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An Evaluation of Preference of Delays to Reinforcement on Choice Responding: A translational study

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An Evaluation of Preference of Delays to Reinforcement on Choice Responding: A translational study

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Abstract

An Evaluation of Preference of Delays to Reinforcement on Choice Responding: A translational study

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Delays to reinforcement are often a necessary component during treatments of challenging behavior (e.g., Functional Communication Training; FCT). In the absence of programmed delay training, the utility and generality of FCT may be limited. Despite the importance of delays to reinforcement during FCT, few studies have empirically isolated and investigated the parameters pertaining to the implementation of delays to reinforcement. Results from basic empirical studies have shown that variable delays, or bi-valued mixed delays to reinforcement, are preferred in humans and nonhuman studies. The current research examined response allocation between fixed and mixed delays to reinforcement using a concurrent schedule of reinforcement. Results showed preference for mixed delays to reinforcement with 4 out of 4 participants. Potential avenues of future research on the use of mixed delays to reinforcement, such as the application within FCT and maintenance of socially appropriate behaviors, are discussed.

TABLE OF CONTENTS

CHAPTER 1

Decades of basic (i.e. nonhuman animal) behavioral research has illuminated fundamental underpinnings of human behavior. However the process of translating innovative basic findings into applied, clinically relevant treatments to improve socially important behaviors has been slow and inconsistent (Mace & Critchfield, 2010). The call for coordination between basic and applied behavioral principles has been an on-going conversation in both disciplines (e.g., "the importance of a science of behavior derives largely from the possibility of an eventual extension to human affairs"; Skinner, 1938, P.441). As basic principles of behavior are evaluated and supported within the laboratory (e.g. alternative reinforcement, choice, and extinction), it is imperative that these findings provide the basis for translational and applied research that can ultimately lead to more effective and efficient treatment for socially important behaviors. However, this process takes time and coordination among disciplines and unfortunately cannot be captured in a single empirical study or a single behavioral principle. Instead, the culmination of a variety of translational works can bridge the basic-applied research gap and better inform practice. Thus, the current research, in part, aims to illuminate the largely unmet potential to translate successful basic findings and principles of behavioral research to applied contexts.

Specific to the topic of the current study, delays to reinforcement and their effect on responding has been a focus of basic behavioral research since the beginning of the experimental analysis of behavior (Ferster, 1953) and continues to inform applied practice with clinical populations today (e.g., Muething, Falcomata, Ferguson, Swinnea, & Shpall, 2018). Delay to reinforcement has been a topic that has continued to transcend the basic-to-applied research continuum with research consistently published on both ends of the continuum. The extensive experimental literature on the parameters of delays to reinforcement has provided multiple areas of research, both basic and applied. However, a review of the literature has shown a lopsided representation favoring the basic empirical literature base (Lattal, 2010). The findings from simple to complex basic research have transformed our understanding of how delays to reinforcement can impact acquisition (e.g., Wilkenfield, Nickel, Blakely, & Polling, 1992; Lattal & Gleeson, 1990), maintenance (e.g., Costa & Boakes, 2007), persistence (e.g., Peterson, 1956), and generalization (e.g., Escobar & Bruner, 2007) of responding. These basic studies have led to refinements in how applied clinicians understand delays and their potential effects on responding. Additionally, basic studies have paved the way for many evidence-based interventions for individuals with and without disabilities (e.g., Tiger & Hanley, 2005; Tarbox & Ghezzi, 2006; Okouchi, 2009). As with any progressive discipline, the more questions being investigated, additional questions tend to arise.

Functional Communication Training (FCT; Carr & Durand, 1985) is one of the most common empirically supported interventions for the treatment of challenging behavior displayed by individuals with developmental disabilities and autism (Tiger, Hanley, & Bruzek, 2008). FCT is a differential reinforcement procedure that involves teaching an individual to emit an appropriate, functional communicative response (FCR), as a means of accessing reinforcement that previously maintained their challenging behavior (Carr & Durand, 1985). During initial phases of FCT, a motivating operation (MO) that has been identified to evoke challenging behavior (e.g., removal of a preferred activity) is systematically introduced. While the MO is in place, the FCR is taught during a procedure known as mand training. During mand training, reinforcement is generally provided immediately, contingent on the FCR, while challenging behavior is placed on extinction and no longer results in access to the functional reinforcer. Successful FCT implementation has led to decreases in challenging behavior and increases in appropriate communication. Numerous studies have emerged since Carr and Durand (1985) was published; and many second generation studies have sought to identify components of the FCT intervention that have contributed to its continued demonstrated success (Tiger et al., 2008).

Despite the success of FCT in quick decreases in challenging behavior, difficulty with the maintenance and generalization of the initial, clinically significant effects continues to be an issue for researchers and clinicians implementing FCT (Tiger et al. 2008). Common concerns regarding the effective, long-term success and maintenance of FCT are related to issues that arise when the FCR is not consistently and immediately reinforced (Hagopian, Boelter, & Jarmolowicz, 2011). Consistent reinforcement is a necessary component of establishing or increasing operant behavior, such as appropriate responding. Research conducted in both applied and basic laboratory experiments has shown that reinforcement is most effective when delivered immediately following the target response (e.g. Sutphin, Bryne, & Poling, 1988). In the natural environment, delays to reinforcement often occur between a response and subsequent reinforcer delivery. Even relatively small delays to reinforcement can jeopardize treatment fidelity, and potentially lead to the recovery or resurgence of challenging behavior to pre-treatment levels (e.g., Hanley, Iwata, & Thompson, 2001; Volkert, Lermanm Call, & Trosclair-Lasserre, 2009; Lieving, Hagopian, Long, & O’Connor, 2004; Hagopian et al., 2011). An intervention component, dedicated to increasing tolerance of delays to reinforcement, is often necessary for cases in which an individuals rate of communication is high, making consistent and immediate reinforcement of the FCR impossible or impractical for most natural settings (Hagopian, Fisher, Sullivan, Acquisto, & LeBlanc, 1998).

As a result, researchers have investigated ways of thinning the schedule of reinforcement to more practical levels while simultaneously maintaining near-zero rates of challenging behavior (e.g., Tiger et al., 2008; Hagopian et al., 2011; Hagopian, Kuhn, Long, & Rush, 2005). Hagopian et al. (2011) reviewed the published literature on reinforcement schedule thinning within FCT, and identified four procedures that have strengthened the practical application of FCT. The procedures reported by Hagopian et al. included chain schedules of reinforcement, multiple schedules of reinforcement, response restriction, and delayed reinforcement. Chained schedules of reinforcement are most frequently used when challenging behavior is maintained by negative reinforcement and involve systematically increasing the response requirements (e.g., academic work) before the appropriate request is reinforced (e.g., Fisher et al., 1993). Multiple schedules are compound schedules in which (a) one component is correlated with a specific signal stimulus and (b) the reinforcement schedule is alternated with a different component comprised of its own correlated schedule and stimuli. In a typical reinforcement schedule thinning procedure during FCT, the different components of the multiple schedules represent periods of immediate reinforcement of the FCR, alternated with increasing intervals of extinction for the FCR (Hanley, et al., 2001). In procedures using response restriction during FCT, response materials used to request reinforcement are withheld during times in which reinforcement is unavailable (e.g., Roane, Fisher, Sgro, Falcomata, & Pabico, 2004; Falcomata, Roane, Feeney, & Stephenson, 2010). Response restriction is therefore only possible when access to communication materials (e.g., picture-exchange cards, speech generating devices) can be manipulated. Similar to multiple schedule procedures, times during which the communication materials are unavailable are systematically increased relative to periods in which the material is available and reinforcement is provided immediately. The final method identified in the literature for thinning reinforcement schedules involves requiring the individual to wait an increasing amount of time between the FCR and reinforcement (e.g., Fisher, Thompson, Hagopian, Bowman, & Krug, 2000; Hagopian et al., 1998; Hanley, et al., 2001; Braithwaite & Richdale, 2000; Hagopian, Contrucci-Kuhn, Long, & Rush, 2005; LeBlanc, Hagopian, Marhefka, & Wilke, 2001; Hagopian, Wilson, & Wilder, 2001; Rooker, Jessel, Kurtz, & Hagopian, 2013).

Behaviors that yield delayed reinforcement are highly adaptive in everyday life and tolerance for those delays have been shown to correlate positively to many positive life outcomes (Stromer, McComas, & Rehfeldt, 2000). Although delaying reinforcement is not the most efficient method for behavior change, it can be an effective procedure for maintaining behavior change (Renner, 1964). Research has shown that delayed reinforcement can lead to greater resistance to changes in the environment, such as extinction or satiation (Peterson, 1956). How resistant an FCR is to changes in the environment, such as when a reinforcer is not available or delayed, is an important variable when assessing strength and validity of FCT implementation. Although reinforcement delay is common in the natural environment, and tolerance of delays to reinforcement has been correlated with positive outcomes, an evaluation of FCT interventions has shown limited studies have empirically examined the delay to reinforcement component (Hagopian et al. 2011), and even less empirical research has investigated the specific delay arrangement within FCT. In a large-scale analysis of FCT outcomes, Hagopian et al. (1998) found that only five out of 12 applications of delay to reinforcement procedures used during FCT were clinically successful (e.g. 90% reduction in problem behavior at the terminal delay schedule). Hagopian et al., (2011) later advised that if the goal of an FCT intervention is to sustain appropriate responding and maintain low levels of problem behavior for long delay intervals, the delay to reinforcement approach might not be the most effective option. Recognizing the detrimental effects of delayed reinforcement (i.e., resurgence of challenging behavior) in natural environments without programmed delay training, it is imperative to empirically identify strategies to promote the maintenance of the FCR during FCT when reinforcement is delayed.

As with much of the research in the field of applied behavior analysis, delays to reinforcement procedures have their origin in non-human, animal research. Ferster (1953) found that pigeons maintained normal response rates when delays of up to 1 min were imposed, if the delay duration was gradually increased for each pigeon. However, Ferster and Hammer (1965) found that gradual increases in the delay, from small to larger values, was not a necessary condition for achievement of sustained responding during delays; instead the large delays could be imposed with relatively normal response rates, if large amounts of food were delivered as reinforcement and the behavior was first under control of the relevant stimuli with shorter delays. Newman and Loew (1977) compared the effects of increasing delays to reinforcement progressively over time, decreasing delay values over time, and imposing constant fixed delays to reinforcement. They found that increasing delay values over time led to significantly more resistance to extinction than the other methods. Basic research on self-control has also contributed to the literature on delays to reinforcement, with possible implications for FCT. In a typical self-control procedure, a choice is provided between a small, immediate reinforcer and a larger, delayed reinforcer (Mazur & Logue, 1978). Schweitzer and Sulzer-Azaroff (1988) increased self-control in impulsive children by initially offering both large and small reinforcers immediately and then slowly increasing the delay to the large reinforcers, while keeping the small reinforcer immediate. They found that children continued to display self-control, by selecting the delayed reinforcer over the smaller, immediate reinforcer, as the delay value increased for the larger reinforcer.

