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Review of the use of Differential Reinforcement in Skill Acquisition

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by

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ABSTRACT

The purpose of this paper was to review and synthesize the literature investigating the impact of differential reinforcement on skill acquisition. Specifically, the aim of this review was to determine the most efficient differential reinforcement arrangement for skill acquisition in individuals with intellectual or developmental disabilities. Researchers synthesized the results of 12 articles with the following categories: (a) participant characteristics (i.e.,, age, sex, diagnosis, verbal repertoire, communication modality, receptive and imitation skills, prompt dependency), (b) target behavior information (i.e., target behavior, measurement system), (c) pre-evaluation assessments (i.e., preference assessments, reinforcer assessments, magnitude edible and size assessments), (d) teaching procedures (i.e., teaching format, prompt type, prompt fading procedure, error correction, experimental design, mastery criteria), (e) reinforcer parameters manipulations and class of reinforcers (f) reinforcement conditions, (g) results, and (h) social validity and generalization measures. Across the 12 studies, the majority of the participants were males, had an ASD diagnosis and communicated vocally. The differential reinforcement condition in which reinforcement favored independent responses resulted in the quickest acquisition for the majority of participants. When compared across reinforcer parameters, skill acquisition was quicker when the quality of the reinforcer was manipulated within the differential reinforcement procedure relative to other reinforcer parameters. This review discusses limitations of the previous research, makes recommendation for future research, and summaries implications for clinical practice.

CHAPTER ONE:

INTRODUCTION

Intervention is essential for individuals with autism (ASD) to acquire new skills (Corsello, 2005). Although various types of interventions (e.g., behavioral, developmental, and cognitive-behavioral) (Corsello, 2005) are available, it is important to ensure that the appropriate intervention or combination of interventions are implemented to target specific skill deficits (Weiss, 1999). Intensive behavioral intervention (e.g., 30-40 hr per week) has been demonstrated to promote skill acquisition in individuals with ASD (Weiss, 1999) and the rate of acquisition at the onset of intervention has been shown to accurately predict speed of acquisition of future skills (Lovaas, 1987). Thus, early intervention is important (Weiss, 1999).

Individuals with ASD frequently require prompts to emit novel skills and thereafter, prompt fading procedures, to transfer control of the behavior from the prompt to the discriminative stimulus (SD; Cengher et al., 2016). Prompting procedures may include time delay procedures (i.e., constant and progressive time delay), in which a constant or increasing delay between the presentation of the SD and the prompt, allows for independent responding prior to the prompt (Ackerlund Brandt et al., 2016). Simultaneous prompting, on the other hand, does not allow for independent responding because prompts are delivered immediately following the SD. Then to test for transfer in stimulus control, daily probes are conducted (Akerlund Brandt et al., 2016). When compared, results demonstrate the effectiveness of both prompting procedures in skill acquisition for children with ASD (Akerlund Brandt et al., 2016). Examples used to eliminate prompts include most-to-least (MTL) and least-to-most (LTM) prompt fading (Cengher et al., 2016). MTL prompt fading procedures entail presenting prompt topographies in a sequence of most intrusive to least intrusive whereas the reverse sequence is employed during LTM prompt fading procedures (Cengher et al., 2016). When compared across young children with ASD, MTL prompt fading resulted in the quickest acquisition of skills for all three participants (Cengher et al., 2016).

Along with prompting and fading procedures, error corrections may be implemented during skill acquisition. In the single-response repetition procedure, the teacher provides a vocal model following an error and reinforces a correct echo, or moves on to the next trial following another incorrect response (Carroll et al., 2015). During the remove and re-present error correction procedure, following an error, the stimuli and attention are removed for 2-s then re-presented with a model (Carroll et al., 2015). In the re-present until independent procedure, a model prompt is presented following an error and the initial trial is then re-presented which continues until independent responding occurs, or 20 error correction trials are presented (Carroll et al., 2015). The multiple response repetition procedure is similar but, following a correct imitation of the model prompt, the cycle must be repeated until the learner engages in five correct responses to the model (Carroll et al., 2015). When compared across five children with ASD, the re-present until independent procedure led to the quickest acquisition in three, where the single-response repetition or the remove and re-present procedure were effective for the other two participants (Carroll et al., 2015).

Teaching procedures such as discrete-trial teaching (DTT), direct instruction, and artificial interventions, are structured training methods controlled by the teacher in which trials are presented to target specific skills (Delprato, 2001). A dissimilar instructional format is incidental teaching, where teaching opportunities arise dependent on the antecedent stimuli selected by the learner in a free operant setting (Delprato, 2001). When compared to DTT across multiple studies, incidental teaching demonstrated a more rapid acquisition of skills (Delprato, 2001). All teaching procedures include a combination of prompts, prompt fading, and/or error correction procedures, and as described previously, variations within each of these components can impact speed of acquisition. Another variable that has been shown to affect skill acquisition is, the reinforcement contingency in effect for prompted, independent, and incorrect responses, in other words, whether differential reinforcement is in effect (e.g., Karsten & Carr, 2009).

Differential reinforcement is defined in Vollmer et al., (2020) as “providing greater reinforcement, along at least one dimension, contingent on the occurrence of one form or type of behavior, while minimizing reinforcement for another form or type of behavior” (p. 1300). Differential reinforcement may be used to reduce problem behavior and increase alternative behavior, increase independent responding while decreasing prompted responding in skill acquisition, and reinforce closer approximations during shaping (Vollmer et al., 2020). The various forms of differential reinforcement that are typically used to reduce maladaptive behavior include differential reinforcement of other behavior (DRO), differential reinforcement of low rates (DRL), differential reinforcement of incompatible behavior (DRI), and differential reinforcement of alternative behavior (DRA; Cooper et al., 2007). For instance, Jowett Hirst et al. (2019) implemented a DRO procedure to decrease toe walking that consisted of the delivery of a generalized conditioned reinforcer (i.e., smiley face drawn on board) contingent on 15-s that she did not walk on her toes (e.g., walked flat footed). The participant exchanged the conditioned reinforcers for prizes. Toe walking decreased following the implementation of DRO plus verbal rules and feedback (Jowett Hirst et al., 2019). Two DRL procedures (i.e., spaced responding

DRL, full session DRL) were implemented in Piper et al., (2020) by giving the participants a generalized conditioned reinforcer (i.e., a point) following the engagement in the target behavior no more than two times in a session (full session DRL) or only once every set number of seconds (spaced responding DRL). The duration of access to the reinforcer was contingent on the number of points earned. The results demonstrated both DRL conditions reduced, but did not completely eliminate, the target behavior for all four participants (Piper et al., 2020).

Unlike the DRO and DRL in which reinforcement is received contingent on low rates or non-engagement in the maladaptive behavior, DRI and DRA procedures reinforce engagement in a different behavior. Dixon et al., (2001) employed a DRI procedure to decrease inappropriate statements that consisted of, the delivery of social reinforcement contingent on appropriate verbal behavior. Similarly, Slocum and Vollmer (2015) decreased problem behavior using a DRA procedure in which a preferred edible or tangible item was delivered following compliance with demands, while any problem behaviors that occurred during these demands were reinforced with 30-s of escape. The DRA procedure led to an increase in compliance and a decrease in problem behavior for all five participants (Slocum & Vollmer; 2015). Although Slocum and Vollmer (2015), reinforced the engagement in problem behavior, DRA procedures, as well as DRI and DRO procedures, typically involve extinction of the maladaptive behavior (Trump et al., 2020). This is evident in functional communication training (FCT), which is a type of DRA in which, the reinforcer delivered for the appropriate behavior is functionally equivalent to the reinforcer maintaining the problem behavior (Carr & Durand, 1985). When implementing FCT, a functional analysis (FA) is conducted to determine the function of the problem behavior (Dunlap et al., 2006). For instance, following the completion of an FA in Dunlap et al., (2006) the participants were then prompted to use appropriate communication (e.g., “play with me”) which was reinforced with access to the same reinforcer as shown to maintained maladaptive behavior. For both participants, following the implementation of FCT, the percentage of intervals with challenging behaviors decreased across multiple settings (Dunlap et al., 2006).

