced-responding, have been included in graduate and undergraduate behavior analysis coursework. Although the definitions are open for discussion, the terms "session" and "interval" have been used inconsistently in recent studies to explain the three DRL procedures' variants.

Becraft et al. (2018) provides an example of this ambiguous terminology. Their definition of the full-session variation needs further clarification, as they based it on an interval less than or equal to a predetermined criterion, rather than a full experimental session. The procedures are like those used in an interval DRL variation. However, it must be noted that Becraft et al. (2018) discussed that Deitz (1977) defines the interval in a full-session DRL as the entire session duration. Alternatively, he names another DRL variation called an interval DRL. According to Deitz, an interval DRL breaks the session into split intervals. The authors of Becraft et al. (2018) provided their opinion that conceptually one may view the interval and full-session DRL as the same procedure, and for their studies, they label the interval DRL as a full-session DRL. Future research should evaluate under what circumstances is the full-session DRL more utilized then a

interval DRL. Future researchers should also analyze the differences between sessions, and intervals and defining what makes a session, and an interval.

Participants

The number of participants that were targeted in each study was slightly higher than average for single-subject research, ranging from 2 to 16 participants (Kazdin,2021). However, there was one outlier that may have altered our average participant age for our literature search. Jessel and Borrero (2014) included 16 participants from the university, which could have been a limitation due to the students needing to be sufficient at manipulating computer mice and had experience using computers. Future research should continue to use a variety of participants.

DRL Variants

The collection of studies included all three DRL variants. These variants included full-session, spaced-responding, and interval. Full-session DRL has been used the most frequently since its inception in 1977 as it has been one of the more effective variants. However, this yields for further research for the interval DRL as we discovered the interval has a higher percentage of improvement. Because of the limited research on spaced-responding and interval variation, it warrants further research to evaluate under what settings and targeted behaviors does the interval variation provides socially significant results. For example, the spaced-responding DRL variant and interval variant should be evaluated under what results could be demonstrated by using signals in the reduction of RRBs.

Target Behaviors

DRL variations can reduce various target behaviors, including bids for attention, SIB, talk-outs, disruptive behaviors, motor, and vocal stereotypy, rapid eating, question asking, attention-maintained behaviors, and verbal aggression. The full-session DRL can be an effective treatment for reducing, if not eliminating, problem behavior. Full-session DRL yields similar results to differential reinforcement of other behavior (DRO). For example, Jessel and Borrero (2014) suggested that a full-session DRL might eliminate responding entirely, similar to a DRO. This is interesting in regards to DRL as the procedure is not designed to eliminate behaviors, but only to reduce behaviors. As we continue the research in the DRL literature, we must be mindful of which variation we are using as full-session was shown to nearly eliminate the target behavior that is being focused on, whereas spaced-responding was shown to reduce the behavior but not eliminate it. Future research must continue to evaluate its effectiveness on a variety of target behaviors. For example, researchers should evaluate the DRL variants with more RRBs as they are a concern for many families as discussed in our methods.

Functional Analysis

In this review only three studies used a functional analysis as part of their intervention. In recent years, the field of behavior analysis has moved towards using function-based treatments to reduce challenging behaviors, and function based treatments are considered among the most effective behavioral interventions (Iwata et al., 1982/1994). DRLs are not designed to require knowledge of function to work. They do, however, include components that might benefit from a knowledge of behavioral functions. For example, DRA uses an extinction component of not providing

reinforcement to the target behavior. Given the positive improvements in reducing behavior with the DRL variation that targeted function-based behaviors (attention maintained, automatic), further examination of this topic is warranted (Bonner & Borrero, 2017; Looney et al., 2018; Shaw & Simms, 2009). A study might compare the treatment of attention-maintained behavior self-injurious behavior, and automatic self-injurious behaviors with these DRL variants.

Experimental Design

A majority of the collected studies used the reversal design to show experimental control. The reversal design should continue to be used in future research, as it has been the most potent within-subject design for demonstrating a functional relation between a DRL variation and behavior. This design should continue to be used moving forward as it has been used in over half of the DRL variants. The reversal design also allows for the most convincing demonstration of experimental control with the DRL variants.