Based on basic research, applied researchers have translated similar delay to reinforcement fading procedures during implementation of FCT (Hagopian et al., 1998; Hagopian et al., 2011). Most, if not all, studies investigating delays to reinforcement during FCT have incorporated an increasing delay, or delay fading, procedure where the delay period began with a brief delay (e.g., 5 s delay; Hagopian et al., 2005) and then progressively increased until the terminal criterion was reached. Hagopian et al. increased the delay between FCR and reinforcement for two children with developmental disabilities. For one participant, delays to reinforcement were gradually increased to 60 s, but levels of challenging behavior did not remain consistently low, which necessitated a return to a 15 s delay. Even after a return to a 15 s delay to reinforcement, challenging behavior continued to remain at unacceptable levels and other treatment components were required (e.g., competing stimulus) to achieve clinically successful outcomes. Hagopian, Wilson, and Wilder (2001) also examined the use of reinforcement delay fading procedure during FCT and found that a 10 s delay could only be achieved when noncontingent access (NCR) was included in the treatment package. LeBlanc, Hagopian, Marhefka, and Wilke (2001) investigated the use of increasing delays to reinforcement and found that the highest successful delay value was 5 s. In an attempt to enhance the effectiveness of FCT with extinction, they included NCR with highly preferred toys, which resulted in greater success with the delay procedure. Brainwaite and Richdale (2000) were able to implement delays to reinforcement during FCT for an individual with multiply maintained challenging behavior with no additional treatment components, however their terminal delay was only 5 s. Austin and Tiger (2015), following the recommendation of Hagopian et al. (2005), incorporated access to alternative reinforcers during the delay interval. They found that challenging behaviors were less likely to occur when alternative reinforcers were available during the delay compared to when no alternative reinforcers were provided during the delay.

Although focus has shifted to evaluating additional treatment components within the delay to reinforcement procedures (i.e., Austin & Tiger, 2015) and other schedule thinning procedures (e.g., multiple schedules; e.g., Saini, Miller, & Fisher, 2016), less empirical research and overall attention has been devoted to understanding specific delay arrangement procedures that could lead to increased efficacy and efficiency during FCT implementation. It is possible that specific delay procedures, rather than issues such as delay duration, may have an impact on the behavioral effects during FCT reinforcement thinning (e.g., Lattal, 2010; Pierce, Handford, & Zimmerman, 1972; Stromer, et al., 2000). Therefore, experimental evaluation of reinforcement delay arrangements during FCT reinforcement schedule thinning may lead to more effective and efficient procedures. Empirical evaluation of alternative delay to reinforcement procedures are needed to help identify methods to increase the efficiency FCT.

Few translational studies have examined specific delay procedures and their effect on responding. Hagopian, Toole, Long, Bowman, and Lieving (2004) compared two different methods for thinning alternative reinforcement schedules with three clients who exhibited severe problem behavior. In the dense-to-lean (DTL) condition reinforcement was provided relatively dense initially, followed by systematic schedule thinning to progressively leaner schedules. During the fixed lean (FL) condition, reinforcement was continuously delivered on a lean schedule, which was equivalent to the terminal schedule of the DTL condition. For two of the three cases, the clinical delay goal was attained more rapidly in the FL condition and for the third participant the difference between conditions was marginal. The findings of this study raise questions about whether schedule thinning (i.e. progressive increases in delays to reinforcement) should be involved in treatment versus initiating treatment under the terminal delay schedule from the outset. However, within their limitations, they were not able to determine the processes that underlie the observed differences across the DTL and FL conditions. They go on to suggest future research investigate the use of moderately dense schedules of reinforcement that would potentially engender a level of responding that is tolerable but also results in sufficient contact with extinction. Another study conducted by Betz, Fisher, Roane, Mintz, and Owen (2013) found gradually thinning schedule of reinforcement from dense to lean was not necessary in maintaining clinical outcomes. Betz, et.al. found that by using a multiple schedule for delays to reinforcement, they were able to rapidly switch from a dense schedule of reinforcement to a lean schedule of reinforcement while maintaining low rates of problem behavior and maintained FCR. These studies have translated basic principles of behavior (i.e. schedule thinning and signals) into applied research pertaining to socially important behaviors.

Stromer et al. (2000) reported that the particular arrangement of the delay interval is an important factor that appears to influence response allocation in concurrent schedules of reinforcement. Specifically, Stromer et al. identified evidence that intermittent or partial delays to reinforcement appeared to increase resistance to extinction for responding, whereas constant delays to reinforcement weaken resistance (e.g., Crum, Brown, & Bitterman, 1951). Renner (1964) reviewed the literature on delayed reinforcement and concluded that variable delays to reinforcement lead to increased resistance to extinction the longer the maximum delay and possibly the higher number of delayed trials. However, Renner also reported that the mechanisms involved are far from understood and that it is unclear if it is the variability of the delay, or that the delay is present during only a portion of the trials that lead to this resistance to extinction. Murphy, McSweeney, and Kowal (2007) examined how variability in delay to reinforcement altered reinforcer effectiveness in rats by evaluating within-session changes of lever press responding for alcohol reinforcement after delays to reinforcement were implemented. They found that within-session lever press responding was slower to decline when variable delays to reinforcement were presented versus sessions that produced fixed delays to reinforcement. Bakarich (2014) also found that rates of within-session responding in rats declined more slowly when access to reinforcement was available after a variable delay versus a constant delay. Lattal (2010) reported that additional research on the specific delay interval arrangement, fixed and variable delays, because they have different behavioral effects on responding.

There is a relatively small empirical basis on the behavioral effects of variable delays to reinforcement on human responding (Harris, 1967; Berch, 1970). Within the delay to reinforcement literature, mixed delays have an even smaller empirical literature base. Mixed delays to reinforcement consist of two delay values (i.e. short and long), which are presented with equal probability. Although the two values that make up a mixed delay can vary, the mean of the two values equal the scheduled value. Cicerone (1976) studied preference for constant and mixed delays to reinforcement within four pigeons. The study employed a free-operant procedure in which delay intervals of mixed length were superimposed on the reinforcers scheduled on one response key while delay intervals of a constant length were superimposed on the reinforcers assigned to another concurrently available response key. They examined preference as the delay interval, both mixed and constant, increased across conditions. They examined the preference across a variety of delay intervals and found pigeons preferred mixed over constant delay to reinforcement and preference for mixed delays increased as the interval increased. Rider (1983) extended the literature on preference for mixed delays to reinforcement with rats and found preference for mixed delays in all rats.

Interestingly, they further extended the literature and investigated the effects of different probabilities of the short delay within the mixed delay arrangement and found that 3 out of 5 rats preferred the mixed delay, even when the proportion of small delay (i.e. 0 s) was presented only 10% of the time, with the other 9 of 10 trials being the large delay. All rats preferred the mixed delay when the proportion of small delay was presented only 25% of the time. This study demonstrated the impact intermittent small delays to reinforcement have on maintaining preference and responding.

In addition to the basic findings on preference of mixed delays to reinforcement, few studies have translated these findings to human operant settings. Kohn, Kohn, and Staddon (1992) examined the principle of preference for mixed delays with human subjects. Undergraduate college students were asked to play a video game in which they chose between two buttons that provided reinforcement either on a constant or mixed delay schedule of reinforcement. Within their results, they reported all subjects showed a significant preference for the mixed delay key. Locey, Pietras, and Hackenberg (2009) further bridged the gap between human and nonhuman animal research in delay-based preference and found 3 of 4 participants preferred the mixed delay option. For the fourth participant, no preference was observed. In an effort to replicate the human operant research on preference for mixed delays, a study was conducted by Locey et al. by enlisting five undergraduate students to participate in a computer program that evaluated preference between two concurrently available keys, which had correlating delay values. Preference was evaluated by providing a set of forced choice trials, where participants were exposed to each response key and its corresponding delay value, followed by 20 choice trials. All participants showed a 100% preference for the mixed delay key (1/19 seconds) over a constant delay key (10 s) in the final phases of the study.

The first step in innovation is not to investigate the most complex procedures, or the most complex problems facing the community; instead, it has been suggested that innovation should begin with research at the simplest level (Hake, 1982). Given the evidence from the basic literature, there is preliminary support for the investigation of the use of mixed delays to reinforcement during reinforcement schedule thinning within FCT implementation. However, prior to applied intervention research, it is important to further translate the basic findings and empirically evaluate the parameters necessary for effective implementation.

Purpose of the current study is to expand the empirical research on preference for mixed delays to reinforcement within an applied population. To narrow the gap between basic and applied research, and empirically validate the basic research findings, it is imperative that translational research is conducted and expanded upon. The goal of this study is twofold. One purpose is to replicate findings from previous research with human and nonhuman animals examining preference sensitivity to fixed/constant delays versus mixed delays to reinforcement and provide evidence for the cross-species generality of preference for mixed delays to reinforcement. The second goal of the current study is to extend these findings to children with developmental disabilities and socially important responses within an applied setting. This research will help inform alternative methods for introducing delays to reinforcement within the applied setting and ongoing treatment protocol.

CHAPTER 2

Introduction

Delays to reinforcement can have an adverse effect on appropriate behavior during treatments of challenging behavior (e.g., Functional Communication Training; FCT). In the absence of programmed delay training, the utility and generality of FCT may be limited in many cases. Despite the importance of considering delays to reinforcement during FCT, few studies have empirically isolated the effects of parameters pertaining to the delay. Although research exists showing the effectiveness of various methods of reinforcement schedule thinning during FCT (e.g., multiple schedules; progressively increasing delays), it may be beneficial to explore additional alternative procedures that may lead to successful outcomes. The purpose of this literature synthesis was to investigate the basic behavioral literature pertaining to delays to reinforcement and to explore and identify potential mechanisms and procedures for increasing individuals' tolerance of delays to reinforcement. Results help to identify potential avenues of future research, such as the use of variable or mixed delays in the application of delay to reinforcement in FCT and understand the mechanisms of behavior change.

Method

Systematic Search Procedures

A search of the literature was conducted to identify peer-reviewed, empirical-based studies examining the behavioral effects of variable delays to reinforcement. Several databases were searched including EBSCOHost, PsychINFO, and ScoUT, using variable delay in combination with keywords; reinforcement delay, mixed delay, risk-sensitivity, choice and preference. This initial search revealed 798 studies. After reviewing the titles, 179 studies were identified as relevant and their abstracts were further evaluated. Abstracts were reviewed and 43 studies were identified as potential studies to be reviewed based on the inclusion criteria.

Inclusion Criteria

A study was included based on the following criteria: published in a peer-reviewed journal, preference was the primary dependent variable, variable and fixed delays were reported separate from other measures (e.g., amount), and the average of the fixed and variable delay values were equal. After filtering 43 studies through the inclusion criteria, 22 studies were identified.

Data Extraction

Each included study was summarized in terms of: (a) participants, type of reinforcer, and signal inclusion; (b) dependent variable; (c) delay variable; (d) experimental arrangement; (e) reported results; (f) theory employed; and (g) conclusions provided by the authors regarding their results, including secondary dependent measures (e.g., response rates, latency to response).