Studies along with Slocum and Vollmer (2015) have shown that differential reinforcement procedures can be effective in reducing disruptive behavior even when extinction is not implemented. MacNaul and Neely (2018) conducted a systematic review of the published literature on the use of DRA without extinction to reduce problem behavior in individuals with ASD. They identified 10 articles, nine of which attained positive outcomes when DRA without extinction was implemented while one had mixed results in that, DRA without extinction was effective for one participant, while DRA with extinction and DRA with extinction plus response blocking was effective for two of the three participants. The article findings demonstrated that DRA, with or without extinction, successfully decreased problem behavior and increased alternative behavior by manipulating parameters of reinforcement. The different variations of DRA compared the manipulation of quality, magnitude, immediacy, and schedule of reinforcement. Five articles reviewed manipulated schedules of reinforcement which involved altering the reinforcement schedules so that a denser reinforcement schedule was in effect for the appropriate alternative behavior (MacNaul & Neely, 2018). For instance, for one participant of Kelley et al., (2002) the reinforcement schedule was set to variable ratio 8 (VR8) for the engagement in the maladaptive behavior but appropriate alternative behavior was continuously reinforced (CRF). For this participant, differential reinforcement without extinction led to high rates of the alternative behavior and low rates of the problem behavior however, the addition of extinction or extinction plus response blocking was necessary for the other two participants.

The additional five studies reviewed by MacNaul and Neely (2018) implemented DRA in which the quality, magnitude, or immediacy of the reinforcer was manipulated. For example, in Davis et al. (2012), which manipulated the quality of reinforcement, problem behavior was reinforced with 30-s of escape from tasks while the alternative behavior was reinforced with 30-s of escape plus access to a preferred activity. This intervention led to an increase in alternative behavior and decrease in maladaptive behaviors for three of four participants. The manipulation of magnitude and immediacy of reinforcement were investigated by Athens and Vollmer (2010), in which magnitude was manipulated by reinforcing appropriate behavior with a larger magnitude reinforcer (i.e., 30-s escape from task) compared to presenting a smaller magnitude reinforcer (i.e., 10-s escape from task) following problem behavior. Immediacy of reinforcement was manipulated by providing reinforcement with 0-s delay contingent on the alternative behavior while delaying reinforcement following problem behavior by 30-s or 60-s. For all participants, appropriate behavior increased and problem behavior decreased. In summary, the articles in this literature review demonstrate the effectiveness of differential reinforcement when differing parameters of reinforcement are manipulated.

In addition to reducing problem behavior, differential reinforcement is often used to foster acquisition of new skills and reduce prompt dependency by providing high-value reinforcement (e.g., highly preferred item, large quantity of edible) for independent responses and lower-value reinforcement (e.g., low to moderately preferred item, small quantity of edible) for prompted responses (Fiske et al., 2014). The effectiveness of differential reinforcement in skill acquisition can be demonstrated by comparing acquisition of novel skills under conditions in which the differential reinforcement or is not in effect. For instance, Karsten and Carr (2009) compared skill acquisition of tacts and picture sequencing for two participants with ASD across two conditions. In the non-differential reinforcement condition, reinforcement for independent and prompted responses was an edible plus praise whereas in the differential reinforcement condition an independent response was reinforced with an edible plus praise while a prompted response was reinforced with praise only. The results demonstrate that for both participants, skill acquisition occurred more rapidly in the differential reinforcement condition.

Similar procedures were implemented in Cividini-Motta and Ahearn (2013) in which acquisition of picture-to-word matching was compared across three reinforcement conditions for four individuals with ASD. In the non-differential reinforcement (i.e., no DR) condition the potent reinforcer (i.e., tokens or edible plus praise) was provided for both independent and prompted responses. In one of the variations of a differential reinforcement condition (i.e., DR 1 high/mod) the potent reinforcer was delivered contingent on an independent response and a less potent reinforcer (i.e., praise alone) was provided for prompted responses. Finally, in the second differential reinforcement procedure (i.e., DR 2 high/ext), independent responses resulted in access to the potent reinforcer while no reinforcers were delivered following prompted responses. In this study three of the four participants reached mastery criteria more rapidly in the DR 1 (high/mod) condition, while the DR 2 (high/ext) condition was most efficient for the final participant.

Just as in problem behavior reduction, multiple parameters of reinforcement can be manipulated to promote skill acquisition. These parameters include manipulations of quality, magnitude, schedule and immediacy of reinforcers. Independent responses are reinforced with high-quality reinforcers, high-magnitude reinforcers or a denser schedule of reinforcement while prompted responses are reinforced with low-quality reinforcers, low-magnitude reinforcers, and a leaner schedule of reinforcement (Vladescu & Kodak, 2010). Johnson et al., (2017) explored the effects of multiple parameters by comparing differential reinforcement iterations in which quality, magnitude, or schedule were manipulated, to determine which parameter manipulation was most efficient. When manipulating immediacy of reinforcement, the reinforcer delivery is immediately following independent responses but delayed following a prompted response (Majdalany et al., 2016). The effect of the onset of the implementation of differential reinforcement can also be compared, to best aid in skill acquisition (Campanaro et al., 2020). Therefore, the purpose of this review was to review and synthesize studies that investigated the impact of differential reinforcement of prompted and independent correct response on skill acquisition. Limitations of the previous research as well as clinical and research recommendations are discussed.

CHAPTER TWO:

METHOD

Initial Search Procedures

In January 2020, two electronic databases were used to conduct searches for potential articles to review related to differential reinforcement in the context of skill acquisition. These databases included: Google Scholar and EBSCOhost. Articles from the last 40 years (1980 – 2020), written in the English language, and peer-reviewed, were reviewed. The Boolean terms used in the search included: "differential reinforcement", "differential reinforcement" AND "skill acquisition", "reinforcement" AND "skill acquisition", "differential reinforcement" AND "autism" and "skill acquisition" AND "autism." In addition, an extended search was conducted by reviewing the reference section of all articles selected for inclusion. During this initial search, articles were excluded if they had (a) non-human participants, (b) were reviews or analyses of articles, or (c) if they did not fit the context of the interest of this review.

Inclusion Criteria

Following the Boolean search, the titles and abstracts of the articles were evaluated using the following inclusion criteria: (a) participants were diagnosed with an intellectual or developmental disability, (b) differential reinforcement was one of the independent variables manipulated in the study, (c) the target behavior evaluated was a skill (not a maladaptive behavior). Studies satisfied the first criterion if the participants were diagnosed with an intellectual disability (ID) or developmental disability (DD) including but not limited to ASD, Down's syndrome, attention deficit hyperactivity disorder, mood disorder, emotional and behavior disorder (EBD) or unidentified ID or DD. The independent variable criterion was met if the study compared or evaluated at least two conditions in which the consequence (i.e., reinforcer delivered) for correct prompted, correct independent, or incorrect was manipulated. Examples of parameters of reinforcer manipulations included reinforcer quality, magnitude, schedule, and immediacy. This criterion was also met if the onset of the differential reinforcement procedure was manipulated. The target behavior criterion was met if the study focused on direct teaching of an appropriate response rather than a reduction in maladaptive behavior. Examples of target skills taught in the studies include verbal operants (e.g., tacts, intraverbals, listener responding), receptive identification, matching and picture sequencing. The same criteria were used to review the title and abstracts of articles identified during the extended search. Twelve articles meeting the aforementioned criteria were identified and extensively reviewed.

