Stimulus Control and Generalization of Operant Variability
in the Block Play of Children with Autism

Dissertation

Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Graduate School of The Ohio State University

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2012

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Abstract

Children with autism have a tendency to engage in repetitive behaviors across multiple domains, including play. One method for decreasing repetitive behavior that has been studied in humans and other animals in both laboratory and applied settings is the explicit reinforcement of variability. Basic research suggests that varied responding can be brought under the control of an antecedent stimulus that reliably predicts the availability of reinforcement for variability. The purpose of this study was to examine the effects of a lag 3 schedule on the diversity of forms constructed during block play by children with autism. In addition, the study evaluated the effects of a procedure designed to establish stimulus control over repetition and variation, and examined the extent to which variability would generalize to a novel task in which the same discriminative stimuli were presented.

Three boys diagnosed with autism, ages 7 to 9, served as participants. All three lacked appropriate play skills. During daily sessions, the experimenter presented the students with materials to either build block structures or create patterns on a pegboard. Variability was defined as the degree to which the forms created varied from one another. In an initial continuous reinforcement (CRF) phase, any form that the students created resulted in reinforcement. In a subsequent variability (VAR) phase, the experimenter asked the participant to make something “different,” and then reinforced only the creation
of forms that were different from the previous three that were built (a lag 3 schedule). After this, students experienced a repeat (REP) phase in which they were instructed to make “the same,” and only forms that repeated one of the three most recently produced resulted in reinforcement (a rep 3 schedule). After experiencing multiple reversals between these two phases, an alternating schedule (ALT) phase was introduced in which each trial was determined by a random sequence to operate on either the VAR or REP contingencies, and the discriminative cues (“same” and “different”) were presented on each trial. An S^d absent (SDA) phase in which the discriminative cues were removed followed this. Finally, students were exposed to a novel task (painting a series of squares) in which the same cues were used. A reversal design was employed to compare the effects of these schedules on response variability.

All three participants increased the diversity of block forms produced under the lag 3 schedule. All three participants also demonstrated evidence of stimulus control in that responding varied more under the VAR component of the multiple schedule in the ALT phase, but the two conditions did not have the same effect when the discriminative stimuli were absent during the SDA phase. During the generalization task, students did not demonstrate stimulus control, in that the sequences of colors produced were equally likely to vary whether students were asked to make “same” or “different.” The implications of these findings for the education of children with autism are discussed, along with suggestions for future research directions.
Dedication

To my wife Melissa, and my son Elliott, who have supported me in every way possible during this process. To my mother, Paula Miller, for her selfless generosity throughout my life. And, to the memory of my father, David Miller, who gave me everything.

“Does the poet create, originate, initiate the thing called a poem, or is his behavior merely the product of his genetic and environmental histories?”

B.F. Skinner
Acknowledgments

I would like to acknowledge Allen Neuringer, who advised me as an undergraduate at Reed College years ago. I don’t even know what I would be doing today if it weren’t for the influence he’s had on me. In those psychology classes I took with him, I discovered a passion for behaviorism that has since become an inextricable part of who I am. Over the years he has always been there when I’ve needed him, and has pushed me to pursue my dreams. Allen’s research and writings still inspire and amaze me, and I truly cherish his generous feedback and advice over the years. I am very lucky to have a mentor of his caliber in my life.

I also want to express the deepest gratitude to my advisor, Nancy Neef, who has had faith in me throughout this process, and contributed immeasurably to my growth as a scientist. She has been everything I could have wanted in an advisor, and I can only hope that I will be able to live up to her example in my life. In the last three years, she has provided me with a level of guidance, encouragement and support that I never imagined possible. She has not only given me the tools I am going to need as a researcher and teacher, but also helped me to believe in myself. I will be forever in her debt.

I want to thank my dissertation committee, Dr. William Heward, Dr. Helen Canella-Malone, Dr. Ralph Gardner, and Dr. Nancy Neef for supporting this crazy idea I had, and allowing me to pursue it to its conclusion. Each of you contributed to my formulation of this dissertation.
I also want to acknowledge Dr. Morten Haugland for his encouragement and his invaluable support of my efforts.

Finally, I want to thank all of the students who I have worked side by side with during the development and execution of this research, especially James Meindl, Jonathan Ivy, Joshua Garner, and Jessica Heacock. I am indebted to each of you for your assistance and kindness.
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Fields of Study

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Specialization: Applied Behavior Analysis

Special Education
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Chapter 1: Introduction

Behavioral variability refers to the extent to which an organism responds in novel or unexpected ways when exposed repeatedly to the same environmental stimuli. Because behavior analysts seek to discover principles that allow prediction and control of behavior, such variability has traditionally been viewed as a problem, reflecting the effects of uncontrolled or unidentified variables (Johnston & Pennypacker, 2009; Sidman, 1960). An alternative approach is to treat behavioral variability as a phenomenon of interest in its own right (Lee, Sturmey, & Fields, 2007; Neuringer, 2002, 2009; Rodriguez & Hunziker, 2008; Schoenfeld, 1968). Behavioral variability can occur along a continuum, ranging from patterned and repetitive at one end to random and stochastic at the other (e.g., Grunow & Neuringer, 2002; Neuringer, 2002; Stokes, 1999). By identifying the environmental variables that influence levels of variability, it may be possible to bring variation under experimental control. This approach holds significant potential for the field of education, where novel, unpredictable behavior can be either adaptive (as in the case of generating a novel solution to a problem, writing an original essay, or producing a creative work of art) or maladaptive (as in the case of answering an arithmetic problem, spelling a word, or following a classroom rule). If educators could identify and manipulate the environmental variables that influence behavioral variability, it might help them to better address the educational needs of their students. This is
particularly true in special education, where children with certain diagnoses are described as displaying levels of variability that are either too low, as in autism, or too high, as in attention-deficit/hyperactivity disorder (ADHD) (Aase & Sagvolden, 2006; Napolitano, Smith, Zarcone, Goodkin, & McAdam, 2010; Neuringer, 2009; Saldana & Neuringer, 1998).

A number of basic and applied studies with human and nonhuman subjects have identified factors that may influence behavioral variability (Lee et al., 2007; Neuringer, 2004; Rodriguez & Hunziker, 2008; Shahan & Chase, 2002). These can be broadly categorized as acting either directly or indirectly. Indirect procedures that increase variability include extinction, intermittent reinforcement, delayed reinforcement, food deprivation, and the ingestion of drugs or alcohol (Carlton, 1962; Cohen, Neuringer, & Rhodes, 1990; Eckerman & Lanson, 1969; Kinloch, Foster, & McEwan, 2009; Pesek-Cotton, Johnson, & Newland, 2011; Wagner & Neuringer, 2006). Direct procedures involve explicitly reinforcing responses that vary from those recently emitted (Goetz & Baer, 1973; Machado, 1992; Page & Neuringer, 1985; Pryor, Haag, & O’Reilly, 1969).

The finding that variability can be reinforced challenges some common assumptions about how reinforcement works. Skinner (1953) defined reinforcement as a process by which responses are selected by the consequences they produce. This suggests that when responses are reinforced, the inevitable outcome is one of increased repetition of the response, which is incompatible with behavioral variability. Based on this principle, some have argued that reinforced variability is a paradoxical concept (Schwartz, 1982a, 1982b). On the other hand, Skinner’s description of operant behavior
also seems to suggest a central role for variation in reinforcement. The possibility of environmental consequences selecting novel responses depends upon the existence of a variable substrate of responding upon which the environment can act (Epstein, 1991; Marr, 2003; Neuringer, 2009; Neuringer & Jensen, 2010; Skinner, 1981). The notion of a response class also suggests the possibility of variation; reinforcement is said to influence not only a single response, but also to affect other similar responses (Johnston & Pennypacker, 2009; Skinner, 1953). The number and type of responses that comprise a functional response class will determine the extent to which individual instances of behavior can differ from one another. Reinforcement also allows for variability in that its effect is described as probabilistic rather than absolute (Epstein, 1991; Neuringer, 2004, 2009; Skinner, 1953). Although the contingent delivery of reinforcement increases the future probability of members of a specific response class, the individual responses remain unpredictable at any given moment. Neuringer (2009) suggested that such response variability might in fact be viewed as one of the qualities that separates operant from respondent behavior: “The ‘openness’ of the operant response, its modifiability, depends to a large extent on the ability of the response to vary in a way that is influenced by contingent reinforcers” (p. 320).

**Operant Variability**

Experimental evidence appears to indicate that contingent reinforcement can be used to increase the extent to which an organism’s responses vary within a response class (Lee et al., 2007; Neuringer, 2002; Shahan & Chase, 2002). As a result, some have suggested that variability itself should be viewed as an operant, in that it can be altered by
its consequences (e.g., Page & Neuringer, 1985). However, variability is a measure that reflects a complex relation among multiple instances of operant behavior, and thus is neither a response, nor a property of an individual response (Johnston & Pennypacker, 2009). Instead, behavioral variability represents a relationship between multiple instances of responding, which makes it similar to other properties of behavior, such as rate or interresponse time (IRT), that have been shown to be sensitive to the effects of contingent reinforcement (Blough, 1966; Page & Neuringer, 1985; Rodriguez & Hunziker, 2008). Increased variability due to operant and induced procedures has been demonstrated across several species, including rats, pigeons, dolphins, and humans (e.g., Goetz & Baer, 1973; Machado, 1989; Mook & Neuringer, 1994; Pryor et al., 1969). These procedures have been used to increase the degree to which an organism varies its behavior along several different response dimensions, including IRT, location, duration, force, and topography (Antonitis, 1951; Blough, 1966; Margulies, 1961; Skinner, 1938; Vogel & Annau, 1973). Additionally, applied researchers have shown that both direct and indirect methods of increasing variability can be used to address behavior problems of social significance (e.g., Grow, Kelley, Roane, & Shillingsburg, 2008; Lee, McComas, & Jawor, 2002).

The explicit reinforcement of variation has potential advantages over induced variability for application in educational settings. First, the contingencies used in explicit operant procedures can exert precise control over the amount or degree of variability (e.g., Grunow & Neuringer, 2002; Mook & Neuringer, 1994; Souza, Abreu-Rodrigues, & Baumann, 2010) and the dimension of responding along which variability will occur
(e.g., Maloney & Hopkins, 1973; Ross & Neuringer, 2002). Another advantage of operant variability is that such procedures can be used to establish stimulus control over variation and repetition (e.g., Denney & Neuringer, 1998; Ward, Kynaston, Bailey, & Odum, 2008). Thus, a teacher might be able to explicitly reinforce varied behavior in one situation (i.e., when a student is asked to write a short story), while reinforcing repetition in other situations (i.e., when that student is asked to write a word’s definition). To date, research on stimulus control of variability has been conducted in laboratory settings, but not in applied educational situations.

**Variability and Autism**

One applied area in which research on variability is particularly relevant is in the education and treatment of children with autism. Children diagnosed with autism engage in patterns of behavior that may reflect aberrant levels of variability (Neuringer, 2009). Repetitive, stereotyped behaviors, and restricted interests are among the central diagnostic criteria for autism (American Psychiatric Association, 2000). This has led some researchers to ask whether explicit reinforcement of variation might be useful in the treatment of these individuals (Esch, Esch, & Love, 2009; Lee & Sturmey, 2006; Miller & Neuringer, 2000; Napolitano et al., 2010). Although these efforts have been promising, a phenomenon that has yet to be studied in this population is stimulus control of operant variability. If it is possible to do so, bringing variability and repetition under the control of relevant discriminative stimuli may be useful in remediating some difficulties faced by these students.
One area of functioning in which the problem of repetitive behavior manifests itself is in play; children with autism tend to engage in play that is considered less creative, and more repetitive, than typical peers (Baron-Cohen, 1987; Lu, Peterson, Lacroix, & Rousseau, 2010). Wulff (1985) described the play of individuals with autism as having “a sterile ritualistic quality…that appears to contribute little, if anything, to the child’s pleasure” (p. 139). Such restricted play can negatively impact social and educational development, and frustration related to a lack of success during play activities may contribute to the occurrence of challenging behaviors (Terpstra, Higgens, & Pierce, 2002; Wing, Gould, Yeates, & Brierley, 1977). Operant variability procedures could be used to encourage more creative, unpredictable patterns of responding during play, thus addressing this deficit. Researchers have demonstrated that variability of block play can be increased through contingent reinforcement in both typically developing children (Goetz & Baer, 1977) and children with autism (Napolitano et al., 2010).

**Generalization of Operant Variability**

Another issue related to variability that has received relatively little attention from both basic and applied researchers is the concept of generalization. Holman, Goetz, and Baer (1977) studied this phenomenon with preschool children. They found that when reinforcement (i.e., praise) was contingent on varying responding during one activity, there was a concurrent increase in variability during other, similar activities. The authors suggested that reinforcing variable responding might represent an effective method of promoting response generalization. Harding, Wacker, Berg, Rick, and Lee (2004) investigated a differential reinforcement procedure to increase response variability in a
martial arts setting and found that variability increased simultaneously in the training setting and another setting in which no experimental procedures were in place. Although these studies seem to suggest that variability can generalize across stimulus conditions, no research to date has investigated the conditions that are required to promote such generalization, or identified the underlying process behind such untrained gains in variability. One way that generalization might be promoted is through the establishment of stimulus control. If similar discriminative stimuli can be programmed across training and generalization settings, this may be effective in promoting appropriate variation in novel, untrained settings (Stokes & Baer, 1977).

**Purpose of Paper**

The purpose of this dissertation is to investigate (1) the effects of operant reinforcement procedures on behavioral variability of children with autism within the context of a play activity they are being taught, (2) the extent to which stimuli paired with contingencies that reinforce repetition and variation come to exert control over behavioral variability with this population, and (3) the degree to which stimulus control of variability will promote generalization of variable responding when presented with a novel activity. A comprehensive literature review will be described that will detail existing basic and applied research on the topic of operant variability and identify procedural and conceptual issues that future research might address. Also, an empirical study that was conducted to answer these questions will be described, including results and a discussion of the findings. Finally, the implications of this study will be discussed, as well as
suggestions for how future studies and clinical practices might build upon the findings of the current study.
Chapter 2: Literature Review

Defining and Measuring Variability

The idea of studying behavioral variability is relatively novel within the field of behavior analysis, due in part to a tradition of this science viewing variability as experimental “noise” that must be eliminated in order to discover important relationships between behavior and the environment (Sidman, 1960). The experimental designs that typify behavior analysis are based on successive comparisons of stable patterns of responding across manipulations of an independent variable (Cooper, Heron, & Heward, 2007). In keeping with this focus, behavior analysts have typically not attempted to define and measure the variability of behavior in the same way they have defined and measured other dimensions such as frequency, duration, or latency (Johnston & Pennypacker, 2009). Thus, in order to study the phenomenon of behavioral variability, it is necessary to develop a clear definition of the concept of variability, and to devise valid and reliable ways to measure it. Rodriguez and Hunziker (2008) reviewed the existing literature on behavioral variability, and discussed the extent to which researchers had developed a consistent model of studying the topic. They concluded that variability has been defined in a relatively consistent manner in behavior analytic research; all researchers have defined variability as the extent to which behavior differs along some property or dimension in comparison to a referent (i.e., prior responding). However, these studies have not always been consistent in the methods used to quantify variability.
In various experiments, behavioral variability has been measured according to the dispersion of performance around a central value (e.g., Eckerman & Lanson, 1969), the degree of equiprobability of members within a set of responses (e.g., Page & Neuringer, 1985), the number of novel responses produced (e.g., Pryor et al., 1969), and the sequential dependence of a series of responses (e.g., Machado, 1992). Each of these can be said to broadly represent measures of variability, but they do not necessarily measure the same aspect of behavior. These various measures differ in the type of variation they assess, and whether they deal with molecular or molar indices of variability. Understanding the differences between these diverse approaches to assessing variability may prove useful in selecting a measure that best captures the phenomenon of interest, which would be of particular importance in applied settings. As Maltzman (1960) suggested, defining what constitutes an uncommon response “may be a problem more readily solvable within the laboratory than without” (p. 229).

**Measures of dispersion.** When researchers have evaluated variability in terms of dispersion around a central value, they have typically used descriptive statistics such as variance or standard deviation (e.g., Aase & Sagvolden, 2006; Kinloch, Foster, & McEwan, 2009; Morgan & Lee, 1996; Perry, Sagvolden, & Faraone, 2010). Antonitis (1951) used a dispersion measure to analyze the effects of an extinction procedure on variability in the location of nose-thrust responses made by rats along a 50 cm slot. When the rats pressed their nose into the response slot at any point, it broke a beam aimed at a photoelectric cell, causing the apparatus to take a photograph of the rat’s exact position. During conditioning, such responses also caused food to be delivered, but
during a subsequent extinction phase, no food was produced. The experimenter then determined the median position of the rat’s nose on the response slot across all trials emitted each session and calculated, in centimeters, the amount that each response varied from that central value. This was used to calculate the mean variation from the median value, which served as an index of response variability in each condition. A greater amount of dispersion around the median position was interpreted as evidence of greater variability in location.

Kinloch et al. (2009) used a similar measure of variability in their second experiment, which looked at the performance of college students on a computer task that involved drawing rectangles on the screen to earn points on a differential reinforcement of low rates of responding (DRL) schedule. The authors evaluated the effects of extinction on the variability of rectangle size and IRT by calculating the mean value and standard deviations for each variable across multiple trials. Higher standard deviations were interpreted to mean that there was greater variability in that aspect of the response. In order to measure behavioral variability in this way, it is necessary that the response vary along a continuous, quantifiable dimension, such as force, IRT, or distance. Dimensions of behavior that are measured using ordinal or nominal scales cannot be described according to dispersion around a central value.

**Equiprobability and U-value.** An alternative approach is to define variability as the degree of equiprobability within a set of responses (e.g., Gates & Fixsen, 1968; Pesek-Cotton et al., 2011; Neuringer, 1992; Schoenfeld, Harris, & Farmer, 1966). Actions that produce a random result, such as rolling a die or flipping a coin, demonstrate
how this type of variability works. If one were to roll a six-sided die, on any given roll there would be an equal probability that any one of the six sides would come up. Over the course of many rolls, a pattern of equiprobability would emerge in that there would be a relatively even distribution among the universe of possible outcomes. Similar patterns can also indicate variability in behavior. If an individual is behaving in a stochastic or unpredictable manner, responses will be distributed evenly across the set of all potential responses.

An early example of this is Blough’s (1966) investigation of the IRTs produced by pigeons pecking keys in an operant chamber. To assess the variability of IRTs, the range of possible IRTs was first divided into 16 bins, representing ranges of values. A given response would then be classified as falling within one of these IRT bins (i.e., an IRT between 3.7 and 4.1 seconds would fall into the 13\textsuperscript{th} bin). Rather than having bins of equal intervals, the range of values defining each bin was determined based on the predicted distribution of IRTs that would occur given a completely random performance (which was defined based on the naturally occurring stochastic decay rates of radioactive particles). The IRT bins were spaced so that if responding occurred at random, the probability of the current response falling in each of these 16 bins would be equal. The number of responses that actually fell into each of these bins was used as an index of variability. A greater degree of distribution of responses across the 16 IRT bins would indicate greater variability.