Number of sessions

We calculated a range of 20 sessions up to 171 for the current DRL literature review. We believe there is nothing indicative to highlight he number of sessions used in the DRL variants.

Setting

Deitz (1977) noted that one benefit of using the DRL variations was that they are probably easier to implement for teachers. This seems to be supported by the literature, where the full-session DRL considered the easiest, was used in more than half of the studies. The full-session DRL has been discussed as the easiest DRL session to conduct, however there has never been a questionnaire provided to teachers or implementers to

assess the feasibility of conducting this variant. Future research should consider social validity data from most implementers such as practitioners, teachers, and parents and provide them a questionnaire one which one is the least effortful. Over half of the articles reviewed were in classroom settings. These findings highlight a need for more research on the varied DRL variations in several different contexts. Given the number of studies that conducted a DRL procedure in the classroom setting. It would be beneficial to conduct DRL variations outside of the classroom and determine the efficacy as a stand-alone intervention. Other common settings where DRL might be useful include playground, therapy room, and at home. Studies in each of those environments would be useful to demonstrate that DRL can be useful in a variety of settings.

Future research should explore if there is a functional difference between the full-session DRL, and interval DRL. However, if there is no functional difference, the data may suggest no real reason to separate the two terms. For example, researchers should evaluate under what functions of behavior does a full-session interval yield a greater reduction in behaviors, relative to the interval DRL variant.

Limitations

Despite this review's limitation of terminology, and that DRL procedures have yielded near zero rates for targeted behavior, several implications and future recommendations have been made when considering a DRL variation as a treatment for the future topic of study. These variations included spaced-responding, full-session, and interval.

Summary

In summary, we reviewed 21 studies that included all three DRL variants including full-session, spaced-responding, and interval. We discovered that these variants are utilized in a range from a controlled therapy room to an open playground. These variants yielded results that were effective in reducing a variety of topographies of targeted behaviors. Limitations in the literature include the interchangeability that has been used with full-session, and interval DRL. Another limitation to this research is that the DRL procedures have been used to reduce target behaviors to near zero rates.

Although DRL's have been effective at reducing challenging behaviors, the use of DRLs in applied settings has been limited to a select few settings such as classrooms, and therapy rooms. We also know little about the percentage of improvement with each DRL variant. This procedure merits further investigation to understand when and how researchers are using DRL variations in applied settings. Previous DRL research studies aimed at a reduction in the focused targeted behavior of students with and out ASD. Considered the characteristics of these individuals, and educational settings. The outcomes have generally been favorable and have suggested effective DRL procedures. This review suggests that the DRL variations utilized have effectively decreased challenging behaviors across a variety of topographies. Also, the studies reviewed here point to the feasibility of conducting these DRL variations across various contexts.

Figures

Table 1
Summary of DRL Variables

Studies in Alphabetical Order	Children treated	Participants	DRL Variation	Target Behaviors	Functional Analysis	Design	Number of Sessions	Setting	Percentage of Improvement (Decrease/Increase)
Anglesea et al., 2008	Autism	3	Spaced-Responding	Rapid Eating	No	Reversal	28	Classroom	Spaced- Responding 58%
Austin & Bevan, 2011	Autism	3	Full-Session	Bids for Attention	No	Reversal Design	171	Classroom	Full Session: 96%
Becraft et al., 2018	No Autism	5	Spaced-Responding Full-Session	Computer Program	No	Reversal	30-51	Classroom	N/A
Becraft et al., 2017	No Autism	3	Spaced-Responding Full-Session	Excessive Bids	No	Multi-Element	46-61	Classroom	Spaced Responding: 66% Full-Session: 61%
Bonner & Borrero, 2017	Autism	4	Full-Session	Self-Injurious Behavior	Yes	Reversal	20-25	Therapy Room	Full-Session: 97%
Dietz & Repp, 1973	Intellectual Disability	1	Full-Session	Talk-Outs	No	Reversal	35	Classroom	Full Session: 98%
Deitz & Repp, 1974	No Autism	1	Interval	Out-of-seat	No	Reversal	N/A	Classroom	Interval: 96%
Deitz 1978	Intellectual Disability	1	Interval	Talking inappropriately	No	Reversal	35	Classroom	Interval: 89%
Gadaire et al., 2017	Intellectual Disability	5	Full-Session	Prosocial Behaviors	No	Reversal	30	Playground	N/A
Handen et al., 1984	Intellectual Disability	1	Full-Session	Repetitive Speech	No	Changing-Criterion	160 days	Therapy Room	Full-Session 94%
Jessel & Borrero, 2014	No Autism	16	Spaced-Responding Full-Session	Computer Program	No	Reversal	15	Classroom	Spaced Responding: 36% Full-Session: 63%
Kostinas et al., 2001	Intellectual Disability	1	Full-Session	Perseverative Verbalizations	No	Reversal	140	Therapy Room	Full-Session: 100%