Results

Twenty-two empirical articles from eight journals met the criteria for inclusion (results are summarized in Table 1). The 22 studies included articles that spanned two theoretical disciplines including operant (Chelonis, King, Logue, & Tobin, 1994; Cicerone, 1976; Davison, 1969; Herrnstein, 1964; Kohn, Kohn, & Staddon, 1992; Locey, Pietras, & Hackenberg, 2009; Mandell, 1980; McSweeney, Kowal, & Murphy, 2003; Mellon & Shull, 1986; Pubols, 1962; Rider, 1983; and Schrader, & Rachlin, 1976); and behavioral ecology and risk sensitivity theory (i.e., preference for risk or variability in delay, labeled as engaging in risk-prone behavior; Aw, Monteiro, Vasconcelos, & Kacelnik, 2012; Bateson, & Kacelnik, 1995; Case, Nichols, & Fantino, 1995; Craft, 2016; Kirshenbaum, Szalda-Petree, & Haddad, 2000; Kohn, Kohn, & Staddon, 1992; Locey, Pietras, & Hackenberg, 2009; O'Daly, Case, & Fantino, 2006; Orduña & Bouzas, 2004; Orduña, García, & Hong, 2009; Reboreda & Kacelnik, 1991; and Zabludoff, Wecker, & Caraco, 1988).

Study	Participants, R+, Signal presentation	Dependent Measure	Delay Variable	Independent Variable, Experimental Arrangement	Results	Theory	Reported Conclusions
Aw et al. (2011)	12 Starlings Food Yes	Latency Preference	Interval Mixed	M (5/25s) F (5; 10; 15; 20; 25s) Concurrent Chain	All subjects preferred variable delay	Risk Sensitivity; Behavioral Processes	As delay time increased, preference for variable delay increased. Latency shorter in variable delay no-choice
*Bateson & Kacelnik (1995)	6 Starlings Food Yes	Latency Preference	Interval Mixed	M (2.5/60.5s) F (20s) Concurrent Chain	All subjects preferred variable delay	Risk Sensitivity; JEAB	Latency shorter in variable delay no-choice
Case, Nichols, & Fantino (1995)	4 Pigeons Water Yes	Preference	Interval Variable	V (15s) F (15s) Concurrent Chain	3 out of 4 subjects preferred variable delay, 1 subject indifferent	Risk Sensitivity; Energy Budget JEAB	Preference for variability regardless of energy budget manipulation; Responses were faster in a restrictive budget
Chelonis, King, Logue, &	5 Pigeons Food Yes	Preference	Delay Mixed	M (1/9s) F (5s) Concurrent Chain	All subjects preferred variable delay	Operant JEAB	Variable delays may increase self-control; use of multiple values in variable delay may limit its effectiveness

Tobin (1994)							
Cicerone (1976)	6 Pigeons Food Yes/No	Preference	Delay Mixed	M (6/10s; 2/14s) F (0; 8; 16; 32s) Concurrent	All subjects preferred mixed delays	Operant JEAB	Preference for mixed delay increases as range or variability of the delay interval increases
Craft (2015)	10 Rats Food Yes	Latency Preference	Delay Mixed	M (1/3s; 1/19s) F (2s; 10s) Concurrent Chain	All subjects preferred mixed delays	Risk Sensitivity; Animal Behavior	Latency significant longer in fixed option; As delay increased subjects preference for mixed delay increased, especially when reward quality was low
Davison (1969)	5 Pigeons Food Yes	Preference	Interval Mixed	M (15/45s) F (30,10,20,15,25s) Concurrent Chain	All subjects preferred mixed delay	Operant JEAB	Preference for mixed interval, even when fixed interval was lower than arithmic mean (25s), indifferent at (20s)
Herrnstein (1964)	4 Pigeons Food Yes	Preference	Interval Variable	V (15s) F (15s) Concurrent Chain	All subjects preferred variable delay	Operant JEAB	Support for subjects weighing the shorter intervals of VI more heavily
Kirshenbaum, Szalda-Petree, & Haddad (2000)	12 Rats Food Yes	Preference	Interval Variable	V (60s) F (60s) Concurrent	All subjects preferred variable delays in all conditions, except in high-effort and high reward	Risk Sensitivity Behavioral Processes	During high-effort and high amount of food subjects reached satiation and stopped responding

Kohn, Kohn, & Staddon (1992)	30 Humans Symbols Yes/No	Preference	Delay Mixed	M (1/9s) F (5s) Concurrent Chain	All subjects preferred variable delay when no signals were used	Operant Risk sensitivity Behavioral Processes	Humans treat choice and outcome phases as distinct and separate when signals are presented and prefer constant delays
Locey, Pietras, & Hackenberg (2009)	4 Humans Video Clips Yes	Preference	Delay Mixed	M (1/29; 1/59; 1/119s) F (15, 30, 60s) Concurrent Chain	All subjects preferred variable delay	Operant Risk sensitivity Animal Behavior Processes	All participants preferred variable delays with higher distributions of shorter delays
Mandell (1980)	4 Pigeons Food Yes	Preference (response strength)	Interval Variable	V (60s) F (60s) Multiple Schedule Concurrent Chain	Response strength was equal for variable and fixed components; All subjects preferred variable delay in concurrent chain arrangement	Operant JEAB	Control concurrent chain procedure found all subjects significantly preferred variable interval
McSweeney, Kowal,	4 Pigeons Food Yes	Preference	Delay Interval Variable	V (5,15,45,105,225s)	All subject preferred variable delay	Operant Habituation Theory	Preference for variable delay stronger when value is longest (225s), preference for variable

& Murphy (2003)				F (5,15,45,105,225s) Concurrent Chain		Learning and Behavior	delay stronger when interval is used
Mellon & Shull (1986)	5 Pigeons Food Yes	Preference (response strength)	Interval Delay Variable	V (60, 120, 30, 60) F (60, 120, 30, 60 Multiple Schedule	All pigeons had greater response strength in the variable delay components	Operant JEAB	Responding produced by variable delay was more resistant to change (satiation and extinction)
O'Daly, Case, &Fantino (2005)	4 Pigeons Water Yes	Preference	Interval Mixed	M (1s 1/4, 9s 3/4) F (7s) Concurrent Chain	All subjects preferred variable delay	Risk Sensitivity Energy Budget Behavioral Processes	All subjects preferred variable delay in both ample and restrictive energy budgets
Orduña & Bouzas (2004)	4 Pigeons Food Yes	Latency Preference (acceptance)	Delay Variable	V (20s) F (20s) Successive-encounters Procedure	All subjects accepted variable delay option more often than fixed option	Risk Sensitivity Energy Budget Behavioral Processes	Increases in search times and decreases in handling times lead to diminished (indifference) variable delay acceptance
Orduña, García, & Hong (2009)	14 Rats Food Yes	Latency Preference (acceptance)	Delay Variable	V (20s, 50s) F (20s, 50s) Successive-encounters Procedure	All subjects accepted variable delay option more often than fixed option	Risk Sensitivity Behavioral Processes	All subjects had longer latencies to respond and lower response rates in the fixed interval option

Pubols (1962)	18 Rats Food Yes	Preference	Interval Mixed	M (0/10s, 0/30s) F (5s, 15s) Y-Maze	All subjects preferred variable delay	Operant Journal of Comparative and Physiological Psychology	The greater the value of the delay, the more rapid preference for variable delay occurred.
*Reboreda & Kacelnik (1991)	12 Starlings Food Yes	Latency Preference	Delay Mixed	M (3/37.3s) F (15s) Concurrent	All subjects preferred variable delay	Risk Sensitivity Behavioral Ecology	Subjects had shorter latency to peck during the no-choice variable delay condition
Rider (1983)	5 Rats Food Yes	Preference	Delay Mixed	M (.2/30s, .2/60s) F (15s, 30s) Concurrent Chain	All subjects preferred variable delay	Operant JEAB	Preference for mixed delays increased sharply as proportion of small delays increased from 0 to .1 and .25
Schrader & Rachlin (1976)	4 Pigeons Food Yes/No	Preference	Interval Variable	V (30s) F (30s) Concurrent Chain	All subjects preferred variable delay	Operant Bulletin of the Psychometric Society	Signal presentation did not impact preferences; decreases in variable delay interval lead to decreased preference for variable delay
Zabludoff, Wecker, & Caraco (1988))	4 Rats Food Yes	Preference	Delay Mixed	M (1s /(2t- 1)s) F (t= 5, 10, 25, 50, 25, 10, 5) Concurrent Chain	All subjects preferred the variable delay over the constant delay, strength of preference increased as the	Risk Sensitivity Energy budget Behavioral Processes	All Subjects preferred constant delay when the interval was 5 and10s, shifted to variable preference with 25 and 50s intervals, finally indifferent during last condition of 10/5 seconds

mean delay
increased

Table 1.

Note: R+, Reinforcer; Latency, Latency to respond in no-choice trial arrangements; Preference, Proportion of responses indicating choice/preference in simultaneous choice arrangements; Interval, response required after delay requirement met to deliver reinforcer; Delay, response initiates delay period and reinforcement is provided when the delay is completed- no response required; Bold number, arithmetic average mean; * denote studies that used alternative form of arithmic mean, Expectation of Ratios (EoR).

Subjects, Reinforcers, and Signals

Subjects. Among the 22 studies, 14 used birds (N= 49), six used rats (N= 63), and two used human subjects (N=34).

Type of Reinforcer. Seventeen studies used food (i.e., grain pellets) as reinforcement and two studies used water (O'Daly et al., 2006; Case et al., 1995). Studies that were conducted with human participants used preferred video clips (identified via preference assessment; Locey et al., 2009) and symbols on a screen (conditioned negative reinforcement; Kohn et al., 1992). The amount of reinforcement varied slightly among studies, which ranged from two pellets or two seconds of access to a food hopper to six pellets/seconds access to food hopper. However, the amount provided among each condition was held constant to control for the effects of the different delay variables on preference.

Signals. All studies used signals in one or more conditions. Signals were used to differentiate the initial and terminal links of the chained schedules, the different choice options within the two components of the multiple schedules, and the components (i.e., search, choice, and handling states) of the successive encounters procedures. The majority of studies included a signal change during the delay period, with the signal lasting until reinforcement was delivered. Cicerone (1976) initially did not include signals, however after preference between the two delay values was not identifiable, further conditions included continuous house lights contingent on responding to the fixed delay key and flickering house lights contingent on responding to the variable delay key, which were counterbalanced across the four subjects. Kohn et al. (1992) initially (i.e., experiment 1-3) used descriptive signals on the computer screen to allow the participants discriminate phases (e.g., choice, delay, or reinforcement phase). In an attempt to reconcile the similarities between the basic and translational research, they conducted a final experiment, which omitted any signals or prompts that segmented the phases of the procedure. Schrader et al. (1976) compared the effects of signaling reinforcement on the preferences for two schedules of reinforcement (i.e., fixed versus variable delay). For half the group of pigeons, they received response-independent signals (i.e., key color change) during the terminal link, which estimated differences in reinforcer predictability across the two groups.