Another way of assessing variability by equiprobability is the uncertainty index known as U-value (Cherot, Jones, & Neuringer, 1996; Doughty & Lattal, 2001; Souza et
Miller and Frick (1949) first proposed this measure as a way to quantify the degree of stereotypy (or, conversely, entropy) within a series of responses. To calculate U-value one must first determine the total number of unique responses that might occur, and then the relative frequencies with which each of those responses do occur. The following is the formula for U-value that has been used most often in most studies of response variability (taken from Ross & Neuringer, 2002, p. 204):

$$U\text{-value} = -\sum_{i=1}^{\beta} \frac{\alpha_i \times \log(\alpha_i)}{\log(\beta)}$$

In the numerator, $\alpha_i$ represents the relative frequency of response $i$, calculated by dividing the number of times that response occurs by the total number of responses. In the denominator, $\beta$ represents the total number of different responses (for example, if there were 16 possible sequences of button presses that participants could produce, $\beta$ would be equal to 16). When a set of values is plugged into this U-value formula, it yields a number between 0 and 1 representing the amount of uncertainty, or entropy, within a dataset. A U-value of 1 would indicate complete equiprobability of response distribution, as would be expected given the random generation of responses. A U-value of 0 would indicate no variability at all, as would occur if the individual always repeated just one of the possible responses. A U-value of 0.5 would indicate a moderate level of variability. U-value has the advantage of being a fairly flexible measure in that it can describe variability within either small or large sets of potential responses. Also, unlike measures of central tendency, U-value can be calculated for dimensions of behavior, such
as topography, that are not readily quantifiable. To the extent that it is possible to identify the universe of possible response topographies, and assign these to discrete categories, variability of topography is quantifiable by U-value. Responses can be said to have a certain distribution among this set of possible topographies, even if it is not possible to measure the degree to which individual responses differ from an “average” topography.

**Sequential dependency.** A third way that variability can be assessed is through a statistical analysis of the degree to which responses occur in a predictable sequence (e.g., Blough, 1966; Stokes, 1995). Machado (1992) used this measure in a study in which pigeons produced sequences of eight pecks on two response keys. In addition to looking at U-value, Machado performed additional analyses based on a statistical model of probabilities known as a first-order Markov chain. This model was selected because it takes into account the likelihood of a given response occurring given the immediately preceding occurrence of some other response (i.e., its conditional probability). In this case, switching between the two keys was selected as the unit of analysis. The probability of switching given a specific position within the 8-peck sequence was calculated, as was the probability of switching given the immediately preceding occurrence of either a switch or the repetition of the same key. The actual probabilities of these events were then graphed and compared to what would be predicted given truly random performance, to assess the degree of variability. Interestingly, the use of sequential probabilities as an index of variability revealed patterns in responding that had not been apparent when only U-value was considered. In spite of the fact that the birds
were distributing responses fairly evenly among the possible sequences, they were engaging in somewhat predictable patterns within these sequences, when the conditional probabilities of switching keys was taken into account. In his discussion, Machado suggested that these different indices of variability might be conceptualized as “molar” and “molecular” scales of analysis (Waltz & Follette, 2009). Whereas measures of equiprobability, such as U-value, give a clear picture of the overall level of variability on a molar scale, looking at specific conditional probabilities within response sequences may be useful in discovering orderly patterns on a more molecular scale.

In some cases, the findings of different molar and molecular measures of variability may disagree, leading to potential ambiguity. Blough (1966) conducted both types of analysis in his research on reinforcing varied IRTs. In addition to the measure of equiprobability described above (the number of IRTs falling into various bins), Blough also used a sequential analysis similar to the one employed by Machado (1992). A chi-square analysis of the sequence of responses suggested serial dependence; relatively long IRTs predicted shorter IRTs, and vice versa. In spite of IRTs being equally distributed among the 16 bins, a pattern was found when the sequence of responses was analyzed more closely. Schoenfeld et al. (1966) reported a similar result. A measure of dispersion (standard deviation) indicated variability in IRTs, but an analysis of sequential dependence revealed a predictable pattern of alternating between long and short IRTs.

The disagreement between these various measures of variability can be explained by the disparate ways variability was calculated. For example, in the study by Antonitis (1951) that measured the locations of nose-thrusts along a response slot, one could
imagine three distinct ways of measuring variability. The method employed by the
author, as described above, was to determine the most common location, and measure
how far from that position responses tended to be. An alternative approach would have
been to divide the 50 cm slot into 50 discrete 1 cm “locations,” and measure the
distribution of responses among those 50 possible locations. Finally, one could evaluate
whether responding in one location was predictive of the subsequent response being in a
particular location. If a rat responded frequently at both far ends of the 50 cm slot (that is
in the 1st and 50th locations), but rarely in the center, it would demonstrate high variability
according to the dispersion measure used by Antonitis. However, the same pattern of
responding would yield a very low estimate of probability according to an equiprobability
measure such as U-value, as responses were distributed disproportionately on 2 of the 50
possible locations. Similarly, if a rat responded by sequentially poking its nose in each of
the 50 locations, in order, it would indicate high variability in terms of equiprobability,
but low variability according to the measure of sequential dependence.

Ward, Bailey, and Odum (2006) reported a related result in a study examining the
sequences of four key pecks produced by pigeons given doses of d-amphetamine or
ethanol. U-value suggested that alcohol increased variability, but a more molecular
measure indicated that responding was actually patterned in a predictable manner. Due to
the way in which U-value is calculated, it is possible for an organism to generate a
pattern of responding that produces an even distribution of responses among the universe
of possible responses, but does so through a repeated (thus predictable) pattern. Imagine
if a person were to produce the following series of responses by repeatedly selecting a
number between 1 and 4 on a keyboard: 1234123412341234. This sequence represents an equal distribution among the four response alternatives, and thus would be considered to have a U-value of 1 (suggesting high variability). However, an analysis of sequential dependence would indicate low variability, in that responses occurred in a predictable pattern (i.e., after pressing “1,” the individual reliably pressed “2”). Lee et al. (2007) labeled this type of responding “higher-order stereotypy,” and argued that such patterns may be highly likely under certain types of reinforcement schedules. When predictable sequences of this kind are a concern for researchers, the use of only molar measures of variability may be problematic, as they might fail to detect these patterns.

**Response novelty.** Another way of assessing variability is to simply count the number of novel responses that occur (e.g., Betz, Higbee, Kelley, Sellers, & Pollard, 2011; Goetz & Baer, 1973; Maloney & Hopkins, 1973; Pryor et al., 1969). This can be done across either a relatively long period of time, or across a shorter interval. Pryor et al. (1969) measured the novelty of tricks performed by porpoises under different contingencies of reinforcement. Responses were deemed to be “novel” only if they had never appeared before during any session across the entire experiment (a period which lasted weeks).

Cammilleri and Hanley (2005) assessed novelty in a more molecular fashion, in a study with elementary school children. During a free choice period, the students were given a set of 12 activities they could select. In an ABAB reversal design, reinforcement of varied activity selection was introduced, withdrawn, and then reintroduced. To assess the variability of students’ choices, the authors recorded the number of novel selections.
made within each session. Thus, if a student played with a single activity for the entire
free period, it would be recorded as zero novel choices. If the student selected 4 different
activities during that period, this would be considered 3 novel selections. If a student
made more novel selections, this was interpreted to mean he or she was behaving more
variably.

Goetz and Baer (1973) used a similar measure of variability in a study of the
diversity of block building forms produced by preschool children. The authors started by
creating a list of 20 distinct forms that block structures could take. Each structure the
children built was categorized according to which of these forms it resembled, and
variability was determined based on whether or not the child had created that form
previously within the current experimental session. In addition to including data on the
number of novel forms produced per session (a molecular approach), Goetz and Baer also
included a cumulative record of the number of novel forms produced across all sessions
(a molar approach). Molar and molecular approaches to assessing novelty represent
distinct aspects of variability. In some contexts it may be most useful to vary responding
from one response to the next across a relatively short period of time (such as when
playing a game against an opponent). In other situations (such as a problem solving task)
it may be necessary to produce truly novel (never-before-seen) forms of responding, in
order to expand the size of a response class (Chase, 2003; Neuringer, 2003). It may be
useful in applied situations to consider whether molar or molecular forms of variability
are more relevant, and to define variability accordingly.
Further considerations in measurement. Another issue complicating the measurement of varied responding is that many different aspects of a response can be said to “vary.” Ross and Neuringer (2002) illustrated this in a study in which college students were asked to produce rectangles on a computer screen. At various points, reinforcement was made contingent on variation or repetition of three distinct aspects of the response: the location of the rectangle on the screen, the size of the rectangle, or its shape (i.e., the ratio of length to width). The authors found that depending on the contingency in place, variability occurred independently for each of the three aspects of the response. That is, participants could vary shape while repeating size, or vary the size while repeating location, etc. The three different aspects of variability could be manipulated independently by establishing particular contingencies of reinforcement.

Similarly, Maloney and Hopkins (1973) arranged a writing assignment in an elementary school classroom so that in various phases of the experiment, reinforcers were presented contingent on the production of novel adjectives, novel action verbs, or novel sentence beginnings. When a given aspect of creativity was targeted, the number of novel instances for that component increased; the other sentence parts were unaffected. Thus, when students earned points for using new adjectives, they did so, but they did not increase their use of varied action verbs or sentence beginnings. In different studies, behavior analysts have examined variability as it occurs across numerous other response dimensions, including IRT (Aase & Sagvolden, 2006), duration (Gharib, Gade, & Roberts, 2004), location of pecks on a response key (Eckerman & Lanson, 1969), topography (Goetz & Baer, 1973), force of lever-presses (Notterman, 1959), and
sequences produced on two or more manipulanda (Tatham, Wanchisen, & Hineline, 1993).

From a conceptual standpoint, having a definition of variability that is broad enough to encompass all of these different types of variation seems useful. However, when translating this theoretical model into an applied situation, it is essential that researchers are specific about how variability is being defined and measured. Rodriguez and Hunziker (2008) advised, “before characterizing a behavior as variable it is essential to clarify the concept of variability employed and the criteria with which it is being considered” (p. 143). For applied behavior analysts, this process may involve carefully considering the aspect of variability that is of concern, and then picking a measure that best captures it.

**Environmental Factors Influencing Variability**

Lee et al. (2007) outlined a framework for categorizing the different experimental manipulations that have been shown to affect variability. Such procedures fall into two general categories: schedule-induced variability and directly reinforced variability. Schedule-induced variability has been observed during the extinction of previously reinforced behavior (e.g., Antonitis, 1951; Grow et al., 2008), the introduction of delays between responses and programmed consequences (e.g., Odum, Ward, Barnes, & Burke, 2006; Wagner & Neuringer, 2006), the use of intermittent schedules of reinforcement (e.g., Eckerman & Lanson, 1969; Boren, Moerschbaecher, & Whyte, 1978), and the use of variable versus fixed schedules (McCray & Harper, 1962). Operant reinforcement of variability has been observed under such contingencies as lag schedules (e.g., Page &
Neuringer, 1985; Lee et al., 2002), schedules that differentially reinforce novel behavior (e.g., Goetz & Baer, 1973; Pryor et al., 1969), and schedules that reinforce low-frequency responses (e.g., Blough, 1966; Miller & Neuringer, 2000). Experimental evidence suggests that these different types of schedules may affect variability differently. Thus, a careful consideration of these methods is needed in order to develop an effective applied technology to promote variability in real world situations where such responding would be adaptive.

**Extinction.** Antonitis (1951) was among the first to demonstrate the effect of extinction on response variability. He conducted a study in which he compared the effects of an extinction procedure and a CRF schedule on rats’ nose-poking responses along a 50 cm response panel. Under the CRF schedule, the locations of nose-pokes (which could occur at any point along the panel) became increasingly stereotyped (i.e., they occurred only within a limited range of locations). When reinforcement was discontinued, the position of nose-pokes showed greater variation, as measured by dispersion around the median position). This finding was replicated by Stokes (1995), who studied the effects of extinction on variability in the topography of rats’ leverpresses. Whereas responding under a dense schedule of reinforcement was characterized by increasingly stereotyped sequences of behavior, extinction led to marked increases in variability.

Morgan and Lee (1996) replicated this result with humans. Participants were initially trained to press the space bar on a keyboard to produce points according to a DRL schedule. Then, reinforcement was discontinued. Under this extinction condition,
IRT showed significantly greater variability, as measured by dispersion around the mean. Kinloch et al. (2009) also confirmed this relationship between extinction and variability. Following a period during which a DRL schedule was in place for drawing rectangles on a computer, human participants were exposed to an extinction procedure. This resulted in increased variability with respect to IRT and rectangle size. Souza et al. (2010) also studied the effects of extinction on variability of behavior by humans in an analog laboratory task. College students were asked to produce sequences of key-presses on a computer keyboard. When a schedule that reinforced repetition was followed by an extinction procedure, more varied sequences were produced. Taken together, these studies provide robust evidence that variability can be induced by extinction.

In a related applied study, Goh and Iwata (1994) described the effects of an extinction procedure on the frequency of two different problem behaviors exhibited by an adult with developmental disabilities. The intervention targeted self-injurious behavior (SIB), which was hypothesized to serve an escape function. The authors measured the effects of extinction of SIB on the frequency of both SIB and aggression (a behavior that served the same function, but was not targeted by the intervention). They found increased variability among these responses in that aggression, which had occurred rarely at first, increased in frequency when extinction was implemented for SIB. Similarly, Grow et al. (2008) investigated the effects of an extinction procedure on the variability of mands emitted by children with autism. Problem behaviors were identified for each student that could be replaced with a functionally equivalent communication response. Under extinction conditions, the previously reinforced problem behavior was no longer
reinforced, and any instance of the appropriate alternative was reinforced. This intervention resulted in an increase in communicative responses, and a decrease in problem behavior, indicating that extinction may have induced variability. However, the findings of this study and several others ostensibly using “extinction” to promote variation in an applied setting (e.g., Duker & van Lent, 1991; Harding et al., 2004; Lalli, Zanolli, & Wohn, 1994) should be interpreted with caution due to their combined use of reinforcement and extinction. This arrangement prevents one from determining whether variability was induced by extinction per se, or whether differential reinforcement played a role. Nonetheless, the applied findings described above are generally consistent with basic laboratory research on extinction and variability. However, it should be noted that although extinction appears to increase variability, it brings with it the potential of unwanted side effects that need to be considered. Extinction has been shown to produce aggressive behavior (e.g., Goh & Iwata, 1994; Lerman, Iwata, & Wallace, 1999), and brings with it an inherent risk of possibly eliminating responding altogether. Thus, although extinction may affect variability, it may not always be a preferred approach in applied situations.

Research on the topic of resurgence may add further support to the hypothesis that extinction induces varied responding (e.g., Epstein, 1985; Lieving, Hagopian, Long, & O’Connor, 2004; Volkert, Lerman, Call, & Trosclair-Lasserre, 2009). Resurgence refers to the recurrence of previously reinforced behavior when another behavior is placed on extinction (Lieving et al., 2004). Chase (2003) argued that resurgence might be conceptualized as the combined effects of response variability and stimulus control. This
interpretation is supported by evidence from Neuringer, Kornell, and Olufs (2001). These researchers studied the variability (equiprobability) of response sequences produced by rats on two response levers. Following a phase during which reinforcement was contingent on repeating a particular sequence, rats were exposed to a condition in which reinforcement was discontinued. This extinction procedure led to a greater distribution of responding across the possible sequences. However, the response sequences that had previously produced reinforcement remained more likely than those that had never been reinforced. The authors described these findings in terms of two seemingly contradictory effects of extinction upon behavior: increased variability, and structural stability. To account for why such an effect might emerge, Neuringer et al. (2001) noted: “It is as if the subjects generally bet on what had worked in the past but occasionally probed to see whether anything better might appear by doing something completely different” (p. 92).

These results are consistent with those described in resurgence research, in which response class hierarchies have been established that appear to determine the pattern of responding during extinction (e.g., Bruzek, Thompson, & Peters, 2009; Harding et al., 2001; Lieving et al., 2004; Shabani, Carr, & Petursdottir, 2009). For example, Volkert et al. (2009) investigated the effects of extinction on problem behavior and functionally equivalent alternative responses for 5 children with autism and developmental disabilities. Following a period during which appropriate responses produced reinforcement, participants were exposed to extinction conditions in which neither appropriate behavior nor problem behavior produced the consequence that had
maintained the problem behavior. Under these conditions, the problem behaviors that had been eliminated re-emerged. The effects of extinction-induced variability and resurgence might account for behavior during problem solving when an organism emits multiple responses until one is successful (Shahan & Chase, 2002; Skinner, 1953).

The pattern of behavior typically observed under extinction can be characterized as variability that is constrained by an existing hierarchy of response probabilities. This notion aligns with Neuringer’s (2009) account of how other naturally occurring phenomena can occur randomly. As an example of “bounded stochasticity,” Neuringer described the way in which genetic mutations occur. These mutations are unpredictable, but are also governed by rules that describe the extent to which particular aspects of the genome can be altered, and the probability that such changes will occur. Resurgence under extinction may be described in similar terms in that responses tend to occur probabilistically (in a somewhat unpredictable fashion), but do so in a manner governed by the organism’s history of reinforcement.

**Intermittent reinforcement.** Behavioral variability has also been observed to increase when responding is placed on an intermittent schedule of reinforcement following a period of constant reinforcement (CRF). However, this finding has been somewhat more equivocal, as researchers have at times produced contradictory results (e.g., Boren et al., 1978; Eckerman & Lanson, 1969; Gates & Fixsen, 1968; Gharib et al., 2004; Herrnstein, 1961; Hoyert, 1992). Lee et al. (2007) presented an overview of this body of research, and identified two competing hypotheses. Some studies have suggested that responding may be more stereotyped (that is, less variable) under intermittent
schedules (Gates & Fixsen, 1968; Herrnstein, 1961). This led to a hypothesis that intermittent reinforcement might entail repeatedly strengthening and weakening responses, such that the variability induced by periods of non-reinforcement repeatedly diminishes and returns. A competing hypothesis, also supported by experimental evidence, is that intermittent reinforcement increases response variability (Boren et al., 1978; Eckerman & Lanson, 1969; Maes, 2003; Tatham et al., 1993). To account for this, Schoenfeld (1968) proposed a two-factor account involving variability induced by periods of non-reinforcement, and adventitious reinforcement of varied patterns of responding. The question of how intermittent reinforcement affects variability may hinge upon whether these schedules function more like extinction (which might increase variability) or reinforcement (which might decrease variability).

Herrnstein (1961) offered evidence that intermittent reinforcement might lead to decreased variability. Using a similar apparatus to the one used by Antonitis (1951), Herrnstein trained pigeons to peck on a 10 in. long response key under CRF and VI schedules. Responses could occur at any point along the key, and variability was defined as the amount of dispersion around a median position. Peck location was more stereotyped (that is, less variable) under the VI schedules of reinforcement than it was under CRF. Gates and Fixsen (1968) reported a similar result with humans. Children who had been classified as mentally retarded were presented with an apparatus that contained eight response keys. Tokens (exchangeable for a variety of preferred items and activities) were delivered for pressing any of the eight the keys, according to one of four schedules: CRF, VI, extinction, and non-contingent (fixed time) reinforcement. Most of
the children distributed responding across all eight keys during the initial CRF training. During subsequent intermittent reinforcement and extinction schedules, patterned responding emerged (i.e. children favored one response key over the others). It should be noted that under the CRF schedule, responding was distributed evenly across the keys, but this may have still occurred in a patterned manner. Children produced distributed responding under CRF conditions by pressing each key in a fixed order, then repeating the pattern. Such a pattern could have been detected by a sequential analysis, but was not apparent in the measure of equiprobability used by the authors. Still, the emergence of increased stereotypy under intermittent schedules appears consistent with Herrnstein’s hypothesis that reinforcer intermittency will decrease variation.