Descriptive Synthesis

The studies included in this review were summarized with the following categories: (a) participant characteristics, (b) target behavior information, (c) pre-evaluation assessments, (d) teaching procedures, (e) reinforcer parameters manipulations and class of reinforcers, (f) reinforcement conditions, (g) results, and (h) social validity and generalization measures. Each category is described below.

Participant Characteristics

We extracted participant characteristics reported in the study including age, sex, diagnoses, verbal repertoire, communication modality, receptive and imitation skills, and if they had a history of prompt dependency. In regard to diagnoses, the information reported in the article was extracted. In regard to verbal repertoire, motor or verbal imitation skills, receptive skills, or history of prompt dependency, we coded these as "Yes", "No", or "NR". "Yes" was used to indicate that the article reported that the participant had these responses in their repertoire whereas "No" meant that the article indicate that this response was not part of the participant's skill repertoire; "NR" was used when the article did not report the presence or absence of that response/skill in the participant's repertoire. If a verbal repertoire was reported, we also extracted information about the topography of the verbal repertoire (i.e., vocal, signs, gestures, picture exchange, speech generating device). If a history of prompt dependency was reported, we extracted information on the type of assessment (i.e., interview, record review, direct assessment, functional assessment) employed by the researchers to identify prompt dependency.

Target Behavior

We extracted data on the target behavior taught to each participant and on whether data were collected on secondary responses. The exact tact (e.g., "intraverbal"; "following direction") used by the researchers in regard to the target behavior was recorded. We also extract data on the measurement system used for the target behavior (i.e., frequency, trial-by-trial).

Pre-Evaluation Assessments

We extracted information on assessments that were conducted to identify the appropriate consequence for responding during the teaching phase. These assessments employed were categorized as either preference assessments (i.e., multiple stimulus without replacement, paired stimulus), reinforcer assessments (i.e., progressive ratio, single operant) or edible magnitude and size assessments, and the specific formant employed was also recorded.

Teaching Procedures

We recorded data on the teaching procedures employed including the teaching format (i.e., discrete-trial teaching, incidental teaching, task analysis, naturalistic teaching) and component of the teaching procedure in effect during baseline and the teaching phase. These included prompt type (i.e., model, physical, vocal, combinations of prompts) and prompt fading procedure (i.e., constant delay, most-to-least prompting, least-to-most prompting, progressive delay). In addition, we recorded whether an error correction procedure was employed using "Yes" or "No", or "NR". "Yes" was recorded when the authors indicated that an error correction procedure was used, "No" was recorded if the authors indicated that no error correction procedure were employed, and "NR" was used if the authors did not specify whether error correction procedures were used. For all these categories, a "N/A" (Not Applicable) was recorded if one of these components could not be implemented (e.g., if the study did not include a baseline phase, N/A would be recorded for the prompts used during the baseline phase).

We also extracted data for the experimental design employed (i.e., augmented alternating treatment design, multi-element design, multiple baseline design, reversal, combination of designs) and the mastery criteria (i.e., a determined percentage of correct independent responding across a determined number of sessions, determined percentage of independent responding, determined number of independent responses, determined number of sessions with stable responding). If mastery criteria were not reported in the article, this was coded as “NR.”

Reinforcer Parameter Manipulations and Class of Reinforcers

We then revised the description of the teaching phase to determine the class of reinforcers employed in the study (i.e., edibles, tangibles, tokens, social consequences, combination) and the parameter of reinforcer manipulated (i.e., quality, magnitude, schedule, and/or immediacy). Data were also recorded on whether the study varied the onset of implementation of the differential reinforcement procedure. Quality of reinforcer refers to the manipulation of preference for the reinforcer; magnitude refers to manipulating the amount of the reinforcer that is delivered; schedule refers to manipulating how many responses are required until reinforcement is delivered; immediacy refers to manipulating the amount of time that elapsed between the emission of a target response and the reinforcer delivery. Finally, the onset of differential reinforcement refers to manipulating the inception of differential reinforcement (i.e., the specific amount of independent responses the participant must emit before differential reinforcement is implemented).

Reinforcement Conditions

The type of differential reinforcement (DR) conditions employed by the studies were coded as No DR, DR 1, and DR 2 based on the definitions used by Cividini-Motta and Ahearn (2013) and an additional DR 3 condition. No DR is defined as providing the same reinforcer for both independent and prompted responses. The DR 1 condition consists of favoring independent responses (e.g., delivery of most potent reinforcer) while still delivering a reinforcer for prompted response (e.g., praise). For studies that evaluated two forms of a DR 1 procedure (e.g., one manipulating quality and another manipulating schedule of reinforcement) the parameter manipulated was specified. The DR 2 condition also favors independent responding however, during this procedure no reinforcers are delivered for prompted responses. For both the DR 1 and DR 2 procedures, the parameter of reinforcement manipulated to favor independent responses included quality, magnitude, schedule and immediacy. On the other hand, the DR 3 condition consists of favoring prompted responses (e.g., delivery of a reinforcer on a CRF schedule) while delivering a less favored reinforcer for independent response (e.g., delivery of a reinforcer on a FR3 schedule).

Outcomes

To determine the efficacy of the procedures we reviewed or estimated (i.e., number of sessions multiplied by number of trials per session) the number of trials to meet mastery criteria. If multiple data sets were collected with a single participant, the average number of trials to reach criteria across the datasets was calculated. We then coded the reinforcement conditions as most effective (i.e., least amount of trials to mastery) and second most effective (i.e., more trials to mastery than the most effective but fewer trials required than another condition) when more than two condition were compared in the study. If the study did not specify the mastery criteria or the specific criteria were not met, we coded this category as “N/A”. One study did not specify mastery criteria (Hausman et al., 2014) thus the effectiveness of the conditions was determined by comparing the percentages of correct responding during the last three sessions of each the conditions. In these cases, the condition with the higher percentage of correct responding was coded as most effective.

Social Validity and Generalization Assessments

We sought to extract data on the types of social validity (i.e., questionnaire, interview, rating scale, preference assessment) and generalization assessments (i.e., across stimuli, people, environment) employed by the studies. In addition, we planned to record the respondent (i.e., participant, caregiver, clinical team) for the social validity assessment and whether results of the social validity and generalization assessments were positive (e.g., respondent indicated enjoying the procedures employed; seen value in this type of study; skills generalized to a novel therapist, etc.). However, no studies included social validity assessments. Only two studies included a generalization assessment. Touchette and Howard (1984), assessed generalization across tasks and generalization occurred for all participants. Johnson et al. (2017) assessed generalization across tasks and generalization did not occur for any participants. Due to the lack of these measures, no additional information on these study characteristics will be included in results section.

Interrater Agreement

Interrater agreement (IRA) for the descriptive synthesis data extraction was calculated across two raters. IRA was calculated for 33% of the articles (four of the 12 articles) by comparing the data recorded (i.e., code assigned under each category of the descriptive synthesis) by each of the raters. Then we calculated the number of codes with agreement, divided by the cumulative number of codes assigned, and multiplied by 100. The mean IRA score was

92% (range, 89% to 97%). In instances of disagreement, the raters reviewed the articles together until they reached an agreement.