Experimental Arrangement.

The majority of studies used a concurrent chain procedure to evaluate subject preferences between the two schedules of reinforcement. However, other procedures have been used to evaluate preference, and a brief description will be provided. Additionally, the dependent variable measurement system for evaluating preference under each procedure is discussed below.

Concurrent arrangement. Cicerone (1976) used a free-operant procedure in which delay intervals of mixed length were superimposed on the reinforcers scheduled on one response key while delay intervals of constant length were superimposed on the reinforcers assigned to another, concurrently available, response key. Kirshenbaum et al. (2000) used a runningwheel apparatus to assess choice responding across two, concurrently available, schedules of reinforcement. Subjects were placed in a box, which allowed them equal access to two adjacent single-wheels, and detection in one wheel led to the other wheel became inactive until the schedule requirement was met and reinforcement was obtained. Reboreda et al. (1991) also used a concurrent arrangement where an initial choice response led to either a constant or variable delay, depending on their initial peck. Within a concurrent schedule of reinforcement procedure, preference was assessed by proportion of responses to the variable key over total responses to both the variable and fixed delay keys.

Concurrent chain. 15 of 22 studies used a concurrent chain procedure to evaluate choice between two schedules of reinforcement. A concurrent chain schedule of reinforcement has been shown to be a useful design tool for studying preference (Autor, 1960). In a concurrent chained schedule, two initial-link schedules of reinforcement (i.e., variable-interval [VI]) are in place with two response options (i.e., keys) and responding is free between them. When a subject responds on one key, the alternative key's light is extinguished and further responding on that key has no consequences. After initial responding on the choice key, a terminal schedule of reinforcement link is presented. In the current synthesis, the terminal links are represented by either the fixed or variable delay options. Studies have shown that responding during initial links of a concurrent chained schedule are dictated by preference for that schedule's terminal link. All studies included used equal initial link schedules, such as a fixed response (FR1; i.e., Bateson et al., 1995; Aw et al., 2011) or VI-90 s (i.e., Case et al., 1995) and VI-30 s (i.e., Chelonis et al., 1994). In the studies that used a concurrent chain procedure, preference was calculated by dividing the number of responses to the initial link of the chained schedule associated with the variable delay terminal link by the number of total initial-link responses on both variable and fixed delay keys. This proportion was then averaged and preference greater than 0.5 indicated that the subject significantly preferred the variable option and a value less than 0.5 represented preference for the alternative, constant option. In addition, some studies reported conditions where a subject was indifferent to the choice with an average proportion value of 0.5 (Davison, 1969; Orduña, et al., 2009; Zabludoff, et al., 1988).

Multiple Schedule. Mandell (1980) used two types of multiple schedules to assess response strength, or preference, in pigeons. First, in experiment 1 Mandell used a two-component multiple schedule procedure. The two components multiple schedule consisted of one component (i.e., fixed interval 60 s) signaled by the illumination of the red left key, and another component (i.e., variable interval 60 s) signaled by the illumination of the green right key. The different components were changed regularly. For experiment 3, experimenters wanted evaluate procedures similar to the concurrent chained schedules, and therefore included two link chain schedules within each multiple schedule component arrangement. In the multiple chained schedule procedure, 20 s initial link schedules were assigned to both components; thus, the only difference between the two multiple schedule components was their respective terminal link schedules. Similar to the previous experiment, terminal link responses on one component led to fixed intervals and terminal link responses on the other lead to variable intervals. Mellon et al. (1986) sought to replicate and extend the findings of Mandell (1980)'s experiment 3, by using the same multiple chained procedures. In a multiple schedule arrangement response strength, or resistance to extinction or satiation, represent indices of preference. Within multiple schedules, after baseline responding stabilized across both components, tests of resistance to disruption were initiated and response rates in each component were evaluated. Therefore, the schedule component (e.g., variable or fixed delay) associated with smaller decreases in response rate, when extinction or noncontingent food (i.e., satiation) was implemented, is considered to be the more preferred, or 'valued' component (Mandell, 1980). Previous research by Nevin (1979) found that conditions that produce stronger, or more resistant, behavior are also associated with greater degrees of preference in concurrent-chain procedures.

Successive encounter. Although concurrent chained schedules of reinforcement are typically used in the operant behavioral research to assess preference, successive encounter procedures have been used in the behavioral ecology literature (Lea, 1979). Successive encounters procedure involves progression through three states. The session started with a search state, onset of the house lights and presentation of an illuminated left lever. After a schedule of reinforcement was completed (i.e., FI 5 s), the choice state was initiated. During the choice state, either a red or green light stimulus was presented, which was correlated with the variable and fixed delay values, respectively. The subject was then able to accept the presented delay value (i.e., fixed or variable) by responding on a fixed ratio 3 (FR3) schedule of reinforcement on the left lever and consequently enter the next phase (i.e., handling state). If the subject rejected the presented delay value they could respond on the right lever on an FR3 schedule, or stop responding for 120 s, and be returned to the previous phase (i.e., choice state) and were presented with another choice. If the subject accepted the delay value they entered the handling state for the chosen delay value and completed the delay schedule (i.e., variable or fixed delay) and received reinforcement. After reinforcement was provided, a return to the search state was started (i.e., FI 5 s). In the successive encounters procedure the dependent variable of interest is preference for the two schedules of reinforcement presented in the final handling state, which was measured by the proportion of accepted the variable delay options over the total number of variable delay presentations in the choice state. In studies that have examined choice in successive encounter arrangements, they have found that when a small delay is alternative to a large delay, subject reject the large delay and accept the small delay more often.

Independent Variable and Reported Results.

Fixed delay/variable delay. Four studies evaluated preference for time-based, fixed, and variable delays to reinforcement (i.e., McSweeney et al., 2003; Mellon et al., 1986; Orduña et al., 2009; Orduña et al., 2009). A time-based delay is a schedule of reinforcement that does not require a response, following an initial delay-inducing response, to access reinforcement. Therefore, when the subject responded, the delay was initiated and after the delay period had elapsed no further responding was required to access reinforcement. With this delay procedure, the actual or obtained delays are longer than interval delay arrangement, where there is a requirement of responding (i.e., FR1) to access reinforcement after the delay interval. McSweeney et al. (2003) evaluated the preference for variable and fixed delays across a variety of values (e.g., 5, 15, 45, 105, and 222 s) across sequential conditions. They found that variability in delay was preferred for all subjects and preference for delay was strongest during conditions with the longest delay value (i.e., 225s). Mellon et al. (1986) used a multiple chained procedure to evaluate the preferences (i.e., response strength) between delay arrangements and found that all subjects response rate was higher, and more resistant to extinction and satiation, in the variable delay component. Within the successive encounters procedure, Orduña et al. (2004) presented an initial search time (e.g., FI 10 s) and a choice to accept or reject either (a) fixed delay 20 s or (b) variable delay 20 s and found that subjects accepted the variable delay option with a probability of 1 (i.e., always accepted). In additional conditions, Orduña et al. systematically increased and decreased the handling state (i.e., delay values) and found that preference for variability was slightly diminished by two factors: increased search time (i.e., the initial schedule component) and decreased handling time (i.e., smaller delay values). Orduña et al. (2009) observed similar results with the successive encounters procedure with rats and found that they also preferred, calculated by proportion of acceptance, the variable delay. In their study, the subject's probability of accepting the variable delay, both when the delay values were 20 and 50 s, was calculated as .96-.99, compared to the probability to accept the fixed delay was .52-.54 in both delay value conditions. Secondarily, Orduña, García, and Hong evaluated latency to respond during choice states, as a measure of preference and found that response latencies were shorter (i.e., subjects responded quicker) during choice of variable delays.

Fixed delay/mixed delay. Eight studies evaluated the preferences for time-based, fixed and mixed delays to reinforcement (i.e., Chelonis et al., 1994; Cicerone, 1976; Craft, 2015; Kohn et al., 1992; Locey et al., 2009; Rider, 1983; Zabludoff et al., 1988; Reboreda et al., 1991). Mixed delay arrangements entail the use of a bi-valued delay. Thus, a mixed schedule is represented by two, equiprobable values, which represent a high and low value, whose mean is the schedule delay value. Variable delays are distinct from mixed delays in that variable delays consist of a range of values that average the determined schedule value, whereas mixed delays involve two values. In Condition 1, Chelonis et al. (1994) found that pigeons showed significant preference for a mixed delay of equally occurring 1 s and 9 s delays (i.e., mixed delay 5 s) over a fixed delay with an equal mean (5 s). Cicerone (1976) evaluated different conditions of mixed delay intervals that differed in interval variability across conditions. Specifically, in one condition pigeons chose between a mixed delay key (6 & 10 s) and a fixed delay key (8 s), and in another condition they chose between a mixed delay key (2 & 14 s) and a fixed delay key (8 s). Cicerone found that preference for the mixed delay existed across both mixed delay conditions with all subjects. Cicerone found stronger preference for the mixed delay condition with the greater variability (i.e., 2 & 14 s). Craft (2015) included two conditions that evaluated preference for variability, by utilizing a short mixed delay (1 & 3 s) and long mixed delay values (1 & 9 s). Craft found that as the fixed and mixed delays increased, from a mean of 2 to 10 s, subject's preference for the mixed delay also increased. Locey et al. (2009) also examined preference for variability among three different mixed delay values across different conditions (15, 30, & 60 s) and found that 3 of 4 subjects preferred mixed delays, with preference increasing for the higher delay values. Zabludoff et al., (1988) found that the expected present value of a given reward increases as the variance around the arithmetic mean delay increases. He found that when the delay value was small (e.g., 5 s) preference for the constant delay option was more paramount. However, as the delay value increased, preference shifted towards the variable delay, which was upheld when experimenters subsequently decreased the delay value in subsequent sessions. They concluded that subjects were less inclined to choose the constant option as the delay interval increased, and this preference, once established, continued to persist when delay values decreased again. Rider (1983) is the only study that specifically manipulated the proportion of long and short values within the mixed delay arrangement. Rider examined preference across different proportions of the short/long mixed delay values across a variety of conditions. The conditions comprised proportion of short (0.2 s) over long (30 s & 60 s) values and included 0, 0.1, 0.25, 0.5, 0.75, 0.9, and 1. For example, in one condition (i.e., 1) the fixed delay was 15 s and the mixed delay value was always 0.2 s. However, in a different condition (i.e., 0.5), the fixed delay was 15 s, and the mixed delay values consisted of 0.2 s and 30 s, presented with equal probability. Preference for mixed delays increased sharply as proportion of small delays increased from 0 to 0.1 and 0.25. Kohn et al. (1992) conducted three experiments to evaluate preference of mixed vs. fixed delays to conditioned reinforcement (e.g., symbols on a screen) with human participants playing a simple computer game. Subjects chose between two buttons on a computer screen that provided reinforcement either on a fixed or variable interval schedule. In Experiments 2 and 3, they used signals to indicate different phases of the procedure, including the choice, delay, and reinforcement phases. The results showed that all participants preferred the constant or fixed delay alternative that consisted of a 5 s delay to symbols on a computer screen over the mixed delay of equally probable values of 1 s and 9 s delays. Due to this discrepancy between their results and previous studies from the basic literature, they explored conditions more analogous to previous basic studies. In experiment 4, they omitted all prompts and signals that segmented the phases of the procedure. The results of the final experiment showed that without the use of identifiable phases, all subjects significantly preferred the variable delay option. Reboreda et al. (1991) found all subjects preferred mixed delays (3 & 37.3 s) to fixed delays (15 s).