To the contrary, a number of studies have reported that reinforcer intermittency increases variability. Eckerman and Lanson (1969) used a procedure similar to the one employed by Herrnstein (1961). Pigeons were trained to peck along a 10 in. long response key. Following a period of CRF, responses were reinforced on a series of interval schedules, including fixed interval (FI), variable interval (VI), and random interval (RI). Using a measure of central tendency (average deviation from the median position) to assess variability, the authors found increased variation under all of the intermittent schedules compared to CRF. This finding suggests that intermittent reinforcement may induce variability in a manner similar to extinction, as suggested by Schoenfeld (1968). Ferraro and Branch (1968) also failed to replicate Herrnstein’s (1961) finding. Using pigeons in a similar experimental arrangement involving pecks along an 11 cm strip of keys, the authors evaluated the effects of VI and CRF schedules.
Pigeons varied response location more under the intermittent schedule of reinforcement. Gharib et al. (2004) reported additional evidence of this effect in a study that measured variability in the duration of bar presses performed by rats. In successive conditions, the probability of reinforcement following bar presses was systematically manipulated so that food was delivered following 100%, 50%, or 25% of responses. As intermittency increased, the mean duration of bar presses increased, as did the degree to which their duration varied (according to a measure of central tendency). Variability was also found to increase with reinforcer intermittency for humans (Tatham et al., 1993). This study evaluated variation in sequences of responses on two buttons, under a series of FR and VR schedules. For both fixed and variable schedules, the authors found that greater distribution among the possible sequences occurred as ratio size increased. The authors interpreted this as evidence that variability may increase as a function of the time since the previous reinforcement. Taken together, the results of studies on reinforcer intermittency do support the idea that variability can be affected by such schedules. However, they disagree on the direction of that effect. This lack of consistency suggests that although response intermittency may influence variation, it may not be a particularly appealing approach for altering variability in an applied context, where precise prediction and control of this effect may be needed.

**Schedule type.** Evidence related to the effects of different types of schedules (i.e. fixed versus variable, or interval versus ratio) may be useful in explaining the apparently contradictory findings on reinforcer intermittency. McCray and Harper (1962) compared variable and fixed ratio schedules in a study conducted with kindergarten children.
Participants were presented with an apparatus that included four distinct manipulanda: a pump, a chain, a crank, and a doorknob. Responses on any of these would engage a mechanism that sometimes caused a picture of a cartoon character to be displayed on a screen. Under a CRF schedule, children responded repetitively on just one of the four response options. A similar pattern was found under an FR4 schedule. However, a VR 4 schedule produced varied responding, as measured by distribution of responding among the four alternatives. Thus, intermittent reinforcement increased variability when its presentation was somewhat unpredictable (under a variable schedule), but not when it was predictable (as in the fixed schedule).

Boren et al. (1978) compared variability in the distribution of responses on seven concurrently available levers by monkeys under ratio and interval schedules. The monkeys distributed responding more widely across the levers when reinforcement was presented on increasingly long interval schedules. Under FR schedules, as the ratio increased, response distribution became more restricted. Taken together, the evidence on intermittent reinforcement and the effects of different schedule types appear to support the notion that variability can be induced by certain schedules, and restricted by others. However, the mechanism by which this occurs remains somewhat unclear, and competing evidence exists on what conditions give rise to the greatest degree of variation. As a result, induction by intermittent schedules may not be an ideal procedure for applied efforts to address response variability.

**Delayed reinforcement.** Research has also suggested that variability may be induced by the introduction of delays between a response and delivery of a reinforcer.
(e.g., Neuringer, 1991; Odum et al., 2006; Stahlman & Blaisdell, 2011; Wagner & Neuringer, 2006). In a study by Odum et al. (2006), pigeons produced food by pecking right and left response keys to create discrete sequences of four responses. This meant that there were 16 possible response sequences (i.e. LLLL, RRLL, RLRL, etc.) that could be produced on a given trial. In one component of a multiple schedule, the contingencies required that pigeons repeat the sequence RRLL. Initially, food was presented immediately following each sequence meeting this contingency. In subsequent phases, signaled delays between the occurrence of a response and the delivery of reinforcement were introduced that lasted 5 s, 15 s, or 30 s. Compared to immediate reinforcement, variability in response sequences (measured by U-value) increased as delays became longer. To control for differences in the rates of reinforcement under immediate and delayed schedules, an additional comparison procedure was run in which delays of equal length were introduced after reinforcement. Under this schedule, the overall rate of reinforcement was held the same, but the contiguity of reinforcement differed. Variability was unaffected by delays that followed reinforcement, suggesting that it was the disruption of response-reinforcer contiguity by delayed reinforcement that induced variability. Although delaying reinforcement is a strategy that can be readily employed in applied situations, it may lack a certain amount of precision. That is, delaying reinforcement could increase variability, but would not allow the practitioner to specify the degree of variation that is desired in a given situation.

Explicit Reinforcement of Variability
**Lag schedules.** In contrast to the procedures described above, which involved indirectly causing a change in response variability, schedules can also be arranged so that reinforcement depends explicitly upon a predetermined degree of variation (i.e., variability is directly reinforced). One of the simplest ways to reinforce variability is by using a lag schedule (Lee et al., 2007; Neuringer, 2009; Stokes & Balsam, 2001). This schedule was first described in a series of experiments conducted by Page and Neuringer (1985). On each trial, pigeons produced response sequences by pecking left and right keys in an operant chamber. Under a lag $n$ schedule, the current response sequence was reinforced only if it differed from the previous $n$ sequences the bird had performed. Thus, under a lag 5 schedule, a response would be reinforced only if it did not repeat any of the sequences emitted on the previous 5 trials. This lag requirement can be characterized as a moving window, in that comparisons are made between the current response and some number of previous responses.

In one experiment, Page and Neuringer (1985) compared the effects of different lag values on response variability. A series of lag schedules were employed that had windows of 5, 10, 15, 25, and 50 trials. Measures of variability (equiprobability) under each of these schedules demonstrated increased response variation as the lag requirement increased from 5 to 25, followed by a slight decrease in variability when the lag requirement increased from 25 to 50. The first part of this result seems consistent with the idea that lag schedules can exert precise control over variability. More stringent lag requirements would be expected to produce more varied responding. The decrease in variability observed when the lag schedule increased from 25 to 50 appears puzzling at
first, but may be accounted for when one considers an additional side effect of this increased lag requirement. As lag values increased, the probability of reinforcement decreased. This would be expected even if a completely random process were used to produce the sequences. There were 256 possible eight-peck sequences that could be emitted on a given trial. When the lag window was small (as in the lag 5 condition), the probability of a random sequence failing to meet the contingency was fairly low; thus, completely random responding would produce very high levels of reinforcement. When the lag requirement was 50, the probability of a random sequence repeating one of those in the window of recent responses was much higher. Page and Neuringer proposed that this decline in the rate of reinforcement might have had a detrimental effect on variability under the lag 50 schedule, which could account for the fact that variability did not continue to increase past the level produced by the lag 25 schedule.

In another experiment, Page and Neuringer (1985) examined the way that variability produced by lag schedules was affected by altering the number of responses per sequence. The schedule was manipulated so that pigeons performed sequences consisting of 4, 6, or 8 responses during successive phases. For sequences consisting of 4 responses, there were 16 possible combinations of left and right key-pecks (LLRR, LLLR, LRLR, etc.). For sequences of 6 responses, there were 64 possible combinations (LLRLRR, LLLRRR, LRLRLR, etc.). When sequences were 8 responses long, there were 256 possible combinations of left and right key-pecks (LLRRRLRR, LRLRRLRR, RRLLRRRR, etc.). This meant that as the length of the response sequence increased, it was increasingly unlikely that a random generator would repeat recently performed
responses. For a 4-response sequence, there would be a 1 in 16 chance of failing to meet a lag 1 requirement, but for an 8-response sequence, that probability would be 1 in 256. The authors found that rates of reinforcement increased as sequence length increased, as would be predicted by a random process.

A particularly convincing demonstration of operant control occurred in Page and Neuringer’s (1985) fifth experiment. The authors compared variability under a lag 50 schedule and a condition in which the same rate of reinforcement was presented independent of variability (a yoked control phase). This yoked condition made it possible to isolate the potential effects of reinforcer intermittency, and demonstrate that the contingencies per se were responsible for observed increases in variability. Given the evidence discussed above regarding the effects of schedules of reinforcement, the yoked comparison procedure is a particularly useful tool in the study of operant variability. It permits researchers to disambiguate multiple sources of variability, and distinguish between induced and operant effects.

A number of other studies have corroborated the finding that response variability increases under a wide range of lag values, including lag 1 (Bryant & Church, 1974; Esch et al., 2009; Lee & Sturmey, 2006; Napolitano et al., 2010; Schoenfeld et al., 1966), lag 2 (Morris, 1987), lag 3 (Neuringer, 1992), lag 4 (Hunziker, Saldana, & Neuringer, 1996), lag 5 (Abreu-Rodrigues, Lattal, Santos, & Matos, 2005), lag 6 (Ward et al, 2006), lag 8 (Pesek-Cotton et al., 2011), lag 10 (Odum et al., 2006; Ward et al., 2008), and lag 25 (Stokes, 1999). These studies have demonstrated the effects of lag procedures in a range of species, including humans, rats, and pigeons. In addition, they have measured
variation along multiple dimensions, including the sequences of responses on two or more manipulanda, IRT, and the topography of vocalizations.

Several authors have discussed potential mechanisms by which lag schedules might operate (e.g., Machado, 1997; Neuringer, 2004; Stokes, 1995). The procedure seems similar to other forms of differential reinforcement in that a contingency is arranged such that some members of a response class (those that have not occurred recently) are reinforced, while other members of that class (those that have occurred recently) are placed on extinction. Thus, one might hypothesize that both of these component processes (extinction and reinforcement) are essential to the effectiveness of a lag schedule. Unlike traditional schedules of differential reinforcement, the class of responses reinforced in a lag schedule is fluid, in that a given member of the response class has a high probability of producing reinforcement at one point in time (i.e., when it has not been performed recently), but a low probability of producing reinforcement at other times (i.e., shortly after it has been performed). This has led to some debate over the underlying mechanism that could produce varied responding, and whether such a process necessarily indicates a capacity for stochastic (random) behavior (Neuringer, 2004).

Machado (1997) presented one interpretation of how lag schedules might increase variability. In an experiment with pigeons, Machado evaluated a reinforcement schedule that did not explicitly require variability, but rather required that pigeons produce response sequences that included a certain minimum number of changeovers between the L and R keys. The number of key changeovers in an 8-response sequence could range
from 0 (as in LLLLLLL or RRRRRRRR) to 7 (as in LRLRLRLR). A greater number of possible sequences exist that include 3 or 4 changeovers compared to any other number. As a result, under a lag schedule, sequences with three or four changeovers are much more likely to be reinforced. Machado employed a schedule in which reinforcement was always delivered for sequences that included either 3 or 4 changeovers between the keys, and only occasionally delivered for sequences with a different number of changeovers. These contingencies did not explicitly require variability. A single sequence including 3 or 4 changeovers could have been repeated on each trial to produce consistent reinforcement. However, the pigeons in fact distributed their responding variably among multiple sequences. Performance under this schedule closely resembled that observed under lag schedules by Page and Neuringer (1985). This finding suggests that the mechanisms involved in producing varied responding may entail molecular contingencies beyond those explicitly arranged by the experimenter. Also, Machado’s (1997) results illustrate the fact that it is possible for contingencies that resemble those of a lag schedule to produce a similar effect on responding, even if only some components of a traditional lag requirement are included. Also, regardless of whether the underlying mechanism is conceptualized as reinforcement of “switching” or as explicit reinforcement of varied behavior, the basic finding that lag schedules will increase equiprobability has been consistently confirmed.

Neuringer (1991) also discussed the mechanisms by which lag schedules might operate on variability. To test the hypothesis that rats might use a “memory” strategy to meet a lag contingency, Neuringer introduced an interresponse delay between trials. If
rats were relying on their “memory” of recently produced sequences to meet the lag requirement, such a delay would be expected to degrade performance. In fact, the introduction of a delay facilitated success in fulfilling the lag contingency. Variability increased as the delay became longer. This suggests that the process by which the rats were meeting the lag contingency did not involve any strategy similar to memorization. Instead, it appears likely that a truly stochastic process is responsible for variable responding under such schedules. Furthermore, it indicates that induced variability (from delays in reinforcement) may occur within a procedure designed to promote operant variability, having an additive effect on overall levels of variation.

Several applied studies have used lag schedules (e.g., Lee et al., 2002; Napolitano, 2010; Esch et al., 2009). Lag schedules may be particularly well-suited for use in educational or clinical settings, because the rule involved in determining whether or not to deliver reinforcement is relatively simple. An interventionist need only keep track of the number of recent responses specified by the lag window, and compare these to determine if the current response repeats or differs from the other responses in that window. To date, no published studies have employed lag schedules with values greater than one in applied settings. Such schedules have the potential to discourage higher-order stereotypy, which can be reinforced more readily under lag 1 schedules, where a strategy of alternating between just two response options could produce reinforcement on every trial. However, it could potentially prove difficult to implement larger lag schedules (which may be necessary to promote very high levels of variability) in some applied settings due to the number of responses that would need to be tracked on an
ongoing basis. Although a lag 50 schedule can be implemented with relative ease using a computer algorithm, an interventionist such as a teacher might find it impractical to compare each response as it occurs with the previous 50 in order to determine whether it is eligible for reinforcement. One solution to this might be to apply lag schedules over a longer time scale. That is, one might determine which responses fall in the lag window on a session-by-session basis rather than a trial-by-trial basis. Alternatively, hand-held computing devices such as smartphones or PDA’s might be programmed to aid in the management of larger lag schedules.

It should be noted that the terminology of lag schedules has not always been used consistently in applied research on variability. For example, Cammilleri and Hanley (2005) used a procedure they called a lag schedule to reinforce varied activity selections. However, the procedure did not meet the definition of a lag schedule presented above. In each session, 12 activities were available to the students participating in this study. In baseline, no consequences were presented for selecting any of the activities. In the intervention phase, a card exchangeable for teacher attention was presented contingent on the first occurrence of an activity within that session, up until all 12 activities were sampled (at which point the contingency reset such that activities selected already were once again considered “novel”). Although this loosely resembled a lag schedule in that recently performed responses were placed on extinction, and responses not performed recently were reinforced, other key features of a lag schedule were not included. Under the contingencies used by Cammilleri and Hanley, there was no moving window of comparison. Up until the schedule reset, the current selection had to have never occurred
previously during that session in order to produce a reinforcer. When using a traditional lag schedule, the size of the lag window specifies the point at which a previously emitted response becomes once again eligible for reinforcement. That is, if a lag 3 contingency were in place, a rat might perform the response sequence LRLR; if the rat then emits the sequences LLLR, RLLL, and LLRR in three successive trials, the response LRLR would once again be reinforced if it occurred next. In Cammilleri and Hanley’s study, once an activity was selected, it would not be reinforced again during that session (unless the participant made 12 different choices to reset the schedule). It would be inaccurate to describe this contingency as a “lag 12,” because this would imply that only the previous 12 responses were considered in determining whether or not to reinforce a given selection. In fact, the requirement that all 12 activities had to be selected to “reset” the schedule meant that selections made more than 12 responses ago were included in the comparison. In addition, once the schedule was reset, selections did not need to differ from the previous 12 at all. The above critique is not intended to suggest that the contingencies employed by Cammilleri and Hanley were problematic from a clinical perspective. In fact, their results suggest that the procedures were highly effective in increasing variability. However, their use of the term “lag” to describe these contingencies seems problematic. A more accurate description of the contingencies would be to say that they differentially reinforced novel activity selections.

**Reinforcing novelty.** A number of studies have demonstrated that variability will increase when reinforcement is made contingent on novel behavior. Pryor et al. (1969) used such a schedule to reinforce movements performed by porpoises that had never been
previously observed by the trainer. During each session, the first novel response exhibited by the animal was differentially reinforced (by the trainer blowing a whistle that had been paired with the delivery of food) on a CRF schedule, while any movements that had been observed previously were not reinforced. Under these conditions, porpoises learned to perform a variety of novel movements including flipping, tail waving, spinning, spitting, and breaching.

Goetz and Baer (1973) reinforced novel forms of block building in pre-school students. Verbal praise was delivered contingent on the current construction being of a form that had not occurred previously within that session. Compared to conditions where the instructors reinforced repetition, or offered no reinforcement, the novelty contingency resulted in a greater number of novel block forms. Two other studies on creativity employed a similar novelty contingency (Glover & Gary, 1976; Maloney & Hopkins, 1973). Maloney and Hopkins awarded points to students based on the number of unique adjectives, verbs, or sentence beginnings they used in a creative writing assignment, and found more unique examples of each of these when points were contingent upon such novelty. Glover and Gary (1976) employed a novelty contingency during an activity in which students were presented with a noun (a common object), and asked to write down as many “uses” as they could for it. Four different measures of creativity were evaluated for each response: (a) the number of unique uses, (b) the number of different verbs, (c) the number of total words, and (d) the number of never-before-used verbs. Students were informed at the start of each session which of these aspects of creativity was required to earn points. Students increased variability in whichever dimension of creativity was
targeted. Similar results were attained with adult participants by Maltzman, Bogart, and Breger (1958), who found that originality of responses to a word association task was higher following practice sessions which included instructions to vary and praise contingent on novel responses.

The use of a novelty contingency has some apparent advantages for those attempting to alter levels of variability in educational or clinical settings. First, it employs a common sense definition of variability that can be readily explained. Additionally, reinforced novelty appears to be effective in increasing variability whether the contingency is applied across sessions (e.g., Pryor et al., 1969) or within sessions (e.g., Goetz & Salmonson, 1972). The fact that novelty and creativity are related concepts (Marr, 2003) makes such procedures particularly well suited to situations in which it is desirable for the individual to perform a response that has never been observed (such as in creative writing or art). However, there are some potential limitations to such procedures as well. Lee et al. (2007) pointed out that in some cases, a contingency requiring novelty may lead to prolonged periods during which no reinforcement is produced. In spite of the fact that extinction can induce variability, an overly stringent novelty requirement may run the risk of frustrating the student and result in a decrease in responding, especially for those students who have limited behavioral repertoires. As with the lag 50 schedule employed by Page and Neuringer (1985), a requirement of absolute novelty would produce a relatively lean schedule even given truly random response distribution. As with other types of operant procedures, it seems reasonable that
practitioners should carefully consider current levels of novelty, and set the initial criteria for reinforcement in a way that will ensure continued responding.

In a few applied studies, a novelty requirement was apparently employed, but the researcher failed to acknowledge it as such. As described above, Cammilleri and Hanley (2005) labeled their intervention a “lag schedule” when in fact it appears to have been a contingency based on novelty. Betz et al. (2011) used a procedure they describe as “extinction,” which in fact consisted of the differential reinforcement of novel mand frames. Likewise, Lalli et al. (1994) employed a schedule in which reinforcement was contingent upon a response differing in topography from those previously performed, but described it as an example of extinction-induced variability. Also, Harding et al. (2004) used the term extinction to describe a differential reinforcement procedure that was used to increase novel punching and kicking techniques within a martial arts setting. Given the disparity in the way authors have used this terminology, it may be useful to adopt a more standardized approach to categorizing these procedures. It may also be helpful to develop a nomenclature for describing these schedules that would specify the temporal parameters within which novelty is required (e.g., novelty within a session versus novelty over a longer period of time). It is important for applied researchers to be consistent with one another, and with the basic experimental literature in how they use these terms. Being conceptually systematic is a defining characteristic of applied behavior analysis (Baer, Wolf, & Risley, 1968), and may prove to be essential to the development of an effective applied technology related to variability. Semantic confusion between operant
and induced variability may be particularly problematic, given that basic research has suggested these are two distinct processes.

**Relative frequency.** Another procedure that has been used to reinforce variability is the differential reinforcement of responses that have occurred at a relatively low frequency (Blough, 1966; Grunow & Neuringer, 2002; Miller & Neuringer, 2000; Shimp, 1967). Blough’s (1966) study of variability in IRTs employed such a schedule. Each time a rat pressed the lever, the current IRT was assigned to a bin, as described previously. Each bin, then, had a relative frequency defined by the number of previously emitted IRTs that had fallen into that bin. The variability requirement employed in the study stated that reinforcement was contingent on the current IRT falling into the bin with the lowest relative frequency. Additional requirements were included in some phases of the experiment such that the probability of reinforcement given an IRT falling into the lowest-frequency bin was in some cases less than 100%, but a consistent feature of the schedule was the requirement of IRTs of a specified relative frequency. The results indicated that the highest levels of variation (in terms of equiprobability) were achieved when lowest-frequency IRTs were reinforced.