CHAPTER THREE:

RESULTS

Participant Characteristics

Sex, Age, and Diagnoses

Of the 12 studies reviewed, there were a total of 36 participants. Eleven of the studies reported the sex of these participants (Campanaro et al. 2020; Carroll et al., 2016; Cividini-Motta & Ahearn, 2013; Fiske et al., 2014; Hausman et al., 2014; Johnson et al., 2017; Karsten & Carr, 2009; Majdalany et al., 2016; Olenick & Pear, 1980; Paden & Kodak, 2015; Touchette & Howard, 1984). 81% of participants were male (n=29), 11% were female (n=4), and for 8% of participant their sex was not reported (n=3). Across all studies, the average age of participants was 8.9 years (range, 3 to 38 years old). All studies in the review reported participant diagnoses. 83% of participants were diagnosed with ASD (n = 30) and of those participants, 10% had an additional diagnosis of ID (n = 3). In addition, 8% of participants were diagnosed with ID (n = 3), and 33% of these participants had an additional diagnosis of cerebral palsy (n = 1). Of the remaining three participants, two were diagnosed with Down's Syndrome (6%) and one was diagnosed with Microcephaly (3%; Olenick & Pear, 1980). Of the 12 studies reviewed, the majority of participants were males and the most common diagnosis was ASD.

Communication and Skills Repertoires

Across the studies, information about participants' verbal repertoires were reported for 33 of the participants and of the 33 participants, the majority (55%) communicated with vocalizations alone (n = 18) or in combination with another communication modality (9%; n = 3). Of the 33 participants, five did not have a vocal verbal repertoire in which 6% of the 33 participants communicated with a picture exchange communication system (n = 2; PECS), 3% with gestures (n=1), 3% with an augmentative and alternative communication (n = 1; AAC), and 3% with a combination of AAC and signs (n = 1). For 21% of the participants which were reported to have a verbal repertoire, a communication modality was not reported (n = 7).

Some of the articles included in this review also provided information about the participants' skills repertoire (i.e., receptive and imitation skills) and deficits (i.e., prompt dependency). The presence or absence of receptive skills were reported for 11% of participants (n = 4) and all of them were reported as having a receptive skill repertoire. The presence of vocal and/or motor imitation skills were reported for 31% of total participants (n = 11). Although the presence or absence of prompt dependency was not reported for the majority of participants (n = 32), for Cividini-Motta and Ahearn (2013), this was a participant inclusion criterion. Prompt dependency was determined via a clinical team nomination, two observations of a matching-to-sample program, and a record review. Potential participants were selected for inclusion if during the observations, the learner waited for the teacher's prompt on at least 80% of the trials and the recorded review showed that they quickly moved through prompt hierarchies but rarely emitted correct responses independently.

Target Behavior

Topography of Target Behavior and Measurement

The target behavior that was taught during intervention varied across studies and participants. The target behavior taught for 50% of the participants was tact (n = 18). Matching skill (i.e., auditory-visual, pictures-to-words, coins-to-value) was taught for 25% of the participants (n = 9). Of these participants, three were from Johnson et al., (2017) and were taught auditory-visual matching skills and assessed generalization across tacts and intraverbals. Receptive identification accounted for the behavior taught to 19% of the participants (n = 7). For the final two participants, one participants target behavior was spelling (Hausman et al., 2014), and the final participant's behavior was picture sequencing (Karsten & Carr, 2009), each accounting for 3% of the total participants. Olenick and Pear (1980) was the only study that included comments regarding the target behavior or secondary dependent variables. The comment was that all participants tacts were taught using a training sequence, in which data would be collected for both probed and prompted trials for the target behavior. Other secondary dependent variables included frequency of errors to probes and prompts, frequency of probe and prompt accuracy, frequency of picture-names reaching criterion. All studies but Olenick and Pear, (1980) recorded the occurrence of the behavior on a trial-by-trial basis.

Pre-Evaluation Assessments

Preference Assessments

Preference assessments were conducted with 26 participants (72%) to identify stimuli to be used as reinforcers. These preference assessments included multiple stimulus without replacement (MSWO; n = 7), paired-stimulus preference assessments (PSPA; n = 6) or a combination of both (= 13) in which a PSPA was implemented to determine the stimuli that would be included in the subsequent brief, or single trial MSWO (Boudreau et al., 2015; Paden & Kodak, 2015; Johnson et al., 2017; Campanaro et al., 2020).

To determine the participant's preferred magnitude of a reinforcer, magnitude preference assessments were conducted for 19% of participants (n = 7). Fiske et al. (2014) implemented a magnitude PSPA for all three participants. The stimuli used were identified previously in a PSPA. A large magnitude (e.g., whole gummy bear) of the most preferred reinforcer and a small magnitude (e.g., half of a gummy bear) were presented as pairs in the PSPA across four trials. The magnitude chosen most often, which was the larger magnitude for all three participants, was used as the reinforcer for independent responding during differential reinforcement. Similarly, in Paden and Kodak (2015) a 5-trial preference assessment was completed and during each of these trials the participants were given the choice between a large-magnitude edible, small-magnitude edible, or no edible.

Reinforcer Assessments

A reinforcer assessment was completed for 50% of participants (n = 18). For 72% of these participants a progressive ratio reinforcer assessment was conducted (n = 13). For example, in Johnson et al., (2017) three progressive ratio assessments were completed to compare the reinforcing value of praise to extinction, large edible-plus-praise to praise and large edible-plus-praise to small edible-plus-praise. The response criterion to contact the reinforcer increased by two from the previous session. Sessions lasted for 5 min, until 1 min elapsed without the participant emitting a response or until the participant verbally indicated that they wanted to be done. The participants engaged in more cumulative responses in the praise condition compared to the extinction condition, the large edible-plus-praise condition compared to praise, and the large edible-plus-praise condition compared to the small edible-plus-praise. Due to the higher frequency of responses, this demonstrated that for all participants, the large edible had more reinforcing value than no consequence, praise, and a small edible plus praise. For three of the 13 participants in which a progressive ratio reinforcer assessment was completed, an additional single-operant reinforcer assessment was implemented (Campanaro et al., 2020). To find the value of the reinforcer, a single operant reinforcer assessment was completed for 28% of the participants (n=5; Cividini-Motta & Ahearn, 2013; Karsten & Carr, 2009).

Edible Magnitude Assessments

The same assessment was used to identify the amount of an edible to present following an independent correct response (e.g., large edible) and a prompted response (e.g., small edible) in differential reinforcement conditions with 36% of participants (n=13; Boudreau et al., 2015; Campanaro et al., 2020; Johnson et al., 2017; Paden & Kodak, 2015). This edible amount and size assessment was conducted by allowing a participant free access to the highest preferred edibles for 5 min. The large edible reinforcer (e.g., 3 skittles) was determined by dividing the number of pieces of an edible the participant consumed (e.g., 60 skittles) within the 5 min session by the number of trials in a session (e.g., 20 trials). To find the smallest number of pieces of an edible a participant would respond to, the participant was given one piece of their highest preferred edibles. If consumed, during the next trial the size of the edible was reduced by 50%. This continued until the participant did not consume the edible within 30-s of the onset of the trial or the edible was one-eighth of the original size. This reduced size of the edible was used as the small edible reinforcer.

Acquisition Evaluation

Teaching Procedures

The teaching format used was the same for all participants and evaluations in a study. 100% of the studies implemented a discrete trial training teaching procedure.

Baseline data were collected for 72% of the participants across the studies reviewed (n = 26; Boudreau et al., 2015; Campanaro et al., 2020; Carroll et al., 2016; Fiske et al., 2014; Hausman et al., 2014; Johnson et al., 2017; Majdalany et al., 2016; Paden & Kodak, 2015). Of these participants, 23% (n = 6) received general praise for both prompted and independent responses during baseline, while the other 77% (n = 20) did not receive any consequences regardless of response.

During intervention, 100% of all participants received prompts. Model prompts (vocal or physical model dependent on the target behavior) were implemented for 72% of the participants (n =26) while for 14%, physical prompts were used (n = 5) and 6% implemented a combination of both (n=2). For 8% of participants, a combination of vocal, gestural and physical prompts was used (n=3; Hausman et al., 2014).