Table 1 (Continued)
Summary of DRL Variables

Laprime & Dittrich, 2014	Autism	1	Full-Session:	Vocal Stereotypy	Yes	Changing-Criterion	171	Classroom	Full-Session: 83%
Lennox et al., 1987	Intellectual Disability	3	Spaced-Responding	Rapid Eating	No	Reversal	115	Therapy Room	Spaced Responding: 50%
Looney et al., 2018	Autism	1	Interval	Repetitive Behaviors	Yes	Reversal	47	Therapy Room	Interval: 92%
Otalvaro et al., 2019	Intellectual Disability	2	Full-Session	Question Asking	No	Reversal	24	Therapy Room	Full-Session: 77%
Piper et al., 2019	Autism	4	Spaced-Responding Full-Session	Computer Program	No	Reversal	36	Classroom	Spaced-Responding: 73% Full-Session: 49%
Shaw & Simms, 2009	Intellectual Disability	3	Full-Session	Attention-Maintained behaviors	Yes	Changing-Criterion	63	Classroom	Full-Session:86%
Singh et al., 1981	Intellectual Disability	3	Spaced Responding	Motor Stereotypy	No	Reversal	40	Therapy Room	Spaced-Responding: 86%
Turner et al., 1990	No Autism	1	Full-Session	Verbal Aggression	No	Multiple-Baseline	12 Weeks	Therapy Room	N/A
Wright & Vollmer, 2002	Intellectual Disability	1	Spaced-Responding	Rapid Eating	No	Reversal	45	Therapy Room	Spaced-Responding 72%

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Appendix: A Code Sheet

Code Information	
Name:	
Date:	

Search Procedure	
Academic Database:	
Search Term	

Citation

Report Characteristics	
Authors:	
Year:	
Title	
Journal:	

Participants Characteristics			
Age	Setting	Diagnosis	Notes

*For diagnosis choose from the three:

Intellectual Disability: Any diagnosis that includes mental retardation, developmental disability, or any neurodevelopmental disability that isn't labeled Autism Spectrum Disorder.
Autism Spectrum Disorder: Any diagnosis that is labeled autistic, or includes the terms Autism Spectrum Disorder
Typically Developing: Does not include any diagnosis of any neurodevelopmental disability, autism spectrum disorder, or any definitions that would meet the other two diagnosis.

Appendix: B Database Search Sheet

Database Search			
Database Used:	Keywords	Number of Hits	Citations
EBSCOhost	Differential Reinforcement of Low Rates & Autis*		
	Differential Reinforcement of Low Rates and Intellectual Disabilities		
	Interresponse Time and Autis*		
	Interresponse Time and		
PsychINFO	Differential Reinforcement of Low Rates & Autis*		
	Differential Reinforcement of Low Rates and Intellectual Disabilities		
	Interresponse Time and Autis*		
	Interresponse Time and		
PubMed	Differential Reinforcement of Low Rates & Autis*		
	Differential Reinforcement of Low Rates and Intellectual Disabilities		
	Interresponse Time and Autis*		
	Interresponse Time and		
SpringerLink	Differential Reinforcement of Low Rates & Autis*		
	Differential Reinforcement of Low Rates and Intellectual Disabilities		
	Interresponse Time and Autis*		
	Interresponse Time and		

Eligibility Check		
Single Subject Design:	Yes	No
Peer-Reviewed	Yes	No
Published in English:	Yes	No
Learner with or without ASD or intellectual disability	Yes	No
Minimum of 16 Sessions Using DRL	Yes	No
Used a DRL Variation (Spaced-Responding, Full-Session, Interval)	Yes	No
Functional Analysis	Yes	No