A study by Grunow and Neuringer (2002) investigated the effects of a relative-frequency-based procedure on sequences of responses emitted by rats on 3 manipulanda. A total of 27 three-response sequences were possible on levers L and R, and key K (i.e., LLK, LRK, KRL, etc.), and responses and consequences were programmed through a computer program that assessed variability. Each of the 27 possible sequences was assigned a relative frequency value based on the number of times it had been emitted
divided by the total number of sequences that had occurred. This number was multiplied by a weighting coefficient of .98 following each delivery of reinforcement, so that more recent occurrences of a sequence had greater weight in the calculation. A threshold relative frequency (RF) value was used to determine whether or not to reinforce each sequence that was emitted (that is, the current RF had to be below a predetermined threshold value). Rats were assigned to groups, and each group experienced a different RF threshold. For one group the RF threshold was quite strict, requiring an RF value that was less than .037 (or 1/27). For another group, the RF threshold was more permissive, requiring only that the current sequence have an RF value below .37 (or 10/27). All rats showed some degree of variability under these schedules, but rats with the more stringent RF threshold varied considerably more (as measured by U-value).

Relative frequency has also been used in conjunction with percentile schedules of reinforcement (e.g., Machado, 1992; Miller & Neuringer, 2000; Wagner & Neuringer, 2006). A percentile schedule is one in which reinforcement of a response depends upon that response falling within a specified percentage of recent responses that have been ranked along a specified dimension (see Galbicka, 1994). In an applied study that illustrates this procedure, Lamb, Morral, Kirby, Iguchi, and Galbicka (2004) used a percentile schedule within a program designed to decrease smoking. Daily measures were taken of breath carbon monoxide levels, which served as an indicator of how recently the individual had smoked a cigarette. The experimenters based criteria for the delivery of a reinforcer (a cash bonus) on their 10 most recent breath samples, such that the current reading had to be lower than a specified percentage. If the percentile
requirement was set at the 50th percentile, this would mean that the current measure of breath carbon monoxide would have to fall within the lowest 5 of the 10 most recent responses ranked by value. When these contingencies were in place, the experimenters noted significant decreases in smoking, with most participants achieving breath carbon monoxide levels of less that 4 parts per million, which indicated 24 hours of abstaining from cigarettes. The percentile schedule operated much in the same manner as a traditional shaping procedure in that successively lower levels of carbon monoxide were required as the participants became more successful. However, unlike traditional shaping procedures, the criteria for reinforcement were determined automatically by the participant’s recent behavior. The cut-off value always fell within the range of recently performed responses, ensuring that participants could achieve that target. Interestingly, Lamb et al. (2004) found that more lenient percentile schedules of 30th, 50th, or 70th percentile were more effective at reducing smoking than the more stringent 10th percentile requirement.

In studies of variability, percentile schedules have been used to ensure a consistent rate of reinforcement across conditions. Such schedules have employed variability requirements much like those used by Grunow and Neuringer (2002), in that they are based on calculations of relative frequency (RF). The only difference is that under a percentile schedule, the RF threshold would not be a fixed value predetermined by the experimenter, but would instead be calculated on an ongoing basis according to the organism’s recent behavior. The procedure used by Wagner and Neuringer (2006) illustrates how such a schedule works. Rats produced sequences consisting of three
responses across four manipulanda. The levers and keys were discontinued following their activation to prevent consecutive responses on the same manipulandum (e.g., the sequence LLR would not be possible, but LRX would be possible). This resulted in 36 possible sequences that could be produced. A computer tabulated 36 relative frequency counters that kept track of how many times each sequence had occurred relative to the total number of responses. A weighting coefficient was applied after each reinforcer so that more recent responses had a larger impact on relative frequency counts. Thresholds for reinforcement were determined based on a continually updated ranking of the RF values of the past 25 sequences emitted. Reinforcement depended upon the current sequence having an RF value lower than a specified percentage of these preceding 25 sequences. Three groups of rats were exposed to contingencies requiring high, middle, or low levels of variation. For the high variability group, the current sequence was required to be among the least frequent 20% of the preceding 25 emitted; for the middle group, this percentile requirement was 50%; for the low variability group, sequences only had to fall within the lowest 75%. The results of this schedule were consistent with other findings related to relative frequency in that the more stringent the RF requirement the more variably the rats responded, as measured by U-value. Lee et al. (2007) described percentile schedules as one of several methods for reinforcing operant variability. Although it is true that several researchers have employed such schedules to reinforce variation, it seems problematic to characterize percentile schedules as a method of reinforcing variability per se. It would be more precise to describe these procedures as examples of reinforcing low-frequency behavior (as the percentile schedule was merely
used to automate the process of setting an RF criterion. One reason that percentile schedules have been used in the study of operant variability is that they permit the experimenter to hold the probability of reinforcement constant while the RF criterion for reinforcement changes based on recent performance (e.g., Machado, 1992; Miller & Neuringer, 2000). This has been particularly useful in basic research because it has helped researchers control for the potentially confounding effects of reinforcer intermittency during the operant reinforcement of variability. Percentile schedules have also been employed to protect against the possibility of inadvertently setting an RF criterion that was too stringent (and thus set up extinction-like conditions that would reduce responding). In this regard, percentile schedules could be particularly valuable for researchers attempting to increase variation in individuals who start out with a deficit in variability and require shaping (e.g., Miller & Neuringer, 2000).

Reinforcing variability based on relative frequency has not been common in applied research. Many of the procedures described above are computationally intensive, and would require the application of complex rules and comparisons among large sets of values, making them difficult to implement. Although a computer might be able to track multiple frequency counts simultaneously, this could prove challenging for a human interventionist. However, Duker and van Lent (1991) conducted an applied study which used what could be described as relative frequency contingencies. Six individuals with disabilities who had limited gestural communication skills participated in the study. Initially, all gestural requests were honored, but in a subsequent intervention, those gestures that had occurred the most frequently were placed on extinction while all other
gestural requests were still reinforced. The determination of which responses to place on extinction was made at the start of each treatment phase based on the frequencies that had occurred across the most recent 6 sessions. This intervention led to substantial increases in the number of different requests made (that is, their equiprobability). Although the relative frequency of these behaviors was not assessed on an ongoing basis, as it has been in most laboratory studies employing such a contingency, the principle behind the schedules appears to be the same. By assessing relative frequency across instead of within sessions, some of the potential challenges of computing RF were avoided.

**Stimulus Control**

Some demonstrations of operant variability have also included procedures to establish stimulus control over variation. Page and Neuringer (1985) described such an arrangement in their fifth experiment. Pigeons pecked left and right response keys to produce sequences. The keys could be illuminated with either a red or a blue light. In an initial phase, when the keys were red, reinforcement was contingent on repeating a specific three-response sequence (LRR); when the keys were blue, reinforcement was contingent on eight-response sequences fulfilling a lag 5 schedule. Over the course of several sessions, the sequence length required in the two conditions was manipulated, until eventually each component required sequences of 5 responses (one requiring the sequence LRRLL, and the other operating on a lag 10 schedule). These two conditions alternated (that is, the keys changed color) following every tenth reinforcer. After stable performance was established, the blue and red conditions were reversed, so that red now indicated a lag schedule, and blue indicated that stereotypy was required. Across several
sessions, the pigeons learned to consistently meet these contingencies; they produced highly variable (equiprobable) sequences when the key lights indicated that the lag schedule was in place, and did not vary sequences as much during the condition that required repetition of a single sequence. This finding suggests that the lights came to function as discriminative stimuli (S<sub>d</sub>s), exerting control over response variation. However, there are at least two methodological shortcomings that this study did not address. First, one could interpret the findings in terms of stimulus control of repetition: learning to repeat in the presence of the red light would, by way of contrast, give the impression of greater variation in the presence of the blue light. Second, the effects of the two key lights were never assessed in the absence of their distinctive schedules of reinforcement (that is, under extinction conditions).

Denney and Neuringer (1998) designed an experiment that addressed these methodological concerns, and provided even stronger support for the notion that operant variability can be controlled by discriminative stimuli. Rats responded on two levers to produce sequences of four responses. A multiple schedule was put in place involving a Vary component (in which reinforcement was contingent on sequences falling below a predefined relative frequency threshold) and a Yoked component (in which rates of reinforcement were identical to the Vary component, but were independent of sequence variability). On each trial, a random process was used to select which of these two components would be in place. Trials run under the Vary component were accompanied by the illumination of a light, and the absence of a tone; trials in the Yoked component were accompanied by the absence of the light, and the presence of the tone. Under these
conditions, rats came to emit highly variable response sequences in the presence of the Vary component (i.e., when the light was on), and less variable sequences in the presence of the Yoked component (i.e. when the tone was on). This finding seems to confirm that variability per se was under stimulus control, and that previous findings were not simply due to the effects of reinforcing repetition in the comparison condition. Additional confirmation came from a final phase, in which the authors analyzed the effects of removing the discriminative stimuli. Following a block of sessions under the conditions described above, another block of sessions was run in which the stimuli associated with each condition were withheld. Thus, a given trial still had an equal probability of operating under the Vary or Yoked contingencies, but the tone and light associated with each were never presented. Under these conditions, variability was equal across Vary and Yoked trials (as would be expected given the absence of discriminative cues), and occurred at a level that was in between that observed previously in the Vary and Yoked components. That is, variability in the absence of discriminative stimuli was lower than it was during the signaled Vary condition, but greater than it was in the signaled Yoked condition.

In a more recent study on the topic of operant control of variability, Ward et al. (2008) employed a discrimination reversal procedure. Under this arrangement, an organism is first taught to perform a response in the presence of a stimulus that indicates the availability of reinforcement (S+), and not in the presence of another stimulus (S–). Once performance meets some criterion, the stimulus trained as the S+ becomes the S–, and vice versa. This new arrangement is in place until performance again meets the
specified criterion, at which point the stimuli are reversed again. This process is repeated multiple times, and with successive repetitions, the organism comes to adapt more quickly to these changes in the functions of the two stimuli (e.g., Staddon & Frank, 1974). Ward et al. (2008) attempted to determine if stimuli associated with the contingent reinforcement of variability would operate in a similar manner. Pigeons pecked two response keys to produce sequences of 4 pecks. A multiple schedule was in place that included Vary and Yoked components. In the Vary component, a lag 10 schedule was in place, while in the Yoked component, the delivery of reinforcement was independent of response variability. Each component was in place for blocks lasting however long it took for the pigeon to earn 5 reinforcers. Components alternated in a cyclical fashion (i.e., Vary-Yoke-Vary-Yoke, etc.). Initially, red keylights were used during the Vary component, and green keylights in the Yoked component. These stimuli were subsequently reversed four times over the course of the experiment. The results of this study replicated previous findings in that variability was higher in the Vary component than in the Yoked component. Additionally, variability increased in the Vary component more quickly with successive reversals. In other words, the pigeons became more adept at shifting their pattern of responding when the functions of the two stimuli were reversed. This finding, which is consistent with evidence on stimulus control of other aspects of operant behavior, supports the hypothesis that variation can be brought under the control of discriminative stimuli.

Souza and Abreu-Rodrigues (2010) investigated another aspect of the relationship between stimulus control and variability. Pigeons engaged in a matching-to-sample task
in which the delivery of food was contingent on correctly selecting a stimulus associated with either varied or repetitive responding. A multiple schedule alternated between a Vary condition, in which sequences were required to fall below a specified relative frequency threshold to produce reinforcement, and a Repeat condition, in which responses had to be one of a pre-determined set of target sequences. These components served as the “samples” for a matching-to-sample task that was presented following the completion of a short block of Vary or Repeat trials. White and green keylights were presented. If the pigeon pecked the white light after having just completed the Vary component, this was considered a “matching” response, and resulted in the delivery of food. Errors (i.e., pecking the other key) resulted in a brief blackout of the operant chamber. Following completion of a Repeat component, pecking the green light produced food, and pecking the white light produced a blackout period. Parametric analyses were conducted with regard to the number of sequences potentially reinforced in the Repeat component, and the value of the relative frequency threshold used in the Vary component. When the two components were the most different (that is, a high degree of variability was required in the Vary condition, or a high degree of repetition was required in the Repeat condition), the pigeons readily learned to select the correct key during the matching task. When the difference between the Vary and Repeat components was less pronounced, pigeons did not perform as well on the matching-to-sample task. The results suggest that pigeons can discriminate between variable or repetitive patterns of responding. Interestingly, this suggests that varied and repetitive patterns of responding may themselves be stimuli that can come to serve a discriminative function.
There is very little research investigating stimulus control of variability in humans. However, one would imagine that situations exist in which variability could come under stimulus control in the natural environment (Lee et al., 2007). For example, a person is more likely to engage in varied responding when asked to “do something different” compared to when he or she is asked to “do something similar.” Balsam, Deich, Ohyama, and Stokes (1998) pointed out that behavior that varies under inappropriate stimulus conditions (such as a person shouting random passages from Shakespeare on the subway) tends to be judged as bizarre or maladaptive. Conversely, varied responding under more appropriate stimulus conditions (such as when a painter is creating a piece of artwork) tends to be judged positively. It seems likely that if variability is indeed an operant dimension of behavior in humans, stimulus control of variability will prove essential to developing applications of this technology.

Two recent studies that have not yet been published also support the notion that human response variability is amenable to stimulus control. McClure, Kettering, and Axe (2011) conducted a study with children with developmental disabilities who produced sequences of responses on four colored piano keys. Reinforcers were delivered according to a multiple schedule that included Vary and Repeat components. Under these conditions, children learned to vary in the presence of the stimulus associated with the vary component, as measured by the percentage of trials on which participants met the variability requirement.

Likewise, in an unpublished study, Miller, Neef, Meindl, and Ivy (2012) found that college students playing a computer game responded with greater levels of variability
(as indicated by U-value) when the termination of an unpleasant sound was contingent on fulfilling a lag 3 contingency than when its termination was contingent on repeating one of the three most recent responses. Distinctive background colors were associated with the Vary and Repeat components during blocks of training trials. Subsequent blocks of trials were run during which the Vary and Repeat components were presented in a random order as in Denney and Neuringer (1999). Most participants showed evidence of stimulus control, in that responding was more varied in the presence of the Vary stimulus than in the presence of the Repeat stimulus. In another phase, these discriminative stimuli were eliminated altogether, so that each trial required either variation or repetition, but no signal indicated which would be reinforced. For participants who developed strong stimulus control during training, the elimination of the signals led to decreased variability in the Vary component, and increased variability in the Repeat component, suggesting that the distinctive background colors did function as discriminative stimuli. No studies to date have investigated stimulus control of variability in the context of addressing socially significant behaviors in an applied situation. However, it stands to reason that this principle could be useful in the development of an applied technology of operant variability. The contexts in which we want individuals to vary may be distinguishable from those in which repetition is adaptive. As a result, there may be an advantage to contingencies that promote variability in the presence of discriminative stimuli. This approach permits an interventionist, or teacher, to specify precisely those circumstances in which variability is and is not desired.
Generalization and Operant Variability

**Generalized variable responding.** In an article about the scientific study of originality, Maltzman (1960) asked: “How can the reinforcement of one bit of uncommon behavior increase the frequency of other uncommon behaviors which by definition are different?” (p. 231). This question articulates an important theoretical puzzle for researchers investigating the operant control of variability. In order for these procedures to be viable educational or clinical tools, it is essential to understand how variation generalizes to novel situations. The use of procedures that generalize across settings and behaviors, and that produce lasting effects is considered a hallmark of applied behavior analysis (e.g., Baer et al., 1968). One way of considering the generalization of varied responding is to view *varying* as a skill that can be applied broadly across multiple stimulus conditions (Neuringer, 2002). Just as researchers have taught children to engage in “generalized matching” (e.g., Baer & Sherman, 1964) or “generalized imitation” (e.g., Young, Krantz, McClannahan, & Poulson, 1994), it might be possible to use operant procedures to teach “varying” as a basic strategy, which can subsequently be used in novel situations.

**Operant variability as an aid to problem solving.** One way of considering the generalization of varied responding is in terms of its utility in promoting the acquisition of novel behaviors to deal effectively with changing environmental contingencies. Chase (2004) discussed the similarity between generalized variation and Skinner’s (1953) proposal that with repeated experience, an individual might “learn to learn.” Some experimental evidence supports the notion that exposure to contingencies that promote
variability may promote the subsequent acquisition of novel responses (e.g., Grunow & Neuringer, 2002; Joyce & Chase, 1990; Parsonson & Baer, 1978; Stokes, Lai, Holtz, Rigsbee, & Cherrick, 2008). Grunow and Neuringer asked how differing levels of operant variability would affect the learning of a specific (and uncommon) response sequence. Rats were initially exposed to one of four variability requirements in which the relative frequency thresholds ranged from low (.037) to high (.37). Then, an additional contingency was put in place such that emitting a specific response sequence would produce augmented reinforcement in the form of three food pellets, making it the most adaptive response alternative. The variability contingency was in place concurrently, and produced a leaner schedule (i.e., a single food pellet). Rats who were exposed to the most stringent variability contingency acquired an uncommon target sequence (LKK) more quickly than those exposed to a less stringent variability requirement. This result makes sense when one considers that the shaping of novel forms of responding depends upon the production of sufficiently varied responses from which novel forms can be selected. The rats that were engaging in the highest levels of variability may have been able to acquire the novel response sequence faster because it was already occurring occasionally within their repertoire.

In a related study, Stokes et al. (2008) studied the effects of different variability requirements on subsequent performance of a novel task. College students pressed the left and right arrow keys on a keyboard to move a light from the top to the bottom of a pyramid displayed on a computer monitor. The students were divided into three groups, each experiencing a different type of training. For the Location-only group, sequences
were reinforced only if they resulted in the light reaching a specified location along the base of the triangle. For the Lag group, sequences had to both end at a specified location, and also differ from those emitted on the previous $n$ trials. The size of the lag requirement ranged from 1 to 3 across different blocks of trials. The Alternating group experienced the Lag and Location-only contingencies on successive alternating trials. Following several training trials, all groups were exposed to a novel “transfer” task. The novel task consisted of a different (smaller) triangle, and one of three requirements: ending in a specific location, meeting combined location and lag requirements, or varying location. The authors found that both the Lag and Alternating groups produced more varied sequences, and that this in turn facilitated learning of the novel task.

The results of one study that failed to produce the effect discussed above (Maes & van der Goot, 2006) suggests that there may also be some conditions in which variability will not promote the acquisition of novel behavior. Concurrent contingencies were in place to reinforce varied responding in adult humans creating sequences with a keyboard, and also to reinforce one specific target sequence. Unexpectedly, the reinforcement of varied responding appeared to prevent rather than facilitate the emergence of the target sequence. In a discussion of these results, Neuringer (2009) suggested two likely reasons for this study’s failure to replicate Grunow and Neuringer’s (2002) findings. First, the study did not differentially reinforce “correct” sequences any more than sequences meeting the variability contingency, which may have inadvertently strengthened sequences other than the target (that is, variability produced the same level of reinforcement that could be achieved by repeating the single target sequence). Second,
Maes and van der Goot included instructions for their participants that implied that the goal of the game was to discover the “correct” sequence, which may have influenced responding. In humans, variability can be influenced not only by contingencies of reinforcement, but also by verbal rules. Souza, Pontes, and Abreu-Rodrigues (2012) illustrated this point in a study in which college students produced sequences of responses on a keyboard. Depending on which group they were assigned to, students were given instructions to create a rule to follow, asked to produce sequences at random, or simply given general instructions about the task. Sequences then produced points, exchangeable for prizes, contingent on fulfilling both a lag 2 and a relative frequency requirement. Although all groups increased variability according to equiprobability (U-value), patterns were identified in the order of sequences produced by the group told to use a systematic rule, but not those told to create sequences at random. The group receiving no instruction about the creation of rules included some participants who appeared to select sequences randomly, and others who seemed to follow a predictable rule.