A prompt fading procedure was implemented during intervention for 92% of the participants in the review (n = 33; Campanaro et al. 2020; Carroll et al., 2016; Cividini-Motta & Ahearn, 2013; Fiske et al., 2014; Hausman et al., 2014; Johnson et al., 2017; Karsten & Carr, 2009; Majdalany et al., 2016; Paden & Kodak, 2015; Touchette & Howard, 1984). Of these participants, for 42% a constant delay procedure was implemented (n = 14). A progressive delay procedure was implemented for another 30% of the participants (n = 10). For three of these participants, Touchette and Howard (1984) implemented a progressive delay which had increasing and decreasing components. This was implemented by a 0.5-s increase in delay of the prompt, following four consecutive independent correct responses. Two consecutive incorrect responses, resulted in the delay being decreased to equal the shorter of the two latencies emitted. To increase the delay between the SD and the prompt again, each consecutive correct response produced a 0.5-s increase, until the delay was back to where it was prior to the decrease. A MTL and LTM prompting procedure was implemented for 16% (n = 5) and 3% (n = 1) of the participants, respectively. Finally, for 9% (n = 3) of the participants, a MTL plus constant delay prompt fading procedure was implemented (Hausman et al., 2014).

An error correction procedure was implemented for 67% of the participants (n = 24; Boudreau et al., 2016; Campanaro et al. 2020; Carroll et al., 2016; Fiske et al., 2014; Johnson et al., 2017; Karsten & Carr, 2009; Majdalany et al., 2016; Olenick & Pear, 1980; Paden & Kodak, 2015; Touchette & Howard, 1984) whereas no error correction procedure was employed for 33% of the participants (n = 12; Cividini-Motta & Ahearn, 2013; Fiske et al., 2014; Hausman et al., 2014; Paden & Kodak, 2015). Various types of error correction procedures were used in these studies including a model of or a prompt to the correct response and initiation of the next trial (n = 11; Boudreau et al., 2015; Campanaro et al. 2020; Johnson et al., 2017; Karsten & Carr, 2009), corrective feedback (e.g., “No it’s [correct response]”), then starting the next trial (n = 5; Fiske et al., 2014; Majdalany et al., 2016), modeling the correct response, then repeating until a correct response occurred (n = 5; Carroll et al., 2016; Olenick & Pear, 1980), and a repeated trial with a verbal "No" without eye contact for 10-s plus a decrease in prompt delay, following a second consecutive error (n = 3; Touchette & Howard, 1984).

Parameters Manipulated

Quality of reinforcers. For 33% (n = 12) of the participants in the studies reviewed, the parameter of quality of reinforcer was manipulated (Boudreau et al., 2015; Cividini-Motta & Ahearn, 2013; Johnson et al., 2017; Karsten & Carr, 2009). During the differential reinforcement conditions, independent correct responses were reinforced with a higher quality reinforcer and prompted responses were reinforced with a lower quality reinforcer. The class of reinforcers used included edibles plus praise for 75% of participants (n = 9) and tokens plus praise for the remaining 25% of participants (n = 3). Of these 12 participants, 100% were exposed to the No-DR condition (n = 12), in which the quality of the reinforcer is the equal for prompted and independent responses,100% (n = 15) to the DR 1 condition, in which the reinforcer is of higher quality for the independent response compared to the reinforcer for the prompted response, and 33% (n = 4) to the DR 2 condition, in which the independent response is reinforced with a high-quality reinforcer (e.g., tokens plus praise) and the prompted response is put on extinction (no consequence). The DR 3 condition was not evaluated.

Magnitude of reinforcers. The magnitude of the reinforcer was manipulated for 23% (n = 9) of the participants (Boudreau et al., 2015; Fiske et al., 2014; Johnson et al., 2017). This was evaluated during the differential reinforcement conditions by reinforcing the independent correct response with a larger magnitude reinforcer compared to the reinforcer delivered following the prompted response. The class of reinforcers used for the participants include edibles (n = 4), edibles plus praise (n = 3), social reinforcement (n = 1) and tangible reinforcers (n = 1). Of these 9 participants, 100% experienced the No DR and DR 1 conditions. In the DR 1 arrangement, the large magnitude reinforcer (e.g., 20-s of social reinforcement) was delivered contingent on an independent response and a smaller magnitude of reinforcement was delivered contingent on a prompted response (e.g., 5-s of social reinforcement). The DR 2 or DR 3 conditions were not evaluated.

Schedule of reinforcement. The schedule of reinforcement was manipulated for 31% (n = 12) of the participants in the review (Hausman et al., 2014; Johnson et al., 2017; Olenick & Pear, 1980; Touchette & Howard, 1984). This was evaluated by using a denser schedule of reinforcement for an independent correct response relative to the schedule in effect for a prompted response. The class of reinforcers used for the participants included edibles plus praise for (n = 6), edibles alone, (n = 3) and tokens plus praise (n = 3). 100% of the participants (n = 12) were exposed to the typical No DR condition (e.g., CRF schedule for both independent and prompted responses). For three of these participants, an additional No DR variation was implemented in which the independent and prompted responses were tracked on different schedules, but were reinforced using equal FR schedules (e.g., the participant had to have six correct prompted responses to contact reinforcement, if an independent response was incorrect, this did not restart the prompted schedule; Olenick & Pear, 1980). Of the 12 participants, 100% (n=12) were exposed to the DR 1 condition, in which the independent and prompted responses were reinforced with different schedules of reinforcement. For all participants, this was the typical arrangement in which the denser schedule of reinforcement (i.e., CRF) was implemented for independent responses and a leaner schedule of reinforcement was used for prompted responses (i.e., FR3, FR6, FR8). For 25% of the participants (n=3) a DR 2 condition was implemented. For instance, Hausman et al., (2014) reinforced independent response on a CRF schedule while prompted responses were put on extinction (i.e., received no consequence). In addition, 50% of the participants (n = 6) were exposed to the DR 3 condition in which prompted responses were reinforced on a CRF schedule whereas independent responses were under an intermittent schedule of reinforcement. For three participants exposed to this variation, token plus praise was delivered on a FR 3 schedule contingent on independent responses (Touchette & Howard, 1984) and for another three participants, an edible plus praise was delivered for independent responses on a FR 6 (n = 2) or FR 8 (n = 1) schedule (Olenick & Pear, 1980).

Multiple parameters. For 31% of the participants (n = 12) multiple reinforcer parameters were manipulated simultaneously (Campanaro et al., 2020; Carroll et al., 2016; Majdalany et al., 2016; Paden & Kodak, 2015).

Quality and delay. For the three participants in Majdalany et al., (2016), three variations of the DR 1 condition were implemented. The prompted responses were reinforced with praise whereas the independent responses were reinforced with an edible plus praise. The delivery of the reinforcer (praise or edible plus praise) was delayed by 0-s, 6-s or 12-s depending on the condition. Across these three DR 1 variations, both delay to reinforcement (i.e., 0-s, 6-s, 12-s) and quality of the reinforcer (i.e., edible, praise) are manipulated. The participants were not exposed to the No DR, DR 2 or DR 3 conditions.

For the two participants in Carroll et al. (2016), there are three DR 1 variations. The first DR 1 variation (immediate reinforcement) reinforces the independent response with a highly-preferred reinforcer (i.e., edible plus praise or tangible plus praise) following a 0-s delay and reinforces the prompted response with praise alone following a 0-s delay. The second DR 1 variation (delayed reinforcement with immediate praise), reinforces the independent response with a highly-preferred following a 10-s delay and reinforces the prompted response with praise alone following a 0-s delay. During the third variation (delayed reinforcement), the reinforcers were similar to those in the previous variation, except the prompted response receives the reinforcer after a 10-s delay. Across these two DR 1 variations, both delay to reinforcement (i.e., 0-s, 10-s) and quality of the reinforcer (i.e., edible or token, praise) are manipulated. The participants were not exposed to the No DR, DR 2 or DR 3 conditions.