Fixed interval/ variable interval. Seven studies used an interval delay to reinforcement procedure, in which a response was required following completion of the delay requirement to access reinforcement (i.e., Case et al., 1995; Herrnstein, 1964; Kirshenbaum et al., 2000; Mandell, 1980; McSweeney et al., 2003; Mellon et al., 1986; Schrader et al., 1976). Mandell (1980) used a multiple schedule arrangement to evaluate the effects of fixed and variable delays on response strength within each component. Mandell found no differences in response strength when resistance to change procedures were applied to each component. However, in a control condition, which used a concurrent chain procedure with the same delay values used in the multiple chain procedure, Mandell found all pigeons significantly preferred variable option by allocating 90% of responding to the VI initial link. Case et al. (1995) found only 3 out of 4 pigeons strongly preferred the VI 15 s to an alternative fixed interval (FI). Herrnstein (1964) found all subjects preferred VI 15 s to an alternative FI 15 s. Kirshenbaum et al. (2000) evaluated preference between a VI 60 s and FI 60 s and found all subjects preferred the VI schedule. Schrader et al. (1976) evaluated preference for variability and found all subjects preferred the VI 30 s schedule of reinforcement relative to the FI 30 s schedule. Schrader also examined the effects of different delay values on preference, and found that among 4 conditions, with delay values of 30, 15, 6 s and 2.5 minutes, subjects increasingly preferred the variable delays as the delay value increased. Schrader et al. also evaluated the use of signal presentation, in which half the subjects received a signal (i.e., key light change) prior to reinforcement, and they did not find any difference in preferences for VI schedules across the two groups.

Fixed interval/ mixed interval. Five studies evaluated an interval delay procedure to identify preference for fixed or mixed interval delays to reinforcement (i.e., Aw et al., 2011; Bateson et al., 1995; Davison, 1969; O'Daly et al., 2005; Pubols, 1962). Aw et al. (2011) evaluated different fixed intervals (5, 10, 15, 20, & 25 s) across conditions as an alternative to a mixed interval (5 & 25 s) in a concurrent chain procedure. Aw et al. found all subjects preferred the mixed interval schedule and found preference for the mixed interval schedule increased across conditions as the FI value increased. Bateson and Kacelnik (1995) evaluated the preference for mixed interval (2.5 & 60.5 s) versus FI 20 s in a concurrent chain procedure and found all subjects highly preferred the mixed interval schedule. Davison (1969) examined differences in preference between different FI (i.e., 30, 10, 20, 15, 25 s) across conditions to a mixed interval (15 & 45 s) and found that all subjects preferred the mixed interval schedule in conditions where the FI schedule value was 25 s and 30 s. If the FI value was 20 s, pigeons were indifferent between choices of the mixed interval and FI. O'Daly et al. (2005) evaluated the preference for a mixed interval schedule, in which the two values presented on the mixed interval key was arranged with one value (i.e., 1 s) presented 1/4th of the occasions and the other value (i.e., 9 s) was presented 3/4th of the time and found subjects preferred the mixed interval to the FI 7 s schedule. Pubols (1962) evaluated preference within a concurrent schedule with mixed interval schedule of reinforcement on the left key with equiprobable 0 s or 10 s delays and a FI 5 s on the right key. All subjects preferred the mixed interval schedule option. Pubols provided evidence that preference for mixed delays increased when larger delay values (e.g., 5 s to 15 s) were introduced; Pubols found preferences developed more rapidly in the condition of increased delay value (i.e., 15 s).

Latency. A secondary dependent variable, latency to respond, was measured in six studies (Aw et al., 2012; Bateson, & Kacelnik, 1995; and Craft, 2016; Orduña, et al., 2009; Orduña, et al., 2004; Reboreda & Kacelnik, 1991). Latency to responding during no-choice trials was measured as a secondary variable of preference and was used to predict preference in which multiple alternatives (i.e., fixed and variable delays) were available sequentially, but not concurrently. The six studies that evaluated latency to respond drew upon the Sequential Choice Model (SCM; Kacelnik, A., & Bateson, 1996), which is based on the theory that when certain options are encountered, subjects respond faster (i.e., shorter latencies) for most preferred options. Consequently, latencies to respond to less preferred options would be longer. All six studies that evaluated latency, found increased latencies (i.e., subjects took longer to respond) during the fixed delay conditions over latencies to respond to mixed and variable delays to reinforcement (Aw et al., 2012; Bateson, & Kacelnik, 1995; Craft, 2016; Orduña, et al., 2009; Orduña, et al., 2004; and Reboreda & Kacelnik, 1991).

Discussion

The relation between experimental and applied behavior analysis has resulted in an increase in research extending basic laboratory derived principles to naturally occurring human behavior (Martens, Lochner, & Kelly, 1992). As the literature pertaining to FCT continues to be extended, aspects of the procedures, such as programming for tolerance of delays to reinforcement, warrant further attention. Despite the clinical need for successful reinforcement schedule thinning procedures within FCT, Hagopian et al. (2011) reported that only 29% (i.e., 19 out of 76) of FCT studies published between 1985 and 2009, included a description of a schedule-thinning phase or procedure. As applied behavior analysis becomes more integrated within a wide variety of disciplines, the need for empirically validated procedures that lead to successful treatment is paramount. Thus, it may be of value for applied researchers to translate findings from the experimental analysis of behavior literature to assist in the identification of effective technologies that may work to solve many applied problems. Based on the results of the current synthesis, empirical evaluation of the parameters of the specific delay arrangement may be a worthwhile endeavor. The primary aim of the current synthesis was to assist in the bridging of the gap between findings from the basic research (i.e., preference for variable and mixed delays to reinforcement) and development of potential translational and applied research agendas.

Twenty-two studies were reviewed. A common factor among all included articles was the demonstration that all subjects preferred variable or constant delays to reinforcement relative to fixed delay alternatives. All studies had common characteristics including design, participants, use of signals, independent and dependent measures, and reported findings; however, the procedures of implementation (i.e., delay variable, experimental arrangement) differed among the included studies and yet, the results were all similar.

Given the clear finding across basic studies that strong preference exists for variability in delays to reinforcement, future translational and applied research should examine the effects of variable and mixed schedules of delayed reinforcement on different types of operant behavior in both human and nonhuman participants. Within the current synthesis, only two studies evaluated preference for variable delays among human participants (Kohn et al., 1992;

Locey et al., 2009). Within these studies, preferences for variable delays to reinforcement, although attained for each study, were less clear (i.e., under some conditions, participants preferred fixed delays). This presents an opportunity for future research to expand on the basic preference literature and develop translational studies to address the differences across non-human and human studies; including the use of signals when variable or mixed delays to reinforcement are implemented. Additionally, no studies have examined preference between two different delay schedules with children or individuals with developmental disabilities. Future research should evaluate similar choice paradigms as those identified in the current review, and expand them to include clinically relevant participants. In understanding how different behavioral mechanisms (i.e., variable, mixed, and fixed schedules of delayed reinforcement) effect the behavior of different populations will help progress the field forward, and decrease the dependence on default technologies (e.g., train and hope methodology; Stokes & Baer, 1978).

Within applied research, the important and relevant topic of schedule thinning during treatments of challenging behavior may provide an impetus for evaluating the effects of variable or mixed delay procedures on maintaining low levels of challenging behavior and sustained appropriate responding while increasing delays to reinforcement values. The exploration and evaluation of alternative schedule thinning procedures, such as the use of mixed or variable delays, could lead to more efficient procedures to increase tolerance of increasing delays to reinforcement. Within mixed delays to reinforcement, when a response is emitted, reinforcement is provided after an equiprobable presentation of a small (i.e., 10 s) or large (i.e., 5 minute) delay. For example, in a typical delay fading procedure, the delay value is increased progressively in steps of larger and larger values. Occasionally, the implementer will probe a larger delay value and assess the effects on sustained appropriate responding and changes in challenging behavior. This procedure, which requires careful implementation and, often, clinical intuition, can be time consuming and ultimately progression to higher delay values may not be reached (Hagopian et al., 2011). Mixed delays may offer an alternative to this typical delay thinning procedure via the provision of reinforcement following both short (i.e., 10 s) and long delays (5 min) for appropriate responding within the same session.

The current synthesis only examined choice between two, already delayed, response-dependent schedules of reinforcement. However, issues of reinforcement schedule thinning (i.e., decreasing rate of reinforcement) are common for many behavior reduction procedures and the results of the current synthesis could provide insight into possible application. For example, noncontingent reinforcement (NCR) is a treatment for challenging behavior, in which the functional reinforcer is provided independent of responding according to a predetermined schedule of reinforcement. NCR procedures provide reinforcement on time-based schedules, in which access to the functional reinforcer (a) reduces the motivation for that specific reinforcer, leading to decreases in challenging behavior maintained by that reinforcer and (b) extinguishes the functional relationship between the challenging behavior and access to the reinforcer. Typically, NCR and similar behavior reduction interventions initially employ dense schedules of reinforcement by providing reinforcement (e.g., escape from task demands, access to preferred item) frequently and consistently (Hagopian, Toole, Long, Bowman, & Lieving, 2004). Only after initial decreases in challenging behavior, rates of reinforcement are typically reduced by transitioning to a leaner schedule of reinforcement (i.e., reinforcement schedule thinning; Tiger et al. 2008). Fixed-time (FT) schedules are most commonly used (Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993) in NCR treatments. However, a small research base on the use of variable-time (VT) schedules have emerged (Camp, Lerman, Kelley, Contrucci, & Vorndran, 2000; Carr, Kellum, & Chong, 2001). Van

Camp et al. and Carr et al. evaluated VT and FT schedules of reinforcement during NCR and found no differences in behavior change across the two schedules. Van Camp et al. employed a schedule thinning procedure, and found that both schedules (i.e., FT and VT) were equally effective in reducing problem behavior. More recently, Pinar (2015) evaluated the effectiveness of VT and FT on increasing on-task behavior and decreasing problem behavior for children with and without disabilities. Although the authors found that both schedules of reinforcement resulted in decreased problem behavior and increased on-task behavior, they reported that within the VT schedule, gains were noted to be faster and more consistent. Additionally, they reported that teachers who implemented the intervention performed the VT schedule more easily than the FT schedule. They reported that providing reinforcement at fixed times limited their teaching ability and got in the way of lessons, whereas under the VT condition, they were allowed more freedom when presenting the functional reinforcer (e.g., attention). Despite the emerging evidence that variable schedules of delayed reinforcement may have similar, or more beneficial behavioral outcomes to fixed schedules, they have yet to be systematically evaluated; and no studies have evaluated the effects of mixed delays. Future research should investigate the use of both mixed and variable delays within behavior reduction procedures (e.g., NCR) and evaluate the effects on both appropriate and challenging behavior.