The finding that variability can promote the acquisition of novel responses is consistent with research on a phenomenon called contextual interference, which states that practicing skills in varied ways results in better acquisition. For example, Hall, Domingues, and Cavazos (1994) compared the effects of three types of batting practice on the eventual performance of baseball players in a game-like situation. Those players who practiced hitting blocks of 15 pitches in a row of a single type (fastballs, curveballs, or change-ups) did not do as well as players who practiced the same number of each type
of pitch, presented in a random order. Similarly, Mayfield and Chase (2002) demonstrated that practicing mathematics problems in blocks of a single type of problem was less effective than practice in which various problem types were interspersed. It may be that practicing variation facilitates later performance that demands either variability, or the discovery of a novel solution to a problem. Taken together, the evidence on variability and problem solving suggests that “learning to vary” may be an important educational goal. If students become more adept at varying, they may be able to adapt to changing environmental conditions, and demonstrate the kind of “flexibility” that is valued in academics as well as other domains. However, additional research is needed to explore how to best promote skill transfer in this manner.

**Stimulus generalization and response variability.** A small number of applied studies have investigated the question of whether operant variability, once learned, will transfer across situations (Harding et al., 2004; Holman et al., 1977; Lee et al., 2002; Parsonson & Baer, 1978; Napolitano et al., 2010). Holman et al. (1977) conducted a series of experiments in which novel responses were differentially reinforced during one activity, while variability was also measured concurrently during other activities. In their first experiment, two preschool boys were asked to paint pictures on an easel; during a baseline phase, no reinforcement was delivered, but in a subsequent condition, praise was contingent upon the production of a novel form. Possible unique forms included lines of differing orientations, colors, shapes, patterns, zigzags, and several other topographies. Forms were considered novel if they had not appeared previously on a given painting. The same children were also asked each day to engage in a block-building task. The
researchers assessed the number of novel forms produced during the block activity, but never gave any feedback on variability during that task. Although variability increased during the easel painting activity, this did not appear to have any effect on block building, indicating a lack of generalization. In their second experiment, two other preschool boys served as participants, and response variability was evaluated during four different activities (drawing, painting, block building, and Lego building). When reinforcement (praise) was delivered during the drawing activity contingent upon novel picture forms, concurrent increases in form diversity were observed during painting, but not during the block building or Lego activities. Thus, generalization occurred for a topographically similar task, but not for tasks that were dissimilar. This suggests that the degree of generalization that can be expected following explicit reinforcement of variability might depend in part upon the similarity between the responses being produced.

Harding et al. (2004) evaluated the degree to which variability transferred between “drilling” and “sparring” settings for individuals practicing martial arts. In various phases, contingencies were in place to differentially reinforce novel topographies of either kicking or punching. These were applied exclusively during training drills in which punches and kicks were practiced in a discrete trial format. The contingencies led to greater diversity in the number of different kicks or punches performed during the drills, and also during separate sparring sessions. In this case, the responses required in the training and generalization settings were the same, confirming the finding described by Holman et al. (1977) regarding transfer of variability between topographically similar responses.
Both the Harding (2004) and the Holman et al. (1977) studies were limited in that they only measured generalization across settings rather than explicitly programming for it. As Stokes and Baer (1977) argued, it may be unwise for behavior analysts to rely on a “train and hope” strategy when promoting the generalization of treatment effects. Instead, it may be necessary to adopt procedures explicitly designed to encourage the transfer of behavior changes across settings, and across behaviors. Lee et al. (2002) presented evidence of one method that might promote generalization of varied responding, in a study in which three boys diagnosed with autism served as participants. Variability of vocal responses to experimenter questions was measured both in the training setting and in probes conducted under two different generalization conditions: one that utilized the same location with a different therapist, and the other took place in a different location with the primary therapist. During training sessions, a lag 1 schedule was in place. During the generalization probes, the therapist never explicitly reinforced variability. Using these conditions, the authors were able to evaluate both generalization across settings, and generalization across instructors. The authors found a high degree of co-variation between variability in the training settings and in the two generalization settings. When variability increased in the training setting, it also increased in the generalization setting. A key factor in this generalization may have been the fact that similar stimuli were present in the training and generalization environments. When the location changed, the therapist was kept constant; when the therapist changed, the location was kept constant. In this sense, Lee et al. programmed common stimuli into the
two environments, which is a method that has been demonstrated to promote
generalization of other types of learning (Cooper et al., 2007; Stokes & Baer, 1977).

Although some evidence exists to support the notion that variability can
generalize across settings, additional research is needed to determine the methods that
would be the most effective in achieving this. It is possible that the kind of
generalization across settings that is desirable in many applied situations could be
promoted through the use of certain stimulus control procedures. If stimuli can be
established that will reliably evoke varied or repetitive responding, these discriminative
cues can be programmed across multiple situations, and promote variation in novel
settings. Woods (1987) illustrated this approach to promoting generalization in a study in
which children with autism were taught to perform specific play skills using either
naturalistic antecedents (which would be common across training and generalization
settings) and using contrived instructional antecedents that were unique to the training
environment. Students were more successful at performing the play tasks in the
generalization setting when training occurred using the same antecedent stimuli.
Although this study did not explicitly address variability, it may be reasonable to
extrapolate from this and related research (e.g., Haring, Breen, & Laitinen, 1989;
Stromer, MacKay, & Remington, 1996) that establishing stimulus control over variation
and repetition might facilitate generalization across settings.

Variability and Autism

Children who are diagnosed with autism engage in restricted or stereotyped
behaviors (American Psychiatric Association, 2000). This suggests some impairment in
the way these individuals vary their behavior (either in terms of the degree of such variation, or the extent to which it occurs in the appropriate context). Frith (1972) presented evidence of such impaired behavioral variability. Children with autism and comparison children without autism were asked to produce patterns using either colored stamps or notes played on a xylophone. The response sequences were analyzed according to their complexity, rule adherence, and originality. Children with autism produced sequences that were deemed less original, and were more likely than the comparison children to restrict responding to only some of the available colors or notes. Mullins and Rincover (1985) described a similar result from an experiment in which children with and without autism were exposed to an experimental arrangement involving five concurrent schedules of reinforcement (ratio schedules that ranged from CRF to FR 11). Unlike children in the control group, some of the children with autism failed to sample all of the response options, and as a result did not maximize rates of reinforcement. In this situation, the failure of children with autism to vary their responding contributed to maladaptive patterns of restricted responding (in that more favorable schedules were available, but were never experienced).

Operant variability procedures for individuals with autism. If autism involves a deficit in variability, operant procedures that can increase response variability may be valuable in remediating some of the challenging behavior associated with the disorder. Miller and Neuringer (2000) explicitly investigated the question of how such operant procedures affect behavioral variability in individuals with autism. A group of adolescents diagnosed with autism, and control groups consisting of adults and children
without autism, were asked to press two buttons to produce 4-response sequences.
Levels of variability were compared during a Vary procedure in which variability was
reinforced based on a percentile schedule that differentially reinforced sequences with
lower relative frequencies, and a Yoked procedure in which reinforcement was delivered
with the same probability, but did not depend on variation. Individuals with autism
produced less varied sequences than the other two groups (confirming the hypothesis that
autism is characterized by restricted variability). However, for all participants, including
those with autism, variability increased during the Vary condition. This indicates that
individuals with autism can vary their behavior when the environment is arranged to
provide reinforcement for doing so.

Several applied studies have explored the clinical utility of reinforced variability
in the treatment of autism (Esch et al., 2009; Lee et al., 2002; Lee & Sturmey, 2006;
Napolitano et al., 2010). Lee and Sturmey (2006) used a lag 1 schedule to differentially
reinforce varied (and appropriate) responses to the social question “What do you like to
do?” Three adolescents diagnosed with autism participated. In the absence of the lag
requirement, these young men emitted very few novel appropriate responses. Following
the introduction of the lag 1 schedule, varied responses to the social question increased
for two of the three participants. Using an ABAB design, the authors demonstrated a
functional relationship between the lag contingencies and response variability.

Betz et al. (2011) evaluated variability in mand frames (e.g., “I want ____,” “I
need _____,” etc.) emitted by young children with autism under various reinforcement
contingencies. Auditory script prompts that were combined with differential
reinforcement of novel mand frames (that is, reinforcing only the first instance of a given mand frame), resulted in more varied behavior. Likewise, Grow et al. (2008) described a procedure that differentially reinforced the varied use of mands by three individuals with autism who engaged in problem behavior. The increased variation produced by this schedule facilitated the acquisition of appropriate communicative behavior.

In another applied study, Newman, Reinecke, and Meinberg (2000) evaluated a self-management procedure designed to increase varied responding in individuals with autism. Baseline observations indicated that three children with autism engaged in restricted responses in specific situations. For one student, this was playing with toys; for another, it was answering social questions; for the third, it was a drawing activity. During an initial training period, students were given praise and tokens contingent on novel appropriate responses to an experimenter’s prompts to engage during the target activity. After six sessions of prompting, the experimenter faded the use of praise, and the students instead awarded themselves tokens when they engaged in varied responses (i.e., self-reinforcement). The children engaged in a greater number of novel responses following the implementation of the self-management procedure. Additionally, this increase in variability persisted during a one-month follow-up. This study is notable both for its examination of variability in autism, and its successful use of self-management to promote the maintenance of varied responding.

Although the existing evidence on operant procedures to increase variability in individuals with autism is relatively strong, there remain several unanswered empirical questions regarding this population. First, the effects of lag schedules greater than lag 1
have yet to be evaluated; given Page and Neuringer’s (1985) findings, it would seem likely that a higher lag requirement would lead to a greater increase in variability. As Lee et al. (2007) explained, individuals with autism may sometimes exhibit higher-order stereotypy; in other words, they may fulfill a variability requirement by emitting a repetitive sequence of responses, rather than behaving in a truly unpredictable manner. To date, no research has been conducted on either how higher-order stereotypy is acquired, or how it might be discouraged. Finally, the issue of stimulus control of varied responding has been studied only in a limited fashion with individuals with autism. The one study that has examined this issue (McClure et al., 2011) did so in a contrived context of performing sequences of button-presses. Thus, the utility of stimulus control as an applied tool with this population remains unexamined. Also, the McClure et al. (2011) study did not use a yoked control comparison, but instead compared variability under a lag schedule with performance under a schedule requiring repetition of a single response. Thus, their demonstration of stimulus control was somewhat ambiguous, as the results could be interpreted to mean that repetition, not variation, was under stimulus control.

Teaching play skills to individuals with autism. Many children with autism present deficits in the development of play skills, and are described as lacking spontaneous, creative, or imaginative kinds of play (Baron-Cohen, 1987; Lu et al., 2010; Terpstra et al., 2002; Wing et al., 1977). The kind of play that does typify individuals with autism has been described as being excessively repetitive, and lacking in originality or complexity (Craig & Baron-Cohen, 1999; Honey, Leekam, Turner, & McConachie,
2006; Jarrold, Boucher, & Smith, 1993; Lewis & Boucher, 1988). As a result, the teaching of play skills has been a subject of considerable interest to applied researchers (Stahmer, Ingersoll, & Carter, 2003). Lang et al. (2010) investigated the relationship between repetitive behaviors and the development of functional play skills in children with autism. Participants were exposed to an abolishing operation (free access to an automatically reinforced repetitive response) prior to some teaching sessions in which play skills were targeted. When the abolishing operation was implemented, there was a decrease in repetitive behavior, and an increase in appropriate play during the subsequent training session. The authors interpreted this finding as evidence of an inverse relationship between repetitive responding and play. An alternative to decreasing repetitive responding might be to explicitly target variation, a pattern that is incompatible with repetition, and consistent with many desired features of play such as diversity, flexibility, and spontaneity (Brown & Murray, 2001).

One important example of operant variability being applied to the teaching of appropriate play is a study mentioned previously by Goetz and Baer (1973). In one of the earliest applied examples of reinforcing varied responding by humans, the authors increased the diversity of block forms created by typically developing children by making praise contingent upon the creation of novel block forms. To achieve this, the experimenters first developed a list of potential structures, ranging from simple towers to arches and enclosures. The structures included in each episode of block-building were catalogued, and during the novelty phase, praise was delivered only if the current
arrangement of blocks included structures that were novel for that session. This procedure was effective for typically developing children.

Napolitano et al. (2010) investigated the use of a similar procedure with children with autism, for whom increased variability of block play might be an even more socially significant goal. In this study, the authors employed a lag 1 schedule. Children were given a set of interlocking plastic blocks of differing colors. Variability was defined according to the patterns in which the blocks were combined (both in their form and in the colors used). Each time a child placed another block on the structure, the experimenter made a determination of whether that most recent block was “variant” or “invariant” in relation to the immediately preceding forms. For all six participants, the contingent reinforcement of variability led to an increase in the number of novel forms created compared to the structures built during either the baseline phase, or a reversal phase in which the lag contingencies were removed. This study also included a generalization phase, in which the experimenters presented the participants with a novel set of blocks (wooden instead of plastic). Although the lag 1 schedule did increase variability in block play with the targeted materials for all participants, only one of the six children showed a similar increase in variability with the novel materials.

**Conclusion**

Existing research on operant variability suggests that it is possible for a wide range of organisms to learn to vary their behavior. Furthermore, this variability can come under the control of specific environmental stimuli. In order for such learned variability to be clinically meaningful, it is essential that changes in behavior also generalize across
stimuli. One way to promote generalization of operant variability may be through the establishment of classes of stimuli that evoke varied or repetitive responding. Children with autism often demonstrate a lack appropriate stimulus control over variability, but appear to be sensitive to contingencies that explicitly reinforce variation. A key experimental question, then, is whether stimulus control over variation and repetition can be established with these populations, and whether that learning can then generalize to untrained situations. Creative or non-repetitive play has been identified as an area of deficit for individuals with autism, and play thus represents a group of behaviors particularly in need of increased variability. In this study, I investigated the effects of lag schedules and stimulus control procedures on the variability of forms built by children with autism while playing with blocks, and also measure the extent to which such procedures can promote generalization to a novel play task.
Chapter 3: Study Methods

Participants and Setting

Participants were recruited from a private school for children with autism. The students were all part of a classroom that focused primarily on teaching early pre-academic, social, and play skills in a one-on-one format. The classroom teacher was asked to identify a list of potential participants who would be capable of building with blocks, but lacked functional play skills. A letter was sent home to each of these student’s parents describing the proposed study and asking for consent to allow the child to participate, and students were read a brief script describing the activities and asking them if they wanted to participate (see Appendix A).

Three students met all of these criteria and were included in the study. All were Caucasian boys. All presented significant intellectual disabilities, and occasionally engaged in problem behavior (aggression, property destruction, or tantrums) at school; for all three, current Individualized Education Plan (IEP) goals focused primarily on teaching basic learner readiness and functional living skills. Don was an 8-year-old diagnosed with autism, who was described by his teacher as rarely engaging in play independently without prompting. His communication skills consisted of a limited requesting repertoire, and vocal imitation. Reed was a 7-year-old diagnosed with autism and a developmental delay, who was described by his teacher as engaging in mostly non-functional and repetitive forms of play. His communication skills included a limited repertoire of vocal requests, although most of his vocal output consisted of echolalia. Pete was a 9-year old diagnosed with autism who was identified by his teacher as having
very little interest in most play activities, spending most of his free time engaging in repetitive, non-functional play with leisure items. Pete did not engage in any vocal verbal communication, but would occasionally make requests for preferred activities or items using gestures or picture exchange.

All experimental sessions took place in a well-lit classroom in which there were a table, chairs, and a variety of toys and games. On the table, there was a white piece of paper (21 cm x 29.7 cm) taped to the surface in front of the chair in which the participant sat. The experimenter and student sat in adjacent chairs at the table during all sessions.

**Equipment and Materials**

Materials used during sessions differed across students and across different phases of the experiment. For Reed and Pete, the primary materials used were a set of wooden blocks consisting of fourteen pieces, including four cubes (2.9 cm x 2.9 cm x 2.9 cm), four long flat rectangular blocks (2.9 cm x 1.4 cm x 8.9 cm), four thick rectangular blocks (2.9 cm x 2.9 cm x 6 cm), and two triangular blocks (3.8 cm x 2.9 cm x 6.4 cm). See Figure 3.1 for a photograph of the full set of blocks. During experimental sessions, these blocks were arranged in a random fashion next to the white piece of paper, so that the experimenter could clearly distinguish which blocks had been placed during construction. The blocks were plain wood with a glossy finish. Unpainted blocks were selected over blocks of differing colors in order to isolate the topography of the forms being built, and eliminate block color as a variable.
For Don, the primary materials came from the Easy-Grip Jumbo Pegs and Pegboard set manufactured by Lakeshore, and consisted of an orange foam rubber pegboard (21.3 cm x 21.3 cm) with a 5 x 5 array of evenly spaced holes (with 0.7 cm diameters), and four blue hard plastic pegs (see Figure 3.2). The pegs had a circular top (3.3 cm diameter) that sat on top of a cylindrical base (0.8 cm diameter) that fit snugly into the holes of the pegboard. The pegboard was placed directly on the white piece of paper in front of the student, and the four pegs were stored in an open-topped cardboard box (10.2 cm x 10.2 cm x 20.3 cm) placed next to the paper.
During generalization sessions, all participants were presented with a single sheet of standard 21 cm x 29.7 cm paper with two square frames (7 cm x 7 cm) printed on it in black ink, and four sponge-tipped paint bottles containing red, green, yellow, and purple paint (see Figure 3.3). The bottles of paint were opened before the session by the experimenter and were arranged in random order in a line directly above the paper prior to each trial. Additional materials present in the room included two digital cameras (a video camera mounted on a tripod near the table, and a still camera held by the experimenter), datasheets, writing implements, and a variety of food and toys.
Prior to any engagement in the targeted play tasks, the experimenter conducted a brief preference assessment using a Multiple Stimulus Without Replacement (MSWO) procedure (DeLeon & Iwata, 1996). A set of five edible items was selected by the experimenter for each student based on teacher input about the student’s eating habits and the child’s dietary restrictions. For Don, these consisted of a piece of shortbread cookie, a pretzel, a piece of Trix cereal, a piece of licorice, and an M&M candy. For Reed, they included a veggie snack stick, an almond, a pretzel, a yogurt covered pretzel, and a potato chip. For Pete, the five items were a gummy bear, a piece of Trix cereal, a Skittles candy, a Teddy Graham cracker, and an M&M candy. The five items were presented to the student in a horizontal array along with the instruction “pick one.” After the student selected and consumed one item, this item was scored as “1” and the remaining items were rearranged and presented again (within 15 s of the student consuming the chosen...
item). This process was repeated, scoring items by rank until all items were gone. Then a second and third presentation of the five-item array were conducted in the same manner, yielding a total of three rankings of the students’ preference for the five items. These scores were added together, and items with the lowest scores were considered to be more highly preferred. The top one or two items were then selected as potential primary reinforcers to use with that student. For Don, the most preferred item according to the MSWO was a shortbread cookie; for Reed, it was a veggie snack stick; and for Pete, Skittles and M & M candies were selected. Additional activities had to be identified as potential reinforcers for Don and Reed, due to a decrease in motivation to work for the food items alone over the course of the study. To assess preference for these activities, students were presented with a variety of toys and items, selected based on observations of the students during free time and recommendations from the teacher regarding preferred leisure activities. The experimenter then measured how long they engaged with each choice. Activities that students would engage with for a minimum of 1 min across multiple opportunities were selected as potential reinforcers. For Don, these included swinging, jumping on a trampoline, and playing with a plastic pin toy. For Reed, additional reinforcers included jumping on a trampoline, spinning in an office chair, and playing with tops.