Quality and magnitude. For the four participants in Paden and Kodak (2015), there were two version of the DR 1 condition. For both DR 1 conditions, prompted responses resulted in praise but the conditions differed relative to the size of the edible (large or small) provided for independent responses. Across the two DR 1 variations, both magnitude (i.e., large edible or small edible) and quality (i.e., edible or praise) of the reinforcer were manipulated. These participants were exposed to the No DR condition in which, following both prompted and independent responses, praise was delivered. The participants were not exposed to the DR 2 or DR 3 conditions.

Quality, magnitude, schedule, and DR onset. For the three participants in Campanaro et al., (2020), the parameters of quality, magnitude and schedule were manipulated and compared using the DR 1 condition. Each participant was exposed to three DR 1 conditions in which the independent responses were reinforced with an edible plus praise, a larger magnitude of edible plus praise, or an edible plus praise on a CRF schedule. The prompted responses were reinforced with a lower quality reinforcer (i.e., praise alone), smaller magnitude of reinforcement (i.e., small edible plus praise) or leaner schedule (i.e., FR 3). Once the most efficient parameter manipulation was determined for each participant, (i.e., schedule for two participants, quality for one participant) the onset of the differential reinforcement procedure was manipulated. It is important to note, that for one participant both quality and magnitude manipulated parameters had equal trials to mastery, in which the total training time was compared and the condition which had a shorter duration (i.e., quality) was determined the most efficient by the authors. The onset of differential reinforcement varied across conditions, and it was based on the percentage of independent responses emitted by the participants (0% or immediate; 33% or early onset; 50% of late onset). Of the three participants, 100% (n = 3) were exposed to the No DR condition, in which differential reinforcement was never implemented and both prompted and independent responses received an edible plus praise, and to a DR 1 condition, in which reinforcement favored independent reposes. The impact of onset of differential reinforcement was evaluated using the parameter that was previously determined most efficient for each participant (i.e., schedule or quality). None of the participants were evaluated with the DR 2 or DR 3 conditions.

Outcomes

This literature review identified 12 articles that evaluated the effects of differential reinforcement on skill acquisition. As noted above, studies differed in regard to participants, target responses taught to participants, procedures employed to identify consequent stimuli and appropriate parameters of reinforcement, the instructional procedures, and the type of differential reinforcement evaluated. A total of 36 participants were involved in the studies in which they were exposed to a combination of DR conditions. Of these, 30 participants were exposed to a No DR condition, 10 were exposed to a DR 2 condition, and 6 were exposed to a DR 3 condition. All participants included in the studies experienced a variation of the DR 1 condition (n = 36).

The variations of DR 1 included manipulations of multiple reinforcer parameters in one condition and comparisons across different parameters.

The quality of the reinforcer was manipulated for 12 participants and of these, the DR 1 condition was the most efficient for 84% of the participants (n = 10) whereas the No DR and the DR 2 conditions were each the most efficient for 8% of the participants (n = 1). The DR 3 condition was never evaluated. Johnson et al. (2017) compared the DR conditions across quality, magnitude and schedule of reinforcement manipulations. The DR 1 condition which included manipulation of the quality of the reinforcer, was the most efficient for all three participants. In Boudreau et al. (2015) the DR conditions were compared across quality and magnitude. The No DR condition was most efficient for one participant and the DR 1 condition was most efficient for the other two. Of these two participants, the manipulation of quality was more efficient for one and the manipulation of magnitude was more efficient for the other.

The magnitude of the reinforcer was manipulated for 9 participants and of these, the DR 1 condition was most efficient for 56% (n = 5), the No DR condition for 33% (n = 3), and the DR 2 condition for 11% (n = 1) of participants. The DR 3 condition was never evaluated. In Johnson et al. (2017) described above, the magnitude manipulation condition was not the most efficient for any of the three participants and in Boudreau et al. (2015), also previously described, the manipulation of the magnitude condition was the most efficient for only one of three participants.

The schedule of reinforcement was manipulated for 12 participants and of these, the DR 1 condition was most efficient for 75% (n = 9), the DR 2 condition for 17% (n = 2), and for 9% of the participants (n = 1) the DR 1 and DR 2 conditions were equally efficient. DR 3 was evaluated with six participants and was not an effective condition for any of them. In Johnson et al. (2017), which was previously discussed, manipulation of the schedule of reinforcement was not the most efficient for any participants.

When the quality of the reinforcer was manipulated concurrently with other parameters (i.e., delay, magnitude, onset), and compared across DR conditions, the DR 1 condition was most efficient for all participants (n = 7). For all participants, the DR 2 or DR 3 conditions were not evaluated. When manipulating quality and delay, such as in Carroll et al. (2016), the immediate delivery (i.e., 0-s delay) of the high-quality reinforcer or praise resulted in the quickest acquisition of the skill. The efficiency of immediate reinforcement was also demonstrated by Majdalany et al. (2016), in which for two of the three participants the 0-s delay of reinforcement in the DR 1 condition lead to the fastest skill acquisition. The third participant had equally efficient results when the delivery of the reinforcement was delayed by 6-s and 12-s in the DR 1 condition. When manipulating quality and magnitude, in Paden and Kodak (2015), two variations of the DR 1 condition were evaluated. For two participants, the variation which utilized the large reinforcer was most efficient, for the other two participants the use of the small reinforcer for independent responses was most efficient. The No DR condition was not efficient for any of the participants.

Finally, the results from the manipulation of the onset of a differential reinforcement procedure evaluated only by Campanaro et al. (2020) indicate that the DR 1 immediate onset (i.e., 0-s delay) was the most efficient arrangement for approximately 66% of the participants (n = 2) whereas DR 1 early onset (i.e., onset after 33% independent responding) was most efficient for approximately 33% of participants (n =1). The No DR or DR 1 late onset conditions were not the most efficient for any participants. In addition, Campanaro et al., (2020) also compared the manipulation of reinforcer parameters in the DR 1 condition. The manipulation of the schedule of reinforcement was the most efficient for two of the three participants. The final participant met the mastery criteria in equal trials for the manipulation of quality and magnitude, in which both were equally efficient.

The overall results from the studies indicate that when compared across conditions, skill acquisition was more rapid in the DR 1 condition for 74% of participants (n = 23), regardless of the variation. In addition, skill acquisition was more rapid in the DR 2 condition for 13% of participants (n =4) and in the No DR condition for 10% (n = 3). DR 1 and DR 2 were equally effective for 3% of the participants (n = 1). Across all participants, the parameter of quality was manipulated most frequently (n = 27) and when compared to other parameters (i.e., magnitude, schedule), it is the most efficient for 50% of participants (n = 4), the manipulation of schedules of reinforcement is the most efficient for 25% of participants (n = 2), magnitude is the most efficient for 12.5% of participants (n = 1) while quality and magnitude are equally efficient for 12.5% of participants (n = 1). Both immediate delivery of a reinforcer and immediate onset of the differential reinforcement procedure were also associated with fewer sessions to mastery criteria. Specifically, skill acquisition is more rapid when the quality of the reinforcer is manipulated within a DR 1 condition, in which reinforcement is delivered following a 0-s delay, and the onset of differential reinforcement is immediate.