A second implication derived from the results of the synthesis pertains to the use of mixed delays to reinforcement during the schedule thinning process in response-dependent behavior reduction treatments, such as FCT when large delay values are required. It is imperative that future research continues to develop new technologies to increase the efficiency of thinning reinforcement rate, while sustaining appropriate communication and decreases in challenging behavior (Hagopian et al., 2011). A common issue that arises, when larger delays to reinforcement are programmed for appropriate responding, is the recurrence (e.g., resurgence) of challenging behavior and the decrease of appropriate communication (Volkert et al., 2008; Hagopian et al., 2011). The results of the synthesis showed subjects' preference for the variable or mixed delays increased as the delay value increased (Cicerone, 1976; Awe et al., 2011; Craft, 2015; Davison, 1969; McSweeney et al., 2003; Pubols, 1962). These findings provide preliminary evidence that alternative procedures may be beneficial when increasingly longer delays to reinforcement are implemented. For example, Rider (1983) found that preference for mixed delays increased and shifted from fixed delays, when the proportion of small (e.g., 0.2 s) to large delays (e.g., 60 s) was 0.1 (e.g., small delay presented one out of 10 responses, all other responses to mixed delay key led to large delays). This tendency for subjects to allocate their responding to the schedule of reinforcement that provides, albeit relatively infrequent, short delays to reinforcement, provides support for future systematic evaluations of reinforcement schedule thinning procedures that include mixed delays to reinforcement.

In addition to evaluating the effects of variable and mixed delays during treatments of challenging behavior, studies by Logan (1960) and Mazur (1984) have shown that mixed delays to reinforcement maintained higher levels of responding compared to fixed delays. An area of future research should examine the mechanisms responsible for maintenance of responding during changes in environment (i.e., delays to reinforcement). Specifically, evaluation of mixed delays on skill maintenance among individuals with developmental disabilities. Maintenance of acquired skills is a long-standing concern for both researchers and clinicians (Stokes & Baer, 1977). Progress towards creating a technology to promote maintenance of skill has evolved from the primary use of the 'train and hope method' (Stokes et al., 1977) to antecedent strategies (e.g. multiple exemplar training). However, new and old principles need to be continually evaluated to ensure that this progress continues. Due to the importance of skill maintenance, future research should examine how variable and mixed delays can increase effective maintenance of clinically relevant responding.

Although the applied implications of the synthesis provide recommendations for the evaluation of variable and mixed delays to reinforcement during scheduling thinning and response maintenance, potential translational research on the effects of mixed and variable delays to reinforcement is also recommended. To better understand how mixed delays to reinforcement can contribute to effective treatment procedures, simple translational research on the effects of mixed delay schedules of reinforcement may be of value; future studies need to further examine the effects on operant responding. Currently, the behavioral effects of variable, and to a much lesser degree mixed, delays make up a sparse area of the literature, both basic and applied. The literature on variable delays to reinforcement on operant responding include effects on response acquisition (van Haaren, 1992), speed of responding (Logan, Beier, & Ellis, 1955), probability and discrimination learning (Toppling &Parker, 1970; Berch, 1970), impulsive action (Hayton, Maracle, & Olmstead, 2012), stimulus control within multiple schedules (Richards & Marcattilio, 1978), and resistance to extinction (Peterson, 1956; Logan et al., 1956; Wilke & Kintsch, 1959). Therefore, the impetus to further explore the behavioral effects of variable and mixed schedules of delayed reinforcement is available, but the comprehensive understanding of these effects and the possible application are still unknown.

Limitations

The current synthesis is limited by the selection of the primary dependent measure (i.e. preference). The intention of the synthesis was to identify basic behavioral principles in hopes of translation to applied problems. Preference for variability in delayed reinforcement was examined due to the potential for application within treatments of challenging behavior (i.e., NCR, FCT). Therefore, the current synthesis' limitations include narrow dependent measures of the behavioral effects of variable and mixed delays to reinforcement. Future reviews might include studies that examine other effects of variable or mixed delays to reinforcement.

Conclusions

In summary, the results of the current synthesis show a potential springboard for translational and applied researchers in terms of utilizing variable or mixed delays to reinforcement. In terms of the current synthesis, the simplest level refers to the behavioral effects variable or mixed delays have on a variety of operant responding. Specifically, the possible contribution of mixed delays to reinforcement implemented during the reinforcement schedule thinning phases of FCT. Additionally, recommendations were made for future research to explore the use of mixed delays to reinforcement in both translational and applied application, in terms of overall schedule thinning techniques (i.e., response independent and response dependent). Due to the everyday importance of tolerance, and maintenance of responding, during delays to reinforcement, procedures that seek to sustain appropriate responding during delays are paramount. The current synthesis sought to identify potential procedures to progress the field of behavior analysis forward, and to identify new technologies from the basic literature.

CHAPTER 3

Participants

Participants were recruited from schools and clinics in the Central Texas area.
Inclusion criteria for participation included diagnosis of a developmental disability. Exclusion criteria for participation included independence with a pre-treatment, match-to-sample assessment. A total of four participants met the inclusion and exclusion criteria and were included in the study.

Table 2 displays participant characteristics including, pseudonym, gender, age at time of study, diagnosis (as reported by parents), and CARS-2 assessment scores for each participant. Brandon was a 10-year-old male diagnosed with autism. Brandon engaged in age-appropriate communication and was able to communicate effectively with people in his environment. Brandon scored a 27 on the CARS-2 assessment (conducted by one of his therapists), which placed him in the minimal range of autism symptoms. Clark was an 8-year-old male diagnosed with autism. Clark engaged in age-appropriate communication and was able to communicate effectively with people in his environment. Clark scored a 25.5 on the CARS-2 assessment (conducted by one of his therapists), which placed him in the minimal range of autism symptoms. Lane was a 9-year-old male diagnosed with autism. Lane engaged in age-appropriate communication and was able to communicate effectively with people in his environment. Lane scored a 30 on the CARS-2 assessment (conducted by one of his therapists), which placed him in the mild/moderate range of autism symptoms. Eike was a 7-year-old male diagnosed with autism. Eike engaged in 2-3 word sentences and was able to communicate effectively with people in his environment. Eike scored a 38.5 on the CARS-2 assessment (conducted by one of his therapists), which placed him in the severe range of autism symptoms.

Participant	Gender	Age	Diagnosis	CARS-2 Score
Brandon	Male	10	Autism	27 Minimal
Clark	Male	8	Autism	25.5 Minimal
Lane	Male	9	Autism	30 Mild/Moderate
Eike	Male	7	Autism	38.5 Severe

Table 2. Participant Characteristics

Materials and Setting

The experiment was conducted in a quiet room in the participant's school or home. The materials used included two microswitch buttons with discriminative stimuli (i.e. colors and shapes), which corresponded to the different schedules of delayed reinforcement (e.g., mixed and fixed). In addition to the microswitches, an iPad with a visual countdown timer was utilized during the experiment.

Interobserver Agreement

A trained observer independently scored 100% of all sessions for each participant. Interobserver agreement (IOA) was collected for the free choice trial sessions by using a paper and pencil, trial---by---trial method. Specifically, agreements and disagreements were determined for each trial. The total number of agreements was divided by the total number of trials and the resulting number was multiplied by 100. The mean IOA for the dependent variable, choice, was calculated for each participant and 100% agreement was found.

Data Collection

All sessions were video recorded using a handheld device for subsequent data collection. The experimenter and independent observers used paper and pencil to collect data on forced and free choice responding.

Experimental Design

The current investigation examined choice responding using a concurrent schedule design (Harding et al., 1999), with allocation of responding evaluated across the two schedules of delayed reinforcement.

Pre-Experimental Procedures

Preference Assessment

Free Operant preference assessments (Roane et al., 1998) were used with each participant to identify a preferred item to be used during the experimental conditions. For Brandon, a variety of items were selected to be included in the experimental condition; however, following the forced choice condition, Brandon independently requested access to the school swing. Therefore the selected reinforcer for Brandon for the free choice condition was the swing. Researchers observed continued responding, which demonstrated the swing as a functional reinforcer for Brandon. For Clark, a free operant preference assessment was used and identified silly putty as a high preferred reinforcer. However, the following day when the forced choice condition was implemented, Clark had brought trucks to school and requested access; therefore, trucks were utilized in combination with the items identified during the free operant preferences assessment during the experimental conditions. Logan engaged with iPad games for the entire duration of the free operant preference assessment; therefore, iPad games were utilized during the experimental conditions. Eike engaged with iPad games for the entire duration of free operant preference assessment; therefore, iPad games were utilized during the experimental conditions.

Match-to-sample Assessment

All participants engaged in a pre-experimental assessment to ensure match-to-sample skills were in their repertoire. Each participant immediately engaged in the required independent responding with the match to sample task.

Experimental Procedure

Forced Choice Trials

A trial in the forced choice condition consisted of first programming a specific establishing operation (EO; e.g., preferred item was removed) and one microswitch was presented, depending on the specific delay programmed for that trial. After the participant compressed the button, the button was removed and an iPad with a visual countdown timer was presented, out of reach, for the duration of the delay. Following the delay, the iPad-based timer was removed and 30 s of reinforcement was provided. Following the 30-s reinforcement interval, the preferred item was removed and a new trial was initiated.

Prior to choice trials, each button corresponding with its programmed delay schedule of reinforcement (i.e., mixed and fixed) was presented in isolation for a total of 8 trials. To ensure the participant was exposed to each possible delay duration, 4 trials of each delay value were presented consecutively, followed by 4 trials of the alternative delay value. This procedure was repeated until the participant had been exposed to 8 total trials under the mixed delay and 8 total trials under the fixed delay. With the mixed delay condition, a counterbalanced coin flip procedure determined the order of the short (1 s) or long (29 s) delay presentation. Because the fixed delay was constant (i.e., 15 s), counterbalancing was not implemented in that condition. After a total of 16 forced choice trials were completed, the free choice phase was initiated. The forced choice phase continued to occur if, based on visual analysis of the data, no preference for a delay value has emerged after 20 *free choice* trials had been implemented.

Free Choice Trials

A trial in the free choice condition consisted of first programming a specific EO (e.g., preferred item was removed) and both microswitches were presented. The experimenter initially provided a prompt (i.e., "pick one"); however after two trials this vocal prompt was faded. If the participant did not choose a microswitch within 3-5 s, the microswitches would have been removed and the trial would have been re-initiated; however, this did not occur. If the participant engaged in pressing both buttons simultaneously, the buttons would have been removed and the trial would have been re-initiated; this also did not occur. After the participant compressed one microswitch, the other microswitch was removed and the iPad with the visual countdown timer was presented, out of reach, for the duration of the delay. Following the delay, the iPad timer and microswitch were removed and 30 s of reinforcement was provided. Following the 30-s reinforcement interval, the preferred item was removed and a new trial was initiated.