**Dependent Variable**

The appearance of the block structures (for Reed and Pete) and pegs on the pegboard (for Don) served as primary measures of student behavior during the initial portion of the study; the sequence of colors painted on the two squares was used to
measure student responding during the generalization phase. The pegboard was selected for Don as a substitute for the block building activity after initial attempts to have him build with blocks were unsuccessful. Inserting pegs into a pegboard, which Don would already do readily, was selected as an alternate activity in which variability could be targeted. During sessions, the experimenter classified each response immediately after it was completed, writing this information on a data collection form (see Appendix B). On this form, the experimenter also recorded which antecedent stimulus was presented at the start of that trial, which experimental condition was in place, and what consequence was presented.

In order to determine the degree to which responses varied in topography, the block structures built by the participants were categorized as being one of 17 different forms. An initial list of forms was developed based on those described by Goetz and Baer (1968). Some forms listed in that study were not included due to the different number and shape of blocks available to students in the current study. Unlike Goetz and Baer, who used a system in which a single structure could fit into multiple categories of block forms, the categories used in this study were exclusionary, in that a form would be classified as fitting only one of the 17 categories. This was done in order to permit a clearer definition of response variability, and to better capture the ways in which block structures made from this finite set of blocks could potentially differ. Table 3.1 contains a list of the 17 block forms and a description of each; Appendix C contains photographs illustrating each of these forms.
Table 3.1. List of Block Forms and Descriptions

<table>
<thead>
<tr>
<th>Block Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance</td>
<td>A single structure including a long flat rectangular block perched horizontally atop either a square or a vertically oriented rectangular block.</td>
</tr>
<tr>
<td>I</td>
<td>A single structure including a long flat rectangular block placed horizontally with a narrow stack on top of it, with another horizontal flat block on top.</td>
</tr>
<tr>
<td>Post</td>
<td>A single structure including a long flat rectangular block with either a stack of two or more squares, or a vertical rectangular block on top.</td>
</tr>
<tr>
<td>Single Stack</td>
<td>A single structure in which a group of blocks are stacked on top of each other, but no other forms (e.g., Balance or Post) are present.</td>
</tr>
<tr>
<td>Post &amp; Balance</td>
<td>A single structure that contains both the Post and Balance forms.</td>
</tr>
<tr>
<td>Double Wide Stack</td>
<td>A single structure in which two or more blocks are placed adjacent to one another (touching).</td>
</tr>
<tr>
<td>Enclosure</td>
<td>A single structure in which four or more blocks are arranged adjacent to one another so that they form an enclosed shape (e.g., a square).</td>
</tr>
<tr>
<td>Arch</td>
<td>A single structure that consists of two blocks with a gap between which are spanned by another block placed atop them.</td>
</tr>
<tr>
<td>Fence</td>
<td>A single structure in which four or more blocks are placed adjacent to one another (not on top of each other), to form a line.</td>
</tr>
<tr>
<td>Floor</td>
<td>A single structure consisting of two or more long flat rectangular blocks laid horizontally adjacent to each other to form a base.</td>
</tr>
<tr>
<td>Multi Stack</td>
<td>Two or more stacks of blocks (non-adjacent) that contain no other forms (e.g. Balance or Post).</td>
</tr>
<tr>
<td>Multi Stack &amp; Balance</td>
<td>Two or more stacks of blocks containing at least one Balance form.</td>
</tr>
<tr>
<td>Multi Stack &amp; Balance &amp; I</td>
<td>Two or more stacks of blocks containing both Balance and I forms.</td>
</tr>
<tr>
<td>Multi Stack &amp; I</td>
<td>Two or more stacks of blocks containing at least one I form.</td>
</tr>
<tr>
<td>Multi Stack &amp; Post</td>
<td>Two or more stacks of blocks containing at least one Post form.</td>
</tr>
<tr>
<td>Multi Stack &amp; Post &amp; Balance</td>
<td>Two or more stacks of blocks containing both Balance and Post forms.</td>
</tr>
<tr>
<td>Multi Stack Post &amp; I</td>
<td>Two or more stacks of blocks containing both Post and I forms, but no Balance forms.</td>
</tr>
</tbody>
</table>
Similarly, the patterns of pegs placed on the pegboard were categorized according to 17 discrete forms, comprising all possible permutations of placing four pegs on the 5 x 5 grid. Table 3.2 contains a list of the 17 peg forms and a description of each. Appendix D contains diagrams illustrating these different forms.

To measure responding during the painting task, the experimenter used a code to document the colors of paint used in the left and right squares. Colors were coded “R” for red, “G” for green, “P” for purple, and “Y” for yellow. The first letter of the code indicated the color in the left square, and the second letter indicated the color in the right square. Thus, if the student used green in the left square and yellow in the right square, it would be coded as “GY”; if the student used red in the left square and red in the right square it would be coded as “RR.” There were 16 possible permutations of coloring the two squares using the four colors of paint. The same datasheet was used to record the color patterns participants produced in the painting task as was used to track forms produced with the blocks and pegs.

**Measures of variability.** Two measures of variability were used to determine the degree to which participants had varied their responding. U-value was calculated for each phase by tallying the number of times each of the 17 possible block or pegboard forms occurred, and entering these values into the following formula:

\[
U\text{-value} = - \sum_{i=1}^{17} \frac{\alpha_i \times \log(\alpha_i)}{\log(17)}
\]

The variable labeled \(\alpha_i\) refers to the number of times each of the 17 possible forms occurred. These 17 different \(\alpha\) values \((\alpha_1, \alpha_2, \alpha_3 \ldots \alpha_{17})\) were transformed through this
Table 3.2. List of Peg Forms and Descriptions

<table>
<thead>
<tr>
<th>Peg Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Line</td>
<td>Four contiguous pegs creating a single horizontal line.</td>
</tr>
<tr>
<td>Vertical Line</td>
<td>Four contiguous pegs creating a single vertical line.</td>
</tr>
<tr>
<td>Diagonal</td>
<td>Four diagonally contiguous pegs creating a line.</td>
</tr>
<tr>
<td>Square</td>
<td>Two sets of adjacent pegs on top of one another, to form a two by two square.</td>
</tr>
<tr>
<td>L</td>
<td>Three pegs in adjacent line, with a fourth peg that is adjacent at a right angle to the line intersecting at one end.</td>
</tr>
<tr>
<td>2 + 1 + 1</td>
<td>Two adjacent pegs, and two pegs that are not adjacent to any others.</td>
</tr>
<tr>
<td>3 + 1</td>
<td>Three adjacent pegs in any formation, and one peg that is not adjacent.</td>
</tr>
<tr>
<td>2 + 2</td>
<td>Two sets of adjacent pegs that are separated.</td>
</tr>
<tr>
<td>Angle</td>
<td>Four adjacent pegs forming a straight line intersecting with a diagonal line.</td>
</tr>
<tr>
<td>Diamond</td>
<td>Four pegs that are diagonal to one another, forming a diamond with an empty space in the center.</td>
</tr>
<tr>
<td>T</td>
<td>Three adjacent pegs forming a line, with a fourth peg that is adjacent at a right angle, intersecting at the center of the line</td>
</tr>
<tr>
<td>Zig-Zag</td>
<td>Two sets of adjacent pegs that are contiguous, and parallel, but are offset by one space so they do not form a square.</td>
</tr>
<tr>
<td>Curve</td>
<td>Two pegs that are horizontally or vertically adjacent, with diagonally adjacent pegs on each end to form a concave or convex curve.</td>
</tr>
<tr>
<td>Scatter</td>
<td>Four pegs that are non-adjacent to one another.</td>
</tr>
<tr>
<td>Y</td>
<td>Two pegs that are horizontally or vertically adjacent, with two diagonally adjacent pegs on one end, forming a Y, in any orientation.</td>
</tr>
<tr>
<td>U</td>
<td>Any arrangement that forms a cup-like shape out of four adjacent pegs.</td>
</tr>
<tr>
<td>Bumpy Line</td>
<td>Four pegs that are adjacent, in which three are part of a straight line, and a fourth peg is adjacent but not in line, creating a “bump.”</td>
</tr>
</tbody>
</table>

formula into a single index of equiprobability. A number between 0 and 1 was calculated for each set of data, indicating the degree to which the responses were distributed among
the alternatives. Equal distribution among all 17 forms would yield a U-value of 1, and exclusive repetition of a single form would yield a U-value of 0.

Due to the fact that later phases of the study included intermixed trials in which variation and repetition were being reinforced on successive trials, it was necessary to use an additional index of variability. To account for this, the percentage of trials meeting a lag 3 contingency was calculated for each phase. For each trial, the current form was compared to the previous three. If the form differed from the previous three, it was classified as meeting the lag 3 contingency. If the form was the same as any of the previous three, it was classified as not meeting the lag 3 contingency. The number of trials within a phase meeting the lag 3 contingency was then divided by the total number of trials in that phase and multiplied by 100 to yield a single percentage.

**Interobserver agreement.** The experimenter took a digital photograph of each block structure and peg form immediately after it was made. For the purposes of assessing interobserver agreement (IOA), these pictures were shown to a second observer, who received training from the experimenter on categorizing block structures and peg forms. Training consisted of the experimenter first explaining the rules and showing examples of each block and pegboard form to the observers, and then testing them by presenting a novel photo of a form, asking them to categorize it, and giving them feedback on their response. Training was considered complete when observers correctly identified photos of at least three different forms. IOA was conducted across all phases of the study for all three participants, on a minimum of 33% of the total number of trials (34.2% for Pete, 42.7% for Reed, and 43.1% for Don). Trial-by-trial IOA was then
calculated by determining whether or not the experimenter and second observer
categorized each block structure or peg form the same way. The number of agreements
was divided by the number of agreements plus the disagreements and multiplied by 100
to yield a total IOA for each participant: 98% for Don (range: 95%–100%), 94% for Reed
(range: 93%–98%), and 95% for Pete (range: 94%–99%). During the generalization
phase, the experimenter saved the pages that the student painted on for later analysis by a
second observer. A second observer reviewed and categorized 100% of the
generalization data. Trial-by-trial IOA was calculated by determining whether or not the
two observers agreed, and then dividing the number of agreements by the number of
agreements plus disagreements and multiplying by 100. This yielded IOA values of
100% for Don, 100% for Reed, and 98% for Pete, indicating an acceptable level of
agreement.

**Experimental Procedures**

Sessions lasted approximately 20 min and involved a series of trials in which the
experimenter would present a vocal discriminative stimulus, the student would make a
response, and the experimenter would deliver a consequence. The number of trials per
session varied depending on the rate of responding, and ranged from 5 to 33. One session
was run per day, for 3 to 5 sessions per week for approximately 9 weeks. The total
number of sessions conducted with each student ranged from 28 to 36. Each trial started
with an instruction from the experimenter to “Build something” (for Reed and Pete) or
“Make something” (for Don). The materials needed to complete the activity were on the
table in front of the students. During some phases, the vocal $S^d$ also included a specification to create something “same” or “different.”

Following the delivery of the discriminative stimulus, the experimenter waited until the student completed a form. For the block building activity, a complete structure consisted of a minimum of 4 blocks arranged on the white paper, with blocks placed one at a time. If a participant pushed multiple blocks onto the white paper in a haphazard fashion this did not count as a valid block structure, and the student was asked to start over. Students were not given any systematic training in building block structures prior to the start of the study, and if a participant repeatedly failed to produce a block structure during the initial trials, the task was discontinued, and the peg board response was used instead. If a participant stopped building prior to using at least four blocks, the experimenter told him to “keep going.” A block structure was considered complete when the minimum number of blocks had been used, and the student ceased building, took his hands off of the block structure, and looked at the experimenter. Pegboard forms were required to have all four pegs placed in unique holes. If the participant stopped placing pegs without using all four, the experimenter told him to “keep going.” Peg forms were considered complete when the student had placed all four pegs in the pegboard, let go of the pegs, and looked at the experimenter.

After a form was complete, the experimenter would immediately deliver either reinforcement or a correction procedure. Reinforcement consisted of delivering one of the preferred food items or activities identified in that participant’s preference assessment. Access to activities was permitted for approximately 60 s, after which the
experimenter either asked the student to hand back the toy or to return to the table. For edible reinforcers, the experimenter waited until the item was consumed before starting the next trial. When students built a form that did not meet the contingencies of reinforcement for that phase, the experimenter told the student “No” and did not deliver any reinforcers. During some phases of the study, the response to building a form that did not meet the contingencies also included the experimenter modeling a correct response. Following each trial, the experimenter reset the materials by taking apart the form that had been constructed and putting the blocks or pegs next to the white paper again. The blocks were also shuffled at this time, so that the blocks used in the previous structure would not always be the ones closest to the participant.

**CRF.** In this phase, a continuous reinforcement (CRF) schedule was in place such that any valid form the participant constructed would produce reinforcement. The $S^d$ used during this phase was non-specific with regards to variability. Reed and Pete were asked to “Build something” and Don was asked to “Make something.”

**VAR.** In this phase, a lag 3 schedule was in place such that only forms that differed from the previous three that the participant had produced were reinforced. Thus, if a participant’s previous three block structures were a Single Stack, a Post, and a Balance, creating an Arch form on the next trial would produce reinforcement, whereas creating a Balance form would not. The $S^d$ used during this phase included the word “different” (either “Build something different” or “Make something different”). This $S^d$ was selected over other more arbitrary stimuli (e.g., a visual cue) due to its similarity to the sort of vocal instruction the students might encounter in a classroom when variability
is desired. After a form was created, the instructor determined whether that form met the lag 3 contingency, and then delivered either reinforcement or error correction. The modeling of a correct response was added to the error correction procedure if the student had failed to meet the lag 3 contingency on 3 or more consecutive trials. This procedure consisted of the experimenter building a randomly selected form that differed from the previous three performed by the student, and having the student imitate that response prior to presenting the next trial.

**REP.** In this phase, reinforcement was contingent upon the current form being the same as one of the previous three (a rep 3 schedule). Thus, if Don’s three previous peg forms were Horizontal Line, Square, and Angle, he would produce reinforcement by creating a Square on his next trial, but not by creating a Zig Zag. The S^d used during this phase included the term “same” (either “Build the same” or “Make the same”). This was selected because it resembled the sort of instruction students might encounter in other situations in which variability was not desired. As in the VAR condition, error correction followed trials that did not meet the rep 3 schedule. If three or more trials in a row failed to produce reinforcement, the experimenter also modeled a correct response for the student along with saying “No,” following the same procedures as in the VAR condition.

**ALT.** In this phase, a multiple schedule was in place such that every trial had an equal probability of operating on either the VAR or REP schedule. A random sequence was generated prior to sessions to determine the order of the VAR and REP trials. On VAR trials, the lag 3 contingency was in place, and the S^d included the word “different.” On REP trials, the rep 3 contingency was operating, and the S^d included the word “same.”
Consequences were delivered in a manner consistent with the VAR and REP phases described above.

**S^d Absent (SDA).** In this phase, the same multiple schedule that was operating during the ALT phase was in place, such that each trial had a 50% chance of operating on the lag 3 or rep 3 schedules. However, in this phase the same S^d was presented regardless of whether variability or repetition was being reinforced. Each trial began with the instruction “Build something” (for Reed and Pete) or “Make something” (for Don). Consequences were delivered in a manner consistent with the ALT phase.

**GEN.** In this phase, the painting was presented to determine whether the previous exposure to reinforced variability in the presence of the S^d “different” would lead to generalization of variability to a similar but distinct activity. Participants were presented with a blank piece of paper, and instructed to either “Make same” or “Make different.” The same sort of multiple schedule as was used in the ALT phase was in place, such that there was an equal chance of each trial operating on the lag 3 or rep 3 contingencies, and all trials were preceded by an S^d indicating whether variation or repetition would be reinforced. After a student painted within both squares, the paper was removed, and was replaced with a clean sheet at the start of the next trial. A list of all the key features of each experimental phase can be found in Table 3.3.

**Treatment Integrity**

To ensure that the procedures described above were run in an accurate and consistent fashion, 75% of the sessions were recorded on digital video with a camera set up approximately 3 m from the table on a shelf, aimed downward so that both the
experimenter and participant were in frame. A second observer watched videos of at least 33% of sessions conducted with each student (10 of 28 sessions for Don, 12 of 33 sessions for Reed, and 12 of 36 sessions for Pete). Sessions to be evaluated for treatment integrity were selected so that they represented sessions spanning all conditions of the

Table 3.3. Description of Experimental Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Reed &amp; Pete</th>
<th>Don</th>
<th>Reinforcement Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRF</td>
<td>“Build something”</td>
<td>“Make something”</td>
<td>Continuous reinforcement</td>
</tr>
<tr>
<td>VAR</td>
<td>“Build something different”</td>
<td>“Make something different”</td>
<td>Lag 3</td>
</tr>
<tr>
<td>REP</td>
<td>“Build the same”</td>
<td>“Make the same”</td>
<td>Rep 3</td>
</tr>
<tr>
<td>ALT</td>
<td>Randomly alternated between “Build something different” and “Build the same” depending on schedule</td>
<td>Randomly alternated between “Make something different” and “Make the same” depending on schedule</td>
<td>Randomly alternated between lag 3 and rep 3</td>
</tr>
<tr>
<td>SDA</td>
<td>“Build something”</td>
<td>“Make something”</td>
<td>Randomly alternated between lag 3 and rep 3</td>
</tr>
<tr>
<td>GEN</td>
<td>Randomly alternated between “Make something different” or “Make the same” depending on schedule</td>
<td>Randomly alternated between “Make something different” or “Make the same” depending on schedule</td>
<td>Randomly alternated between lag 3 and rep 3</td>
</tr>
</tbody>
</table>
experiment for each student. The observer watching the video assessed whether the experimenter conducted each individual trial during the session according to the guidelines outlined above with respect to (a) whether the $S^d$ and consequence were consistent with those prescribed by the current schedule, (b) whether the experimenter presented the consequence only after the student completed the form, and (c) whether the experimenter began the next trial within an appropriate interval of time (see sample datasheet in Appendix E). Treatment integrity was then calculated on a trial-by-trial basis. If the experimenter correctly completed all steps on the integrity checklist for a given trial, it was considered correct, and if any steps were missed, that trial was considered incorrect. To determine treatment integrity, the number of trials run correctly was divided by the number of correct trials plus incorrect trials and multiplied by 100. Averaging across all participants, treatment integrity was 96%; considering each student’s sessions individually, Don’s experimental sessions were run with 97% integrity (range: 93%–100%), Reed’s with 96% integrity (range: 92%–99%), and Pete’s with 92% integrity (range: 90%–95%). The most common errors identified by the treatment integrity assessment were the experimenter presenting a consequence too quickly, or presenting a prompt when one was not supposed to be given.

**Experimental Design**

This study employed a reversal design to compare the effects of the VAR versus REP schedules, and the degree to which discriminative stimuli controlled responding under the ALT schedule. In a reversal design, experimental control is demonstrated when changes in responding occur reliably when (and only when) the independent
variable is manipulated (Cooper et al., 2007). For Don and Reed, the sequence of phases was: CRF, VAR, REP, VAR, REP, ALT, SDA, ALT, SDA, ALT, GEN. For Pete, an additional reversal was added during the initial VAR and REP training due to an initial lack of response to the contingencies, making his sequence of phases: CRF, VAR, REP, VAR, REP, ALT, SDA, ALT, SDA, ALT, GEN. It was anticipated that experimental control related to the lag 3 and rep 3 schedules would be demonstrated if students responded more variably during the VAR phases compared to the initial CRF phase or the VAR phases. The effects of the discriminative stimuli (“same” and “different”) would be demonstrated if responding during ALT phases was more variable on trials for which the S^d associated with the lag 3 schedule (“different”) was presented compared to trials on which the S^d associated with the rep 3 schedule (“same”) was presented. If in fact stimulus control had been established, it would be anticipated that no such difference would exist during the SDA phases in which neither S^d was presented.