Table 1

Descriptive Synthesis

Article	Participant Characteristics (# of participants)			Teaching Procedures (# of participants)					Outcome Measures (# of participants)	
	Sex, Age, Diagnosis	Communication	Skills & Deficits	Target behavior	Pre-Evaluation assessment	Reinforcer class	Parameter manipulated	Conditions evaluated	Most efficient condition	Most efficient parameter
Olenick & Pear (1980)	3 M 4 yo, DS (2), Microcephaly (1)	Vocal	Receptive: NR; Vocal IM: Y; PD: NR	Tact	N/A	Edibles & Praise	Schedule	No DR, DR 1, DR 3	DR 1	N/A
Touchette & Howard (1984)	2 M, 1 F; 6-13 yo, ID (2), ID + CP (1)	Vocal (2), Gestures (1)	Receptive: NR; IM: NR; PD: NR	Rec. ID	N/A	Tokens & Praise	Schedule	No DR, DR 1, DR 3	DR 1	N/A
Karsten & Carr (2009)	2 M; 3 & 5 yo, ASD	Vocal (1), Vocal + Gestures (1)	Receptive: NR; Vocal & Motor IM: Y; PD: NR	Picture sequence (1), Tact (1)	MSWO; PR-RA (1), SO-RA (1)	Edibles & Praise	Quality	No DR, DR 1	DR 1	N/A
Cividini-Motta & Ahearn (2013)	4 M; 12-38 yo, ASD	AAC (1), AAC + Signs (1), Vocal + Signs (1), NR (1)	Receptive: NR; IM NR; PD: Y	Matching	SO-RA	Tokens & Praise (3), Edibles & Praise (1)	Quality	No DR, DR 1, DR 2	DR 1 (3), DR 2 (1)	N/A
Fiske et al., (2014)	2 M, 1 F; 5-8 yo, ASD	PECS (2), Vocal (1)	Receptive: Y (2), N (1); IM: NR; PD: NR	Rec. ID	PSPA; PR-RA	Edibles (1), Social (1), Tangible (1)	Magnitude	No DR, DR 1, DR 2	No DR (2), DR 2 (1)	N/A
Hausman et al., (2014)	3 M; 16-20 yo, ASD & ID	NR	Receptive: NR; IM NR; PD: NR	Matching (2), Spelling (1)	PSPA	Edibles & Praise	Schedule	No DR, DR 1, DR 2	DR 2 (2), DR 1 + DR 2 (1)	N/A (3)
Boudreau et al., (2015)	3 NR; 7-10 yo, ASD	Vocal	Receptive: NR; Vocal IM: Y; PD: NR	Tact	PSPA, MSWO; PR-RA; Edible	Edibles & Praise	Quality, Magnitude	No DR, DR 1	DR 1 (2), No DR (1)	Quality (1), Magnitude (1), N/A (1)
Paden & Kodak (2015)	4 M; 4-5 yo, ASD	Vocal	Receptive: Y; IM NR; PD: NR	Tact (3), Rec. ID (1)	PSPA, MSWO, Edible	Edible & Praise	Quality + Magnitude	No DR, DR 1	DR 1	N/A

Table 1 Continued

Carroll et al., (2016)	2 M; 4 & 5 yo, ASD	Vocal (1) Vocal + PECS (1)	Receptive: Y; IM NR; PD: NR	Tact (2)	MWSO (2)	Tangible & Praise (1), Edibles & Praise (1)	Quality + Delay	DR 1 Immediate, DR 1 Immediate praise, DR 1 Delay	Immediate	N/A
Majdalany et al., (2016)	3 M; 5 yo, ASD	Vocal	Receptive: NR; IM NR; PD: NR	Tact	MSWO	Edibles & Praise (3)	Quality + Delay	DR 1 Immediate, DR 1 Delay	Immediate (2), Delay (1)	N/A
Johnson et al., (2017)	3 M; 8-10 yo, ASD	Verbal Repertoire: Y; Mod: NR	Receptive: Y; Motor IM; PD: NR	Matching	PSPA, MSWO; PR-RA; Edible	Edibles & Praise	Quality, Magnitude, Schedule	No DR, DR 1	DR 1	Quality
Campanaro et al., (2020)	2 M, 1 F; 7 & 9 yo, ASD	Verbal Repertoire: Y; Mod: NR	Receptive: NR; IM NR; PD: NR	Tact	PSPA, MSWO; SO-RA, PR-RA; Edible	Edibles & Praise	Quality, Magnitude, Schedule; Onset	DR 1; No DR	DR 1; Immediate (2), Early (1)	Schedule (2), Quality + Magnitude (1)

Note. CP = Cerebral Palsy, IM = Imitation, Mod = Communication modality, PD = Prompt dependency, PR-RA = Progressive ratio reinforcer assessment, Rec. ID = Receptive identification, SO-RA = Single operant reinforcer assessment

CHAPTER FOUR:

DISCUSSION

Differential reinforcement entails varying the consequence for correct and independent responses so that one type of response (e.g., independent correct) is favored as compared to another response (e.g., prompted correct; errors). This review synthesized literature on the use of differential reinforcement for skill acquisition. A total of 12 articles were included in this review and were summarized in regard to participants' characteristics, target behaviors, pre-intervention assessments, acquisition evaluation, and results. The multitude of variations of differential reinforcement conditions and reinforcer parameters manipulated in the studies were previously described. Overall, acquisition was faster when a differential reinforcement procedure was employed but the specific differential reinforcement arrangement resulting in quicker acquisition varied across participants.

Across studies that compared DR conditions, the DR 1 condition¸ which entailed the delivery of a more potent reinforcer for independent responses and a less potent reinforcer for prompted responses (Cividini-Motta & Ahearn, 2013), was the most efficient for 23 out of 31 participants. It is important to note though, that variations occurred within DR 1 conditions across studies. Nevertheless, the DR 1 condition was highly effective when manipulated across multiple reinforcer parameters. In cases where DR 1 with different parameter manipulations were compared, quality manipulations was more efficient than schedule and magnitude for four out eight participants. When delay of reinforcement delivery was manipulated, immediate reinforcement lead to quicker skill acquisition for four out of five participants. Finally, for participants for whom onset of differential reinforcement was compared, mastery criterion was met in fewer sessions when differential reinforcement was implemented immediately for two out of three participants.

The current review offers multiple venues for future research related to both gaps in the literature as well as limitations identified in the reviewed articles. The major gaps identified in this review include lack of social validity, generalization, and maintenance measures. None of the studies included in this review assessed social validity of the procedures or outcomes. Social validity, which can be evaluated via indirect (e.g., questionnaires, interviews) or direct assessments (e.g., concurrent chain preference assessment; Hanley et al., 1997) refers to the appropriateness of the target behaviors, the acceptance of the interventions or procedures, and the validation of the behavior change outcome (Miltenberger, 1990). Thus, the inclusion of a social validity measure is important in determining, amongst other things, the feasibility of implementation of procedure and client as well as caregiver's preference for or acceptability of the procedure (Campanaro et al., 2020; Johnson et al., 2017; Touchette & Howard, 1984). In addition, social validity measures can facilitate treatment selection. For instance, in Boudreau et al., (2015) the most efficient condition and parameter varied across individuals; thus, a measure of participant preference for each of these conditions could have been beneficial in aiding the decision on which arrangement to conduct.

Similarly, generalization measures indicate whether the acquired skill is emitted in a novel setting, with different a person, or towards other behaviors, without requiring direct training (Stokes & Baer, 1977). As described previously, generalization across behavior was only assessed in Touchette and Howard (1984) and Johnson et al., (2017) but, generalization across setting or people were not evaluated in any of the articles included in this review. In addition, given that all studies reviewed used differential reinforcement within a DTT format, future research should evaluate differential reinforcement across multiple teaching formats (i.e., DTT, incidental teaching, naturalistic teaching, and/or task analyses) with each participant to see if the same results are attained.

Additionally, the current review highlights the lack of information on maintenance of skills following differential reinforcement in the literature. Maintenance data could be helpful to collect to determine if the effects of differential reinforcements on skill acquisition maintained over time. Maintenance is important in the clinical setting where skill acquisition programs build on top of each other, in which a specific behavior is needed to complete a novel task (e.g., discrimination skill is required to complete receptive identification tasks). Johnson et al. (2017) mentions that more research on this topic is needed because, for some parameters of reinforcement, it may be more difficult to program maintenance. For example, when manipulating the magnitude of a reinforcer, it may take longer to fade the use of the larger sized reinforcer than the smaller reinforcer, thus potentially eliminating the perceived efficiency of the arrangement (Johnson et al., 2017).