During the delay, attention and preferred items were restricted and challenging behavior was ignored. When the delay was completed, an auditory signal designated the delay had ended and access to attention and the previously identified preferred item was available for 30 s. Across choice trials, the positions of the microswitches were randomly alternated to discern a positional response bias in responding. Following 20 free choice trials, if no differentiation was identified between the two delay options observed via visual analysis, another forced choice phase was initiated.

Delay Presentations

Two delays to reinforcement were programmed for each microswitch button, mixed delay and fixed delay. Following responding to the fixed delay button, a constant 15-s delay was presented. Following responding to the mixed delay button, either 1- or 29-s delay was presented. Presentation of either the short (i.e., 1 s) or long (i.e. 29 s) depended on a pre-session randomly identified, and counter balanced, order of mixed delay presentations. Counterbalancing ensured there were equal presentations of long and short delays when the mixed delay was contacted. Within a mixed delay, the average presentation of either the short or long delay is equal to the rate of reinforcement as the alternative fixed delay.

Data Analysis

Data were graphed using Microsoft Excel©. Data from the free choice evaluation is displayed in cumulative line graph. Data was analyzed using visual analysis.

CHAPTER 4

Results for Brandon. Brandon's results are depicted on Figure 1. After 16 forced choice trials to expose him to each delay alternative, Brandon allocated 11 consecutive choice responses towards the mixed delay button. After 20 free choice trials, Brandon had selected the mixed delay in 18 out of 20 concurrent choice opportunities. Brandon showed preference for the mixed delay in 90% of choice opportunities.

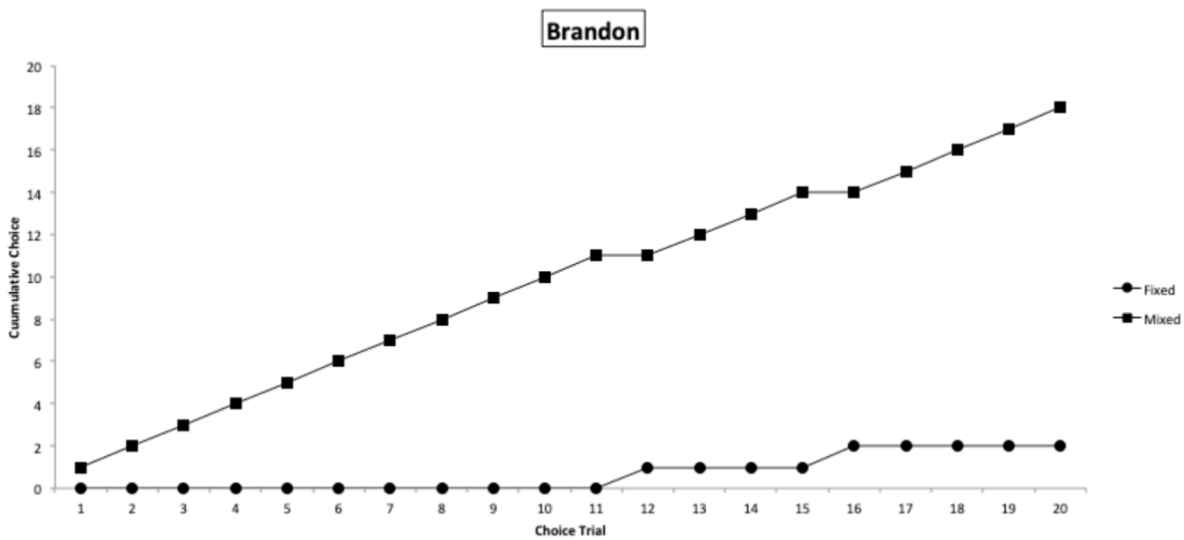

Figure 1. Preference for mixed delays in Brandon

Results for Clark. Clark's results are depicted on Figure 2. After 16 forced choice trials to expose each participant to each delay alternative, Clark initially, for the first 20 choice trials, responded with no preference for either delay value. Following 20 undifferentiated responses, another series of 16 forced choices were initiated. This forced choice condition was identical to the initial forced choice condition in that Clark was exposed to 8 mixed delay and 8 fixed delay to reinforcement contingencies. Following the second implementation of forced choice, 20 additional free choice trials were implemented. Clark's preference for mixed delays emerged while he consistently demonstrated a preference by allocating responding to the mixed delay option 15 out of the last 20 opportunities. Therefore, Clark's preference for mixed delays was 75% of the last 20 trials and 63% of all choice opportunities.

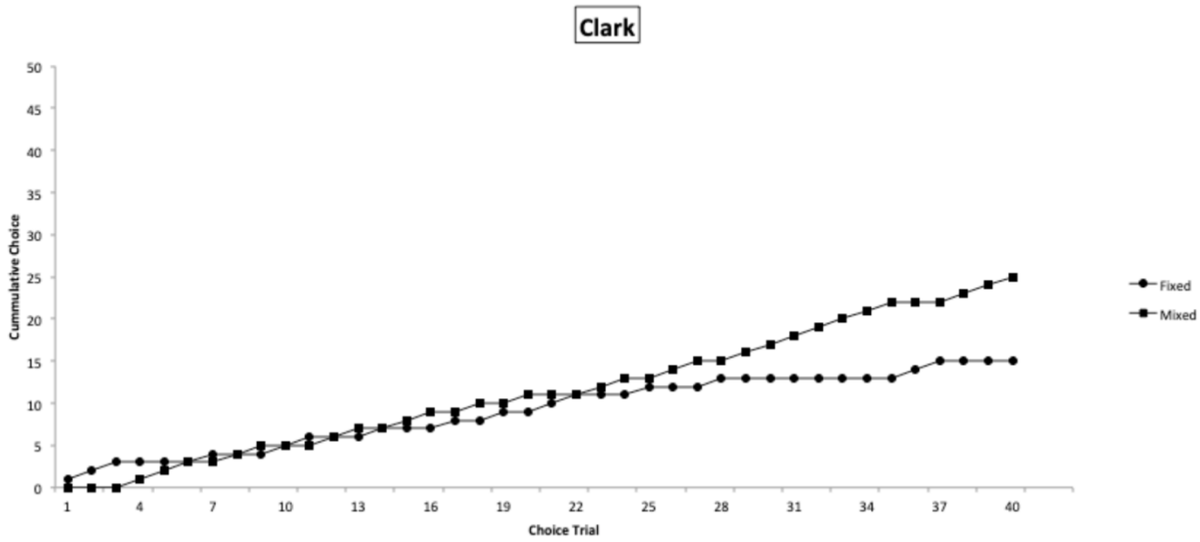

Figure 2. Preference for mixed delays in Clark

Results for Lane. Lane's results are depicted on Figure 3. After 16 forced choice trials to expose each participant to each delay alternative, Lane allocated responding on 19 consecutive trials to the mixed choice option with 95% preference for the mixed delay. Lane engaged in selecting the fixed delay on the last free choice trial.

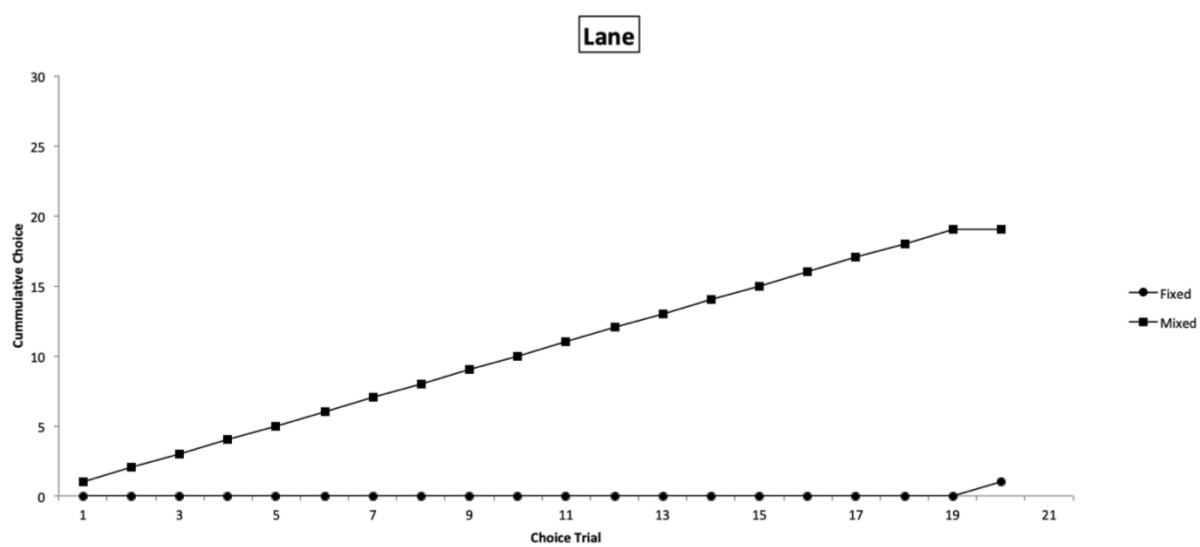

Figure 3. Preference for mixed delays in Lane.

Results for Eike. Eikie's results are depicted on Figure 4. After 16 forced choice trials to expose each participant to each delay alternative, Eike engaged in responding to the mixed delay 50 out of 80 (e.g. 63%) free choice opportunities. Initially, Eike engaged in responding to the mixed choice button 14 out of 20 choice trials. However, during the subsequent 20 free choice trials Eike allocated responding to both buttons equally. Following this pattern of nonpreferencial responding, another 16 forced choice trials were implemented. Following the second forced choice condition, Eike continued to engage in preference for mixed delay with responding towards the mixed delay option 27 out of the last 40 (e.g. 67%) free choice opportunities. In total, Eike engaged in responding towards the mixed delay option for 63% of all free choice opportunities.