In addition to the use of a reversal design, the study also included an additional measure of experimental control due to its use of the multiple schedules that were in place during the ALT, SDA, and GEN phases. The rapid alternation between the lag 3 and rep 3 schedules could be conceptualized as operating in a manner similar to a multielement design, in which a participant is exposed to two different independent variables repeatedly over time, while the effect each has on some aspect of behavior is measured. Although data were not analyzed on a trial-by-trial basis as would be done in a traditional multielement experiment, this feature of the study did permit some degree of
experimental control within each of these phases, and was the basis for interpreting the
effects of the discriminative stimuli during the final GEN phase.
Chapter 4: Results

U-value

Don. U-value was calculated for Don’s pegboard forms in each of the first five phases (see Figure 4.1). In the initial CRF phase, Don engaged in very low levels of variability, indicating a high degree of repetition (U-value = 0.11). In the subsequent VAR phase, in which varied responding was reinforced using a lag 3 schedule, U-value increased to 0.29. When repetition was then reinforced in the REP phase that followed, variability decreased (U-value = 0.04). This pattern was confirmed in the subsequent VAR (U-value = 0.53) and REP (U-value = 0.04) phases. This finding suggests that variability increased under the lag 3 schedule, and was suppressed under the rep 3 schedule. However, it should be noted that although U-value did increase, it remained at a relatively low level, and did not approach the values that one might expect from truly stochastic behavior.

Reed. U-values for Reed across the first five phases of the study are shown in Figure 4.2. In the initial CRF phase, Reed demonstrated low levels of variability (U-value = 0.19). The introduction of the lag 3 schedule in the VAR phase led to a sharp increase in variability (U-value = 0.67). In the subsequent REP phase, variability was reduced (U-value = 0.03). The second VAR phase (U-value = .60) and the second REP phase (U-value = 0.36) seemed to confirm that greater levels of variability were being maintained under the lag 3 schedule. There was a marked increase in U-value between
Figure 4.1. U-value analysis for Don across the first five phases of the study.

Figure 4.2. U-value analysis for Reed across first five phases of study.
the first and second REP phases, which may have either been an artifact of the preceding VAR phases, or alternatively, an indication that Reed was relatively insensitive to the rep 3 contingencies.

**Pete.** Figure 4.3 shows the U-values calculated for Pete across the first seven phases of the study. During the initial CRF phase, Pete engaged in very little variability (U-value = 0.16). In the VAR phase that followed, there was an increase in variability (U-value = 0.37). In the subsequent REP phase, variability continued to increase (U-value = 0.41), in spite of the fact that repetition was now being reinforced. A return to the lag 3 contingencies in the second VAR phase resulted in a continued increase in variability (U-value = 0.51). Then variability decreased upon the second introduction of the REP schedule (U-value = 0.31). The final two phases confirmed that variability was higher under VAR contingencies (U-value = .54) than REP (U-value =0.30).

**Response Distribution During Initial Phases**

Another way of analyzing variability across phases is to look directly at the distribution of responding, to assess which response forms were produced most frequently during each phase. These distributions are the raw data from which U-values were calculated, and reflect a similar measure of variability (one based on equiprobability). However, examining response distribution directly permits a more fine tuned analysis of the response forms being performed.

**Don.** Figure 4.4 shows frequencies for each block form during Don’s initial CRF phase. As the graph shows, Don rarely created any peg forms other than the Vertical Line during this initial phase in which variability was not required. Figure 4.5 shows the
Figure 4.3. U-value analysis for Pete across first seven phases of the study.

Figure 4.4. Frequency with which each possible peg form was produced across the first CRF phase for Don.
distribution of responses for Don during the first VAR phase. In this phase, Vertical Line was still the predominant response form, but additional responses (particularly Horizontal Line) did occur at a higher rate than they had previously. In the REP phase that followed, Don once again showed a strong tendency to repeat a single response to the exclusion of all others (see Figure 4.6). This pattern is nearly identical to that found in the initial CRF phase, except that a different form was now being repeated. Figures 4.7 and 4.8 show Don’s response distributions in the second VAR and REP phases. Again, a wider range of responses occurred under the lag 3 schedule, and more restricted responding occurred under the rep 3 schedule. A summary of frequencies of the forms produced in each phase, and the number of different forms produced per phase are listed in Table 4.1. A greater number of forms were built in the VAR phase than in the other phases.

Figure 4.5. Frequency with which each possible peg form was produced across the first VAR phase for Don.
Figure 4.6. Frequency with which each possible peg form was produced across the first REP phase for Don.

Figure 4.7. Frequency with which each possible peg form was produced across the second VAR phase for Don.
Figure 4.8. Frequency with which each possible peg form was produced across the second REP phase for Don.

Reed. Figure 4.9 shows the distribution of block forms built by Reed during the initial CRF phase. A significant majority of the responses were of the form Multi Stack, indicating a significant tendency to repeat the same block form. In the first VAR phase, Reed continued to produce the Multi Stack block form more than any other, but the number of other structures built increased significantly (See Figure 4.10). It is worth noting that although some block forms became more frequent under the VAR schedule, there continued to be some forms (e.g., Fence) that Reed still never made. When he was placed on the rep 3 schedule for the first REP phase, he returned to building the same form (Multi Stack) repetitively (see Figure 4.11). This pattern was repeated in the second VAR (see Figure 4.12) and REP (see Figure 4.13) phases, in that responding was more evenly distributed among the possible response forms under the lag 3 contingencies.

Table 4.2 shows the frequencies with which Reed built the different block forms across
Table 4.1. Frequencies of pegboard forms created by Don during first five phases of the study.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Pegboard Form</th>
<th>Number of Different Forms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 + 2</td>
<td>3 + 1</td>
</tr>
<tr>
<td>CRF</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>VAR(1)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>REP(1)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VAR(2)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>REP(2)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 4.9. Frequencies with which each possible block form occurred during the CRF phase for Reed.

Figure 4.10. Frequencies with which each possible block form occurred during the first VAR phase for Reed.
Figure 4.11. Frequencies with which each possible block form occurred during the first REP phase for Reed.

Figure 4.12. Frequencies with which each possible block form occurred during the second VAR phase for Reed.
Figure 4.13. Frequencies with which each possible block form occurred during the second REP phase for Reed.

all phases, the total number of forms built per phase, and the number of different forms built. A greater number of different block forms were built during the VAR phases than the CRF or REP phases.

Pete. The frequencies of the 17 possible block forms for Pete also showed repetition of a single block form during the initial CRF phase (see Figure 4.14). During this phase, he produced only the Single Stack and Post forms. During the first VAR phase, Pete continued to respond primarily with those same two forms, but several novel forms did occur occasionally (see Figure 4.15). Figure 4.16 shows the frequencies with which the different forms occurred under the first REP phase. As might be expected from the U-value results for this phase, the response distribution suggests that Pete
Table 4.2. Frequencies of block forms created by Reed during first five phases of the study.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Block Form</th>
<th>Double Wide Stack</th>
<th>Multi Stack &amp; Balance</th>
<th>Multi Stack &amp; I</th>
<th>Multi Stack Post &amp; Balance &amp; I</th>
<th>Multi Stack Post</th>
<th>Single Stack</th>
<th>Total Frequency</th>
<th>Number of Different Forms Built</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRF</td>
<td></td>
<td>Arch</td>
<td>Balance</td>
<td>Floor</td>
<td>I</td>
<td></td>
<td></td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>38</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>VAR(1)</td>
<td></td>
<td>1</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td>21</td>
<td>9</td>
<td>1</td>
<td>63</td>
</tr>
<tr>
<td>REP(1)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>43</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VAR(2)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>12</td>
<td>2</td>
<td>41</td>
</tr>
<tr>
<td>REP(2)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>6</td>
<td>2</td>
<td>40</td>
</tr>
</tbody>
</table>
Figure 4.14. Frequencies with which each possible block form occurred during the initial CRF phase for Pete.

Figure 4.15. Frequencies with which each possible block form occurred during the first VAR phase for Pete.
Figure 4.16. Frequencies with which each possible block form occurred during the first REP phase for Pete.

behaved variably in his responding under this phase in spite of the rep 3 contingencies that were in place. Figure 4.17 shows the response distribution for the subsequent VAR phase. Although responding is distributed across about the same number of distinct responses, the frequencies of the two most commonly produced block forms (Balance and Single Stack) were similar, suggesting that Pete did not show a particularly strong bias to a single response form. In the second REP phase, Pete once again repeated a single block form on most trials (see Figure 4.18). This difference in the pattern of responding under the two schedules was confirmed by the distribution of block forms under the third VAR phase (see Figure 4.19) and the third REP phase (see Figure 4.20). Once again, more distributed responding occurred under the lag 3 schedule, while
Figure 4.17. Frequencies with which each possible block form occurred during the second VAR phase for Pete.

Figure 4.18. Frequencies with which each possible block form occurred during the second REP phase for Pete.
Figure 4.19. Frequencies with which each possible block form occurred during the third VAR phase for Pete.

Figure 4.20. Frequencies with which each possible block form occurred during the third REP phase for Pete.
responding under the rep 3 schedule tended to concentrate on a single form to the exclusion of all others. Table 4.3 lists the frequencies of each form across phases, the total number of forms built per phase, and the number of unique forms built in each phase. More unique forms were built during the VAR phases than the CRF or REP phases.

**Percentage Meeting Lag 3 Requirements.**

Variability in the CRF, VAR, and REP phases was also evaluated by comparing the percentage of trials in each phase meeting the lag 3 contingencies. This measure of variability was also applied to the data collected during the ALT, SDA, and GEN phases. Due to the multiple schedule that was in place during these phases, performance on trials for operating on the lag 3 schedule and trials operating on the rep 3 schedule were separately analyzed, yielding two percentages for each phase (one for the VAR component and one for the REP component). When there was a rapid alternation between the schedules, it prevented a meaningful analysis of response distribution or U-value. Trials operating on the rep 3 schedule sometimes followed immediately after trials operating on the lag 3 schedule, thus increasing the chances of distributed responding on these REP trials. In essence, the multiple schedule actually promoted some degree of distributed responding in the REP component in that participants could meet the rep 3 contingency only by repeating those responses that had occurred recently, and the recent responses may have been varied due to the lag 3 contingency. Due to this confound with respect to equiprobability, the percentage of trials meeting the lag 3 requirement was
Table 4.3. Frequencies of block forms created by Pete during first seven phases of the study.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Block Form</th>
<th>Number of Different Forms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Balance</td>
<td>Double Stack</td>
</tr>
<tr>
<td>CRF</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VAR(1)</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>REP(1)</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>VAR(2)</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>REP(2)</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>VAR(3)</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>REP(3)</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>
determined to be a more appropriate measure of variability for the final six phases of the study.

**Don.** Figure 4.21 shows the percentage of trials meeting the lag 3 contingencies across all phases. A greater percentage of Don’s trials differed from the previous three during the first VAR phase (14.6%) versus the preceding CRF (10%) or the subsequent REP (0%) phases. The percentage of trials meeting the lag requirement increased again under the second VAR condition (35.4%) and then returned to low levels (2.6%) when the REP condition was reintroduced. These findings are consistent with those described above in the analysis of response distribution and U-value.

![Figure 4.21. Percentage of trials meeting lag 3 contingencies for Don across all phases of the study. For phases in which there was a multiple schedule operating, blue bars represent percent of VAR trials meeting the contingency, and red bars represent REP trials.](image)
In the first ALT phase, a higher percentage of trials met the lag 3 requirements under the VAR component (46.2%) than under the REP component (4.4%). This indicates that some degree of stimulus control was exhibited, in that Don’s peg forms tended to be variable on trials in which the instruction “Make something different” was used, but they tended to be less variable on trials in which the instruction “Make the same” was used. In the first SDA phase, variability decreased for the VAR component (13.4%) and increased for the REP component (20.0%) relative to the preceding ALT phase. This finding is again consistent with responding that is under stimulus control, in that when the antecedent stimulus was the same across all trials, the difference in responding between the two components went away. In the second ALT phase, responding was again differentiated between the VAR (38.5%) and REP (5.6%) components, confirming the pattern seen in the first ALT phase. The second SDA phase gave additional confirmation of stimulus control, in that responding was again less variable in the VAR trials (14.3%) and more variable during the REP trials (19.0%). The third ALT phase provided yet another demonstration of the effects of the discriminative stimuli, with greater variability under the VAR component (33.3%) than the REP component (5.3%). Although the difference between the VAR and REP components in the three ALT phases does suggest that stimulus control was established to some degree, it should be noted that the rate at which Don was successful at meeting the lag 3 contingencies remained relatively low (range: 33.3%–46.2%). This may indicate that stimulus control over response variability may not have been as strong or consistent as would be desired in instructional situations.
During the GEN phase, when Don was asked to paint two squares using the four paint bottles, there was no evidence of stimulus control. The percentage of paint sequences that varied on trials in which the “Paint something different” instruction was used (28.6%) was not much different from the percentage of sequences that varied when the “Paint the same” instruction was used (35.0%). This suggests that the stimulus control established during the pegboard task did not promote generalization to the novel task.

Reed. The percentage of trials in which Reed met the lag 3 contingencies in each phase of the study is shown in Figure 4.22. During the initial CRF phase, in which all responses produced reinforcement, Reed rarely met the lag 3 contingency (15.6%). In the first REP phase, where variability was required, Reed met the lag requirement more often (50.0%). In the subsequent REP phase, in which only repeated responding produced reinforcement, the percentage of trials that differed from the previous three decreased to 6.7%. This was followed by an increase in the second VAR phase (42.5%) and then a decrease when Reed returned to the REP phase (22.9%). The percentage of trials meeting the lag 3 requirement during these first five phases appears to corroborate the findings described above for response distribution and U-value. Reed varied responding more in the VAR phase than in the CRF or REP phases.

In the first ALT phase, Reed varied responding more often during the VAR component (50.0%) than the REP component (20.7%). This suggests that there was stimulus control over his responding, in that he varied block forms more when he was instructed to “Build something different” than when he was instructed “Build the same.”
Figure 4.22. Percentage of trials meeting lag 3 contingencies for Reed across all phases of the study. For phases in which there was a multiple schedule operating, blue bars represent percent of VAR trials meeting the contingency, and red bars represent REP trials.

In the subsequent SDA phase, in which no discriminative cues were presented, percentages of trials meeting the lag requirement were roughly equal for the VAR (31.6%) and REP (30.0%) components. When the discriminative stimuli were brought back in the second ALT phase, variability was again greater on the VAR trials (69.2%) compared to REP trials (23.8%). The difference between the two components decreased again when the discriminative cues were eliminated during the second SDA phase; this condition produced a decrease in variability on VAR trials (52.6%) and an increase in variability on REP trials (38%) relative to the preceding phase. The third ALT phase again demonstrated stimulus control with greater variability under the VAR component (68.2%) compared to the REP component (33.3%). Although the patterns of responding
produced under the ALT and SDA conditions are indicative of stimulus control, it is important to note that the overall success rates on the two schedules were far from perfect. Reed’s performance on the lag 3 schedule did not exceed a 70% success rate in any phase; he also continued to vary responding when he should have repeated on 20.7% to 33.3% of the REP trials across the ALT phases.

In the GEN phase, Reed produced only slightly more variable pattern of paint under the VAR component (52.4%) than he did under the REP component (40.0%). This was not a very convincing demonstration of stimulus control, suggesting that the control over variability that was exerted by the instructions “different” and “same” did not influence responding in the context of the novel painting activity. The paintings produced during this generalization phase were more or less equally variable regardless of which discriminative stimulus was presented.

**Pete.** Figure 4.23 shows the percentage of trials meeting the lag 3 contingency in each phase for Pete. In the initial CRF phase, Pete’s block forms differed from the previous three on only 11.4% of the trials. This increased in the subsequent VAR phase (23.0%). In the first REP phase, there was not much change from the preceding VAR phase (21.4%), indicating that the rep 3 schedule had not yet been effective in reducing response variability at that point. In the second VAR phase, there was an increase again in the percentage of trials meeting the lag 3 requirement (48.6%). When the REP schedule was then reintroduced, block forms were less likely to have varied (20.0%). This pattern was confirmed by the third VAR (52.5%) and REP (23.8%) phases. The findings across these initial seven phases were consistent with those presented above for
response distribution and U-value; greater amounts of variability were evident in the VAR phases than the CRF or REP phases, suggesting operant control of variability.

In the first ALT phase, Pete was more likely to meet the lag 3 requirement on trials in which the VAR component was in place (60.0%) compared to the REP component (22.2%). This is indicative of stimulus control in that Pete varied the block forms he constructed when given the $S^d$ “Build something different,” but repeated block forms when given the $S^d$ “Build the same.” In the SDA phase that followed, there was a reduction in variability for the VAR component (38.0%) and an increase in variability for the REP component (30.0%), suggesting that the delivery of the antecedent stimuli “same” and “different” had been exerting some control over responding in the previous

![Figure 4.23](image-url)

Figure 4.23. Percentage of trials meeting Lag 3 contingencies for Pete across all phases of the study. For phases in which there was a multiple schedule operating, blue bars represent percent of VAR trials meeting the contingency, and red bars represent REP trials.
phase. When the stimuli were reintroduced in the second ALT phase, responding was once again more varied on VAR trials (69.6%) than on REP trials (22.7%). In the second SDA phase, variability once again decreased for the VAR component (21.1%) and increased for the REP component (41.7%) relative to the preceding phase, representing a significant drop in Pete’s success rate. This once again suggests that the discriminative stimuli used in the ALT component were a factor in the pattern of responding seen in that phase. This was confirmed in the final ALT phase, in which responding was more likely to be variable in the VAR component (68.2%) than in the REP component (31.8%) of the multiple schedule. As with the other participants, Pete did have room for improvement in the degree of stimulus control. His success with the lag 3 schedule never surpassed 70%, and he consistently varied under the rep 3 schedule on at least 21% of the trials.

In the final GEN phase of the study, Pete engaged in relatively low rates of variability on the painting task regardless of whether the VAR (27.3%) or REP (18.2%) component was in place. This meant that in spite of having the same Sd presented (either “Make different” or “Make the same”), the varied type of responding he had learned to perform in the block-building task did not occur within the novel task.

**Percentage of Trials Earning Reinforcement**

To assess the degree to which variability may have been influenced by factors other than the contingencies being manipulated, relative rates of reinforcement were calculated for each phase of the study. The number of trials on which reinforcers were delivered during each phase was divided by the total number of trials in the phase. If the probability of reinforcement differed reliably across conditions, it would suggest a
possible confound. Intermittent reinforcement has been demonstrated to increase response variability independent of operant procedures (Neuringer, 2004).

**Don.** Figure 4.24 shows the percentage of trials on which reinforcers were delivered in each phase for Don. Once again, trials during the ALT, SDA, and GEN phases were separated according the schedule that was in place, yielding unique rates of reinforcement for the REP and VAR components of those phases. Under the CRF schedule, the probability of reinforcement was by necessity fixed at 100% (all responses were reinforced). In the first and second VAR phases, the probability of reinforcement was significantly lower (14.4% and 35.4%, respectively). These rates of reinforcement were in sharp contrast to the first and second REP phases, which produced high

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**Figure 4.24.** Percentage of trials on which reinforcement was delivered for Don across all phases of the study.
probabilities of reinforcement (97.6% and 97.5%, respectively). The differences in the
density of reinforcement was also present within the multiple schedule in the ALT, SDA,
and GEN phases, where the rate of reinforcement under the VAR component (an average
of 30.0% of the trials) was significantly lower than under the REP component (an
average of 84.9% of the trials).

Reed. The percentage of trials on which Reed earned reinforcers in each phase of
the study is displayed in Figure 4.25. After an initial CRF phase in which reinforcement
was delivered on 100% of the trials, there was a significant reduction in the rate of
reinforcement in the first and second VAR phases (49.2% and 41.5%, respectively). In
the first and second REP phases, rates of reinforcement were relatively high (97.8% and
79.5%, respectively). A difference in the percentage of trials earning reinforcement

Figure 4.25. Percentage of trials on which reinforcement was delivered for Reed across
all phases of the study.
persisted in the first ALT and SDA phases, where higher rates of reinforcement occurred under the REP component compared to the VAR component. However, rates of reinforcement in the VAR and REP components were fairly even across the final four phases, with an average of 66.3% of REP trials and 62.5% of VAR trials earning reinforcement.