Furthermore, previous research on differential reinforcement has not evaluated the feasibility of the implementation of a differential reinforcement procedure in a clinical setting. For instance, in clinical settings the immediate delivery of consequences (e.g., reinforcers) is not always feasible (Majdalany et al., 2016), thus it is likely that differential reinforcement that involves manipulations to the immediacy of reinforcer delivery will not be implemented consistently, or that a delayed reinforcer delivery will be intermittently embedded within other parameter manipulations. Additionally, it is unclear whether more treatment integrity errors occur when conducting DR 1, DR 2, or DR 3 conditions and whether these errors impact outcomes.

Finally, Cividini-Motta and Ahearn (2013) is the only study included in the review to assess the impact of differential reinforcement on acquisition of skills by individuals whose responding was prompt dependent. Due to lack of literature in regard to the subject, the authors suggest methods to evaluate prompt dependency that should be further explored. Furthermore, Karsten and Carr (2009) discuss that, during differential reinforcement, continued engagement in prompted responses may have remained due to prompt dependency in the participants. Conversely, Campanaro et al. (2020) explains that if differential reinforcement is not implemented (i.e., No DR condition), the reinforcement of the prompted responses may promote prompt dependency in learners. These notions should be evaluated to determine whether differential reinforcement is beneficial or detrimental for learners who display prompt dependency.

Our literature review also identified several limitations of the current literature on differential reinforcement. Omissions of a control condition (Majdalany et al., 2016) or a baseline phase (Cividini-Motta & Ahearn, 2013; Karsten & Carr, 2009; Olenick & Pear, 1980; Touchette & Howard, 1984) are seen frequently across studies. A control condition is important to demonstrate that the effects are due to the implementation of the differential reinforcement procedure (Fiske et al., 2014). Without a control condition, it is uncertain whether the acquisition would have occurred without reinforcement or prompting (Fiske et al., 2014). There is also a similar concern with the exclusion of a baseline phase. Without a baseline phase, the skill level of the participant prior to the implementation of the procedure is unknown. An exception is the study by Cividini-Motta and Ahearn (2013) which did not include a baseline phase because the target response was identification of novel sight words (i.e., Portuguese words) and thus likely not in the participants' repertoire.

In addition, various components of the instructional procedures, which differed across studies, may impact acquisition. In regards to emission of prompted responding, it is suggested that the lower response effort associated with emission of a prompted response may be, at least partially, responsible for the persistence of these responses (Karsten & Carr, 2009). Specifically, Karsten and Carr suggested that imitation of a vocal or motor prompt during skill acquisition, may be less effortful than independently emitting a novel behavior (e.g., pointing to or tacting an unfamiliar picture). Similarly, independent responding may be maintained by negative reinforcement. For instance, in a LTM prompting procedure independent correct responses successfully avoid the presentation of intrusive-prompts (Karsten & Carr, 2009; Paden & Kodak, 2015) and in studies that include an error correction, independent correct responses may be negatively reinforced by the avoidance of the error correction (Karsten & Carr, 2009).

Continuing with limitations of previous studies, a differential reinforcement procedure was technically in effect in the No DR condition for some studies due to the delay in reinforcement delivery. The delay to reinforcement delivery when independent correct responses are emitted is likely relatively shorter than the delay to reinforcement during trials with prompted correct responses (Hausman et al., 2014). In addition, in studies in which an errorless teaching procedure was not employed, prompts were sometimes provided following an error and thus many instances of prompted responses were preceded by an error. In these cases, although No DR was programmed, the delay to reinforcer delivery during trials in which an error was emitted prior to the prompted response, was longer than in trials in which the response was correct (Fiske et al., 2014; Karsten & Carr, 2009).

Finally, outcomes of some of the previous studies may also have been impacted by condition sequences, carry over across conditions, and instructional control. For instance, for studies in which participants were exposed to the No DR condition initially (e.g., Touchette & Howard, 1984), results may have been impacted by a sequence effect. Given the directly previous history of non-differential reinforcement in the No DR condition, frequent engagement in the prompted responses when differential reinforcement was in effect may have been due to previous contact with the high-value reinforcement during the No DR condition (Touchette & Howard, 1984; Boudreau et al., 2015). Outcomes of studies that employed an adapted alternating treatments design may have been impacted by carry over effects or multiple treatment interference (e.g., Boudreau et al., 2015; Campanaro et al., 2020; Cividini-Motta & Ahearn, 2013). This also may be due to failed discrimination of conditions by the participants (Boudreau et al., 2015). Lastly, the participants in Paden and Kodak, (2015) had a history of reinforcement in similar DTT settings, thus their responding may have been under the instructional control of the characteristics of the environment.

In addition, when examining delay in reinforcer delivery, as suggested by previous research, future researchers should attempt to develop ways in which delay in reinforcement does not cause a decrease in skill acquisition or reinforcer value (Carroll et al., 2016; Majdalany et al., 2016). Alternatively, research should investigate ways to decrease delay to reinforcement delivery in clinical settings. Carroll et al. (2016) explains that, in the natural environment, the immediacy of the delivery of reinforcement will not be as precise as in research settings. With this, the authors suggest that researchers should evaluate the manner in which reinforcement delay occurs in the natural environment and base future studies on how it carried out in "common practice."

Results of this literature review have immediate implication to practice. Findings from multiple studies indicate that the most efficient DR condition and parameter manipulation is likely specific to each participant (Boudreau et al., 2015; Campanaro et al., 2020; Johnson et al., 2017). Therefore, it may be necessary for clinicians to compare various DR procedures to identify the most efficient procedure for their client and to complete a parameter sensitive assessment, similar to the ones conducted by MacNaul et al. (2020), to determine which parameter of reinforcement to include in the differential reinforcement procedures. However, the value of these assessments, relative to the time required to conduct, is unclear and should be considered (Johnson et al., 2017).

Clinicians considering the use of differential reinforcement within skill acquisition programs must also consider the onset of differential reinforcement. Earlier studies suggest that, to best promote skill acquisition, differential reinforcement should not be implemented immediately (Boudreau et al., 2015; Fiske et al., 2014; Hausman et al., 2014). This is advised so that the correct responses (independent or prompted) are more likely to contact reinforcement at the start of the skill acquisition procedure, before differential reinforcement is implemented. In a more recent study, Campanaro et al., (2020) compares the onset of differential reinforcement implementation, and for two of three participants, immediate onset is most efficient in promoting skill acquisition. Clinicians should consider the findings from these studies to adequately decide at what point in skill acquisition to implement differential reinforcement.

In summary, this review examined 12 studies in which differential reinforcement was implemented for skill acquisition. The overall findings of these studies suggest that, the most efficient differential reinforcement variation is the one that delivers a more favorable reinforcer following independent responding while a less favorable reinforcer is provided following prompted responding (i.e., DR 1). Differential reinforcement was shown to be most efficient when the reinforcer arrangement manipulates the quality of the reinforcer (i.e., higher-preference reinforcer for independent responses, lower-preference reinforcer for prompted responses). Studies also showed that skill acquisition is quicker when the reinforcer is delivered following a 0-s delay after a response (i.e., immediate reinforcement) and when the differential reinforcement procedure is implemented immediately. Future research should aim to develop ways in which delays in reinforcement delivery do not hinder skill acquisition and examine the effects of varying task difficulty during differential reinforcement. Clinicians should be advised that sensitivity to reinforcer parameters vary across individuals, so the iteration of differential reinforcement employed must be specific to their learner and the reinforcer parameters manipulated should be selected through an assessment.

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