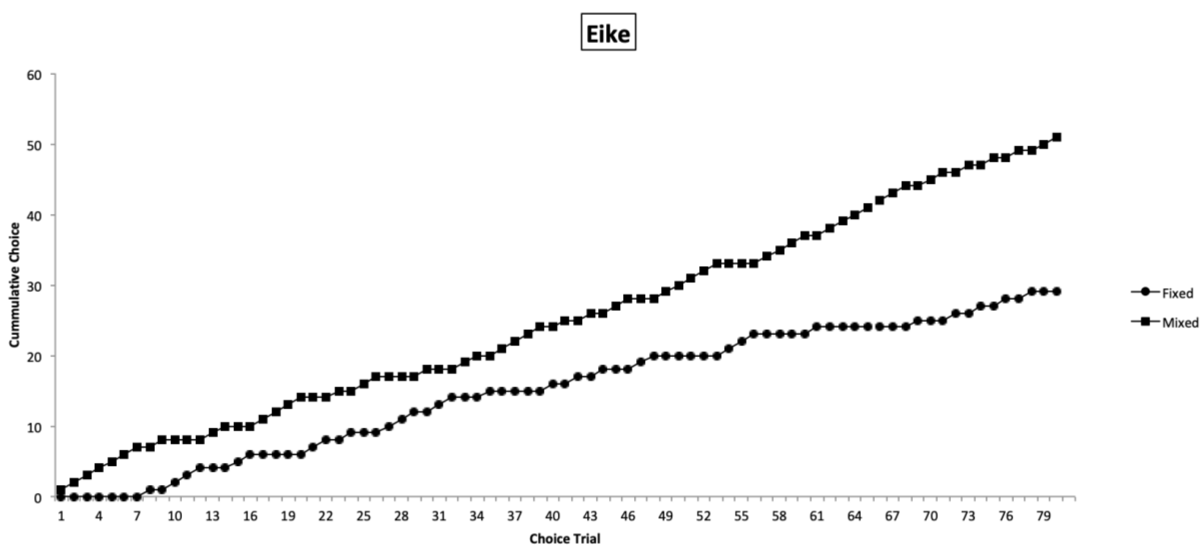

Figure 4. Preference for mixed delays in Eike.

Summary

In summary, all participants preferred mixed delays to fixed delays with an average of 78% (63-95%) preference for mixed delays to reinforcement.

CHAPTER 5

This chapter will discuss results of the current investigation, explore avenues of future research and clinical application, discuss limitations of the current project, and provide a summary of conclusions.

Mixed delays to reinforcement are a type of delayed schedule of reinforcement in which there is an equal probability of receiving an immediate or longer delayed reinforcer as a consequence of responding. The use of mixed delays have an obvious place in applied behavior analysis due to the analogous mechanisms found in the natural environment where functional responses are generally reinforced with a variety of different delay-to-reinforcement lengths. For example, caregivers may not be able to provide attention immediately when a child requests during work hours, however during work breaks access to attention may be reinforced immediately. The mixed delay procedure provides similar rate of reinforcement an individual would access in the natural environment. Although the need for effective treatment methods for issues that arise during delays to reinforcement, there is little understanding of how mixed delays may be a viable intervention procedure to not only teach tolerance and durability of intervention effects during delays to reinforcement, but may be a more efficient way to maintain previously acquired responses.

Currently, the only research on mixed delays to reinforcement can be found in basic and translational research, where the dependent variable is choice responding. More specifically, previous research on the implementation of mixed delays has been the focus of basic research comparing preference for different schedules of delayed reinforcement. Studies of schedule preference typically employ some form of concurrent-chain procedure (e.g., Autor, 1969), which has been demonstrated to be a reliable indicator of preference. The majority of research on mixed delays has been within the basic literature using similar procedures for identifying preference between varieties of different delays to reinforcement and the finding that subjects prefer mixed delays to alterative fixed delays is clear and consistent. As far as the understanding of preference for a mixed delay-to-reinforcement option relative to fixed delays has grown, the variations in context and subjects has been slower and less consistent to develop. In the limited scope in which mixed delays have been utilized, it is difficult for applied researchers and clinicians to understand and implement with confidence mixed delay procedures, even though there is emerging evidence supporting applied preference for this delay arrangement over a more typical fixed arrangement.

The present study examined choice for mixed versus fixed delays of reinforcement, in which the arithmetic average of the two mixed delays equaled the fixed delay. A major objective of the current research was to provide an extension of the previous literature on the use of mixed delays within an applied environment, which provides evidence for cross-species comparisons of findings. Children with autism were exposed to analogous procedures to basic and translational research, which included a series of forced-choice trials and consumable reinforcement delivered across two delay arrangements. The current research incorporated procedural variations adapted from both basic and translational research in order to investigate the effect of delay choice on responding in children with autism. Findings from the current study have contributed to the mounting evidence that the basic procedure of mixed delay has similar effects on response allocation in children with autism as they do with animal and adult non-clinical subjects.

Based on the relative response rates to each delay option, all participants demonstrated reliable preference for mixed delays of 1-s or 29-s delay-to-reinforcement to an alternative option of a 15-s fixed delay to reinforcement. Across all four participants, they averaged 77% preference for mixed delay (63-95%), which is similar to the findings of basic literature with non-human populations. Previous basic research studies have found an average, across studies, of preference for mixed delays to be 68-75%. The current findings help to extend the literature on the use of mixed delays forward in multiple ways, including in translational and applied areas. The current results are one step in understanding how, or if, the application of mixed delays within an applied behavioral intervention package would be beneficial. Therefore, the following sections will explore the different avenues of research that are needed to have a complete picture of the potential application of mixed delays.

Future Research

Translational Research. Without further research, questions about specific mechanisms behind the observed preference for a larger delay within a mixed delay arrangement are going to be difficult to answer. Within the current study, the arrangement of the delay interval, mixed or fixed, appears to be an important factor that influences response allocation within a concurrent schedule design. Although the current research provides support for the previous basic findings, it is important to continuously expand the research by exploring alternative dependent variables, such as response acquisition, maintenance, and long-term effects on behavior, when mixed delays to reinforcement are implemented contingent on responding. Previous research has found evidence that intermittent or partial delays appear to increase resistance to extinction, whereas constant delays to reinforcement appear to weaken resistance (Crum, Brown, & Bitternman, 1951; Nevin, 1974). Understanding variables that influence resurgence of previous behavior is imperative to identifying long-term successful behavioral treatments. For example, recent research has identified proficiency of alternative responding may influence resurgence of challenging behavior within a functional communication training paradigm. Understanding how these factors influence responding can only help adapt interventions procedures to increase maintenance of adaptive behavior while also decreasing maladaptive behaviors. Within mixed delays reinforcement, the two delay values short and long, can be conceptualized to be partially delayed, since half of all responses receive immediate reinforcement and half receive delays to reinforcement. Therefore, future research on the long-term effects of the use of mixed delays have on future responding is warranted. It is important for translational work to answer questions that are not amenable to the applied setting. For example, understanding how differences in the manipulation of the mixed delay value arrangement can effect subsequent responding is necessary to identify more successful and efficient strategies to achieve the best outcomes in applied settings.

Previous basic research with rats have explored the effects of different proportions of small to large delays when implementing mixed delays and have found that preference for mixed delays continue to persist in subjects even when the long delay was presented 3 out of 4 of responses (Rider, 1983), while the short, immediate reinforcement was only presented every 4 responses. These findings have not been replicated outside of animal laboratories, which limits our ability to interpret these results and apply them to clinical application. However, future translational research can expand on these findings and better understand the role the smallest delay value has on preference and maintaining responding. In understanding the effects changes to the smallest delay value in maintaining responding could help with applied problems of increasing delays to reinforcement during behavioral interventions while maintaining preference for that response alternative.

An additional area of translational interest should be to replicate the results of Cicerone (1976) who found that preference for the mixed delay increased as the range of mixed delay values widened. Cicerone found that conditions where the mixed delay values, short and long, were wider apart and more distinguished (i.e. 0 and 32 seconds versus 0 and 8seconds) preference emerged quicker and was stronger than the closer mixed delay arrangement. Although not explored in the current research, because delay values remained the same for all participants, it would be beneficial to continue this area of research to understand the mechanisms behind the preliminary findings by Cicerone, by manipulating the mixed delay value range and observe potential effects on preference and response allocation.

Applied Research and Practice

Each participant in the current study showed preference for a longer delay over a shorter alternative. Thus, the results of the current study have provided preliminary evidence that parameters, outside of rate of reinforcement, can have a substantial effect on response allocation. The current results showed that although the rate of reinforcement was the same for both response alternatives (i.e. mixed and fixed) participants reliably showed a preference for the mixed delay. All participants in the current research shifted their response allocation to an option that provided reinforcement at double the delay value over the alternative. The mechanism responsible for this demonstrated preference should be examined more carefully to help develop new and effective treatments for incorporating delays into practice. Future research could expand these findings and develop a potential preferred, alternative procedure to introduce delays to reinforcement within an applied population and setting. Future research could incorporate mixed delays to reinforcement into reinforcement schedule thinning within functional communication training (FCT; Carr & Durand, 1985). Inherent in the mixed delay procedure is occasional immediate reinforcement, which would maintain appropriate levels of alternative responses, without sacrificing clinically relevant goals of tolerating delays to reinforcement due to the exposure to longer delays.

The findings from the present study may have clinical implications for treatment of problem behavior that persists when delays to reinforcement are implemented in the clinical or natural environment. First, the use of discriminative stimuli in situations in which there is a delay to reinforcement may help clinicians reduce the probability of problem behavior. Within the current study two different visual stimuli (i.e. color and shape) were used to signal not only a delay but more specifically what type of delay. The current research provides support for the use of signals to potentially mitigate the negative effects of delays to reinforcement has on a variety of responses. Although challenging behavior was not a dependent variable in the current study, future research could examine the potential differential effects signaling has on preference between the two delay values when implementing function-based interventions for challenging behavior.

Another clinical implication for practice would be the potential of mixed delays on maintaining pro-social, appropriate responding (i.e. functional communication responses). The current results have provided evidence that mixed delays maintain responding more consistently than fixed delays to reinforcement. Previous basic research has shown that delays to reinforcement can lead to acquisition of new responses (Wilkenfield, J., Nickel, M., Blakely, E., & Poling, A. (1992), however this line of research has not been replicated with applied populations and adaptive responses. Therefore it is important to investigate the maintained effects mixed delays have on newly acquired responses that are in the process of fading to thinner more natural schedules of reinforcement.

Limitations

Dependent Variable. Choice procedures developed by basic research are difficult to translate to applied population in terms of potential implications and applications. Basic research on choice between different delays has implemented hundred of thousands of trials to expose choice options and test preference with animal subjects. In addition, within human operant studies evaluating choice, hundreds of trials are used to assess preference. Therefore within the current study, the relatively minimal exposures to the choice alternatives coupled with the relative low choice trials, requires replication the current independent and dependent variables.

Conclusion

Delays to reinforcement are encountered numerous times a day and the ability to maintain adaptive behaviors in the face of delays to reinforcement are necessary for individuals to access all parts of their environment. Research into delays to reinforcement is important for our field to continue to monitor and push into new territory. It is dependent on translation and applied research to identify potential strategies that mitigate the negative side effects delays to reinforcement have been shown to produce (i.e. resurgence of challenging behavior). Because delays to reinforcement are present in the natural environment and continuously present challenges to behavioral interventions, it is imperative that research is reflective of this and is seeking out alternative procedures. The current research moves the knowledge about delays forward by translating basic findings to an applied population and setting. However, the current research should also be a call for additional research on the use of mixed delays and their potentials within applied behavior analysis. The previous research coupled with the results of the current study provide a framework for future researchers to understand not only why subjects prefer this type of delay arrangement, but also how can it provide insight into how behavior is maintained in the natural environment.

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