**Pete.** Figure 4.26 shows the percentage of trials on which Pete received reinforcement in each phase of the study. The first and second VAR phases produced low rates of reinforcement (23.0% and 48.8%, respectively) compared to the first and second REP phases (78.6% and 80.5%, respectively). This trend continued in the third VAR phase (51.2%) and the third REP phase (76.2%). Differing rates of reinforcement

![Figure 4.26. Percentage of trials on which reinforcement was delivered for Pete across all phases of the study.](image-url)
were also found in the two components of the first ALT phase (52.4% in the VAR component and 78.9% in the REP component), and the first SDA phase (43.0% in the VAR component and 70.0% in the REP component). In the second ALT phase, reinforcement was about equally likely in the VAR (70.8%) and REP (78.2%) components. In the second SDA phase, there was again a difference in rates of reinforcement, with lower rates on the VAR component (31.6%) than the REP component (62.5%). In the third ALT phase, rates of reinforcement again were equal for the VAR and REP components, occurring on 68.2% of trials in each. During the GEN phase, rates of reinforcement were once more higher for the REP trials (81.8%) than the VAR trials (27.3%).

**Response Distributions During GEN Phase**

In order to further evaluate the responses produced during the generalization task, the relative frequencies of each of the 16 possible color combinations were tracked for each participant. Because very little difference in variability was found during this phase, distribution was examined without differentiating between the VAR and REP trials within the multiple schedule. This analysis was undertaken after noticing a tendency for the participants to respond more often with color patterns that consisted of repeating a single color across both squares. Given the way the task was presented, it was possible for a student to paint both squares with a single color of paint; this could have been a more efficient way of completing the task than painting one square, and then putting the paint back and taking another color to paint the next square. Figure 4.27 shows the color
patterns produced by Don during the GEN phase. The sequences consisting of the repetition of a single color across both squares were much more common than any of the other possible sequences, comprising 97.6% of all responses. Figure 4.28 shows the patterns produced by Reed during this phase. Although he did produce more sequences including two different colors than Don, sequences that repeated the same color were still the most common, occurring on 65.9% of the trials. A similar result was found for Pete (see Figure 4.29), who produced the color sequence YY more often than any other sequence. For Pete, 95.5% of the sequences produced consisted of a single color repeated across both squares.
Figure 4.28. Frequencies with which each of the 16 possible color sequences were produced by Reed during the GEN phase.

Figure 4.29. Frequencies with which each of the 16 possible color sequences were produced by Pete during the GEN phase.
Chapter 5: Discussion

Key Findings

The purpose of this study was to determine whether variability in the block play of children with autism could be influenced by a lag reinforcement schedule and whether such variability could be brought under stimulus control. In addition, this study sought to evaluate the efficacy of stimulus control procedures in promoting generalization of varied responding to a novel task in which variability would also be desirable.

Effects of the lag schedule. For all three participants, the lag 3 schedule that was in place during the VAR phases did increase variability. For Don and Reed, this occurred within the first VAR phase; for Pete, variability did not increase immediately, but did so reliably on the second and third reversals. This finding is consistent with existing literature on the effects of lag schedules (e.g., Page & Neuringer, 1985; Neuringer, 1992). It is also consistent with previous research showing that operant procedures can influence the behavioral variability of children with autism (Miller & Neuringer, 2000), and that diversity in the construction of block forms can be differentially reinforced (Goetz & Baer, 1973). By demonstrating a reliable increase in variability of block play, this study adds to a growing body of literature suggesting that operant variability procedures can be used with children with autism to increase the variability of socially important behaviors (e.g., Esch et al., 2009; Grow et al., 2008; Lee & Sturmey, 2002).

These findings replicate Napolitano et al.’s (2010) results with regard to the effect of lag schedules on the play of children with autism, and extend them by utilizing a lag
schedule with a window greater than 1 (a lag 3 schedule), and targeting a task other than block building (arranging pegs on a pegboard) for one participant. Whereas Napolitano et al. defined varied responses as responses that differed from the immediately preceding response, the current study measured variability in terms of equiprobability. The use of U-value and response distributions could be conceptualized as a more stringent way of quantifying variability, because it was sensitive enough to detect patterns such as reliably switching between two forms. Another difference between Napolitano et al.’s approach and that employed in the current study was the scale at which variability was assessed. In the Napolitano et al. study, variability was assessed at the level of the placement of a single block. In the current study, block structures were assessed as a whole, each form consisting of between 4 and 14 individual block placements. It is notable that lag schedules appear to be effective in influencing variability in the play of children with autism at either a molecular level (as in the placement of a single block) or a more molar level (the overall form of a structure). This suggests operant variability may be a fairly robust phenomenon, which can operate on behavior in multiple ways. It is also consistent with the argument made by Waltz and Follette (2009) that operant variability may be a useful way that clinicians can utilize contingencies operating upon behavior on a molar level.

The current findings may be particularly relevant to practitioners working with children with autism. In a review of literature on teaching play to children with autism, Lang et al. (2009) identified modeling, prompting, reinforcement, and the use of naturalistic instructions as key components of effective play interventions, and suggested
further research on the relationship between stereotypy and play. Interventions based on the reinforcement of variability could be both consistent with the behavioral principles that have been effective in teaching play to children with autism (e.g., Dauphin, Kinney, & Stromer, 2004; Gillett & LeBlanc, 2007) and useful in conceptualizing the relationship between stereotypy and appropriate play. For all three participants in the current study, a highly repetitive pattern of block building was occurring at the start of the study, suggesting that the lag schedule simultaneously increased a desired aspect of play (novelty and unpredictability) and decreased an undesired behavior (repetitive and restricted play).

For Reed and Pete, the experimenter informally observed a difference not only in the forms constructed under the VAR and REP conditions, but also in the complexity of forms and the number of blocks used. Although only four blocks were required to complete a valid structure, during the VAR phases of the study, participants tended to use significantly more than four blocks per structure. This pattern of making larger and more complex structures may have been inadvertently reinforced by the contingencies of the lag 3 schedule. A larger and more complex block structure may have been more likely to include a form that differed from one of the previous three. In this regard, changes in structure size and complexity may have contributed to the apparent variability in a manner similar to an effect identified by Machado (1997) related to the production of response sequences on left and right manipulanda. Machado observed that in addition to increasing the equiprobability of response sequences, lag schedules also had the effect of increasing the probability of switching between the manipulanda within those sequences.
Such an inadvertent effect may have occurred in the present study; an increase in complexity of structures could be considered a desirable side effect of a lag schedule.

**Stimulus control.** For all three participants, variability was successfully brought under the control of the distinctive antecedent stimuli associated with the lag 3 and rep 3 schedules. During the ALT phases, students were more likely to produce varied forms when instructed to “Build different,” than when instructed to “Build same.” Performance under the SDA phases confirmed the relevance of the discriminative stimuli by demonstrating that in the absence of the antecedent cues, performance was undifferentiated across the two components of the multiple schedule. Levels of variability in the absence of the S’s fell in between the values in the two components of the schedule during the ALT phase, representing both a decrease in variability for the VAR component and an increase in variability for the REP component. These findings are consistent with both basic research on stimulus control of variability in rats and pigeons (e.g., Denney & Neuringer, 1998; Souza & Abreu-Rodrigues, 2010) and preliminary work conducted with humans (e.g., McClure et al., 2011; Miller et al., 2012).

One distinctive feature of the current study was its use of naturalistic cues as discriminative stimuli. The use of the vocal instructions “same” and “different” may be more easily translated into classroom practice than the use of arbitrary stimuli, and it may promote the acquisition of a wider repertoire of listener behaviors relative to those words (e.g., being able to select “different” versus “same” examples from an array). The fact that variability in children with autism can be brought under stimulus control may be of relevance to those who teach this population. Although variability is a
desirable aspect of responding in some situations (such as creative block play), there are other situations in which it would be considered inappropriate for a student to vary (as when asked to copy an action that the teacher has performed). Stimulus control procedures may be necessary for teaching this distinction to students with autism. This phenomenon may also be of relevance to the treatment of repetitive or stereotyped responding. Brusa and Richman (2008) used stimulus control procedures to reduce the frequency of repetitive string play by a boy with autism that appeared to be maintained by automatic reinforcement. In the presence of a green card, repetitive play was permitted, and in the presence of a red card, stereotypy was blocked and redirected. This procedure was effective in reducing stereotypy in the presence of the red card (an \S\-delta), while maintaining stereotypy in the presence of the green card. The results of the current study suggest that a similar effect might be achieved through the differential reinforcement of varied versus repeated responding; such an approach may have advantages over procedures that establish stimulus control through the use of punishment or extinction, which may produce unwanted side effects.

**Generalization.** None of the three participants engaged in increased levels of variation when given the \S^d\ “Make different” versus “Make same” within the context of a novel painting activity. Although discriminative stimuli were used for the purpose of promoting generalization, the absence of generalization of variable responding is consistent with previous research that found only limited stimulus generalization of variable responding (e.g., Holman et al., 1977; Napolitano et al., 2010). This seems to suggest a potential challenge in clinical applications of these procedures, in that
variability may need to be trained individually for each activity during which it is desired. One factor that may have contributed to the lack of generalization found in the present study was that the painting task differed in several ways from the block building and pegboard tasks used during training. Response variability during painting was defined according to color rather than shape, and was governed by the *selection* of materials (i.e., which paint was chosen) rather than the *placement* of materials (i.e., where blocks were placed within a structure). In this regard, the generalization task may have included more than simply a novel stimulus, but also required the acquisition of some novel responses.

Holman et al. (1977) found that generalization of varied responding was strongest when there was similarity between the responses performed in the training and generalization contexts. It is possible that a greater degree of generalization would have been found had the students been asked to engage in a task that more closely resembled the block building or pegboard activity with which they were trained. However, it should be noted that Napolitano et al. (2010) examined generalization between two similar block-building tasks (using interlocking plastic building blocks versus traditional wood blocks) and found generalization of varied responding with only one of six participants. The implication seems to be that it is necessary to program for generalization in a more explicit manner than was done in the current study. Although stimulus control did not, in this case, promote generalization, it may be possible that it would be effective if stronger stimulus control had been established (i.e., students responded to the antecedent stimuli with a higher degree of accuracy), or if the multiple examples of activities had been used in training.
Limitations

**Confound in rates of reinforcement.** The fact that rates of reinforcement differed systematically between the VAR and REP phases (and in some cases, between components of the multiple schedule in the ALT, SDA, and GEN phases) presents a potential confound. Previous research has demonstrated that variability can in some cases be induced by intermittent reinforcement (e.g., Boren et al., 1978; Maes, 2003; Tatham et al., 1993) or by extinction (Antonitis, 1951; Morgan & Lee, 1996). Additional studies have shown that contingent reinforcement is a procedure that can influence behavior independently of this schedule-induced effect, as evidenced by comparisons between operant variability schedules and schedules in which rates of reinforcement are yoked (e.g., Miller & Neuringer, 2000; Page & Neuringer, 1985). In the current study, the effects of these two variables are impossible to disentangle. A cleaner demonstration of operant variability could be achieved by using a yoked schedule, in which the rates of reinforcement are dependent on those achieved by the participant under the VAR schedule, as a comparison condition instead of a rep 3 schedule.

The fact that stimulus control was apparently achieved in this study may be interpreted as evidence of variability functioning as an operant, as was argued by Denney and Neuringer (1998). However, an alternate interpretation may be that the stimuli that were programmed in this study did not in fact function as discriminative stimuli for operant variability, as it was assumed they would, but rather became associated with specific rates of reinforcement. According to this hypothesis, the antecedent stimulus “different” may have increased variability simply due to its consistent pairing with a
relatively lean schedule of reinforcement, while “same” was paired with a denser schedule of reinforcement, and thus produced lower rates of variability. An interesting empirical question might be whether response variability can be influenced by antecedent stimuli in the absence of contingent reinforcement.

The issue of distinguishing between operant variability and schedule-induced variability has been important in basic laboratory research, where a clear demonstration of the underlying principles is necessary. Interventionists in applied settings are primarily concerned with changing behavior, and may not find it necessary to determine the underlying process responsible for that change. However, there may be some value in teasing apart the relative influences of contingency and intermittency within a lag schedule, to better understand why these schedules affect variability the way they do. One way of conceptualizing the issue would be that, like other differential reinforcement procedures, lag schedules influence behavior through a combination of reinforcement and extinction. Patterns of responding that are “varied” produce reinforcement, while patterns that are “repetitive” are placed on extinction. This results in an increase in variation, and a concomitant decrease in repetition.

An important factor contributing to these differential rates of reinforcement may be the impact of pre-existing repertoires. For individuals with autism, it may be predicted that higher rates of reinforcement would be achieved under schedules such as the one used in the REP phase of this study, where the contingency requires repetition; as evidenced from performance in the CRF phase of this study, repetitive responding was already strong within the students’ repertoires. Under the VAR conditions, relatively
leaner schedules of reinforcement were achieved, perhaps because the students were still developing the necessary repertoire. The use of prompting procedures as error correction was designed to address this issue, but additional shaping or prompting procedures may have been useful in facilitating the acquisition of the responses needed.

**Pre-experimental experience with stimuli.** Another potential confound in the design of this study was the failure to control for the students’ prior experience with the stimuli used in the study. In previous studies evaluating the effects of discriminative stimuli on variability, neutral stimuli have been selected with which the participants were unlikely to have any history. Denney and Neuringer (1998) used a combination of a tone and a light that the rats had never experienced before. Miller et al. (2012) used different colored backgrounds within a novel computer game task. McClure et al. (2011) used colored pieces of construction paper placed under the tasks. In each case, stimuli were selected that had not previously been used to indicate whether or not variability would be reinforced. In the case of the current study, however, an argument could be made that the students may have been exposed to other vocal instructions containing the words “different” or “same” within contexts in which variability or repetition was expected. To the extent that such a history may have influenced responding under the two stimulus conditions, this represents a confound.

The fact that students made numerous “errors” during initial exposure to the VAR and REP phases suggests that such a history was not a significant factor for these students, but such an influence cannot be ruled out. One possibility is that the relatively weak stimulus control achieved in this study was in part a function of students’ history of
exposure to the antecedent stimuli in other situations. In their previous experiences with “same” and “different,” the stimuli may not have always been predictive of the availability of reinforcement for varied or repetitive responding. A neutral stimulus (one without such a history) may have allowed for stronger experimental control. However, the terms “same” and “different” were selected precisely because of their overlap with pre-existing cues in the natural environment, so this issue of history may be an unavoidable factor. An initial phase in which the effects of the selected discriminative stimuli on behavior prior to training might be useful in better controlling for this variable.

Additionally, students may have differed with respect to their existing level of skill at the block-building task. If only some subset of the 17 possible block forms were within the participants’ pre-existing repertoire, there may have been an upper limit to the extent to which variability could be increased using only operant variability procedures. Although such schedules have been shown to evoke novel behavior under some circumstances (e.g., Goetz & Baer, 1973; Pryor et al., 1969), these procedures alone may be insufficient to establish new play responses in individuals with autism. More explicit teaching procedures, such as prompting and reinforcement, have been effective in teaching play skills to children with autism (Stahmer et al., 2003). Such teaching procedures could have been used prior to exposing the students to the lag schedule to ensure that all students started with an equivalent repertoire of block-building responses, and that the student could produce all members of the response class.

**Lack of experimental control with generalization task.** Another weakness in the design of the current study was the fact that the GEN phase was not structured to
permit the degree of control afforded in the rest of the experiment. There was no measurement of baseline variability for the painting task (i.e., the degree to which color sequences would have varied prior to the training that occurred over the course of the study). Also, the rapid alternation between the lag 3 and rep 3 schedule within the GEN phase did not allow for the kind of comparison that was possible in the preceding phases, where the effects of the discriminative stimuli in the ALT phase could be compared to performance in the absence of these stimuli during the SDA phase. Additional reversals of the GEN condition, and the collection of pre-treatment baseline could have strengthened the design of this portion of the experiment. Given the lack of an experimental effect during the GEN phase, it seems unlikely that the inclusion of such controls would have changed the outcome of the current study. Nonetheless, future studies on the topic of generalization should be structured in a way that better affords a demonstration of experimental control.

Response effort during painting task. Distributions of responding during the GEN phase illustrate an additional confound that was not anticipated. When creating a sequence of colors in the left and right squares during this task, students were much more likely to select a single color and use it to color both squares than to select two different colors. The 16 possible sequences that students could produce using the four paint colors were conceptualized as equivalent members of a response class; the experimenter did not take the relative efforts required to produce the different sequences into account. Selecting a single color and using it to color both squares may have taken significantly less effort than using multiple colors.
Relative response effort is a variable that has been demonstrated to influence response allocation when an individual is choosing between multiple alternatives (e.g., Neef, Shade, & Miller, 1994; Shabani et al., 2009). The response class consisting of all possible sequences of colors may have been organized in a hierarchical fashion, with the less effortful sequences (using the same color twice) being more likely to occur than the sequences that took extra effort. This interpretation is supported by the observation that Reed, the student who most often did create sequences with two colors, adopted a novel strategy for completing the painting task during the final group of trials in the GEN phase. On these trials, Reed would pick up two different paint bottles, one in each hand, and then color the two boxes simultaneously. Presumably, this was a faster way of completing the task than picking out colors one at a time, as the experimenter had originally intended for the students to do. The fact that responding was skewed towards those four sequences involving repetition of a single color was likely a factor in determining the degree of variability. One might hypothesize that it would be harder to increase variability among members of the response class if they are arranged in such a hierarchical manner; getting the individual to engage in less frequent responses may be made more difficult if those responses are also more effortful.

**Lack of data on social validity.** Social validity, which refers to the extent to which goals, procedures, and outcomes are socially acceptable to the individuals involved (Wolf, 1978), was not assessed in this study. The decision not to include a social validity measure was based on the participants’ lack of communication skills, and the fact that the experimenter alone was responsible for implementing the procedures throughout the
study. It was anticipated that students would not be able to communicate their level of satisfaction with the procedures or outcomes, and the other relevant consumers (parents and teachers) had very little exposure to either the procedures or their effects. Given the results of the generalization assessment, it may be safe to assume that the behavior changes produced by the operant variability procedures had little impact on students’ play outside of the sessions that were conducted by the experimenter. Thus, an examination of teacher or parent opinions may have simply confirmed relatively poor social validity with respect to the study’s broader outcomes.

A key weakness in the study’s impact on student behavior was the fact that students never achieved optimal levels of stimulus control. If variation and repetition were under tight enough stimulus control, one would anticipate the percentage of trials meeting the lag 3 requirements would approach 100% during the VAR components of the SDA schedule, and approach 0% during the REP components. In fact, all three participants achieved significantly weaker stimulus control than this. This outcome is in contrast to the results of Miller et al. (2012), who found much stronger stimulus control when similar procedures were employed with typically developing adults. This difference could be a function of the students’ autism diagnoses or stem from differences in the types of tasks and measures of variability used across the two studies. It is possible that individuals with autism will require additional training to establish appropriate stimulus control of variable responding, as has been described in the teaching of other skills such as receptive labeling (Grow, Carr, Kodak, Jostad, & Kisamore, 2011), tacting (Partington, Sundberg, Newhouse, & Spengler, 1994), and hand-raising (Charania et al.,
Future investigations of this topic might consider evaluating various combinations of prompting, shaping, and chaining to discover optimal procedures for initially establishing varied patterns of responding in this population.

The overall levels of variability that were produced by the lag 3 schedule were also of an unclear value from a social validity standpoint. Although students reliably varied more under the VAR conditions than under REP conditions, it is unclear whether that change represented a meaningful improvement in the quality of students’ block or pegboard play. Response distributions for all three participants suggest that even during their most variable responding, a number of possible forms were simply never produced. Although it seems reasonable to assume that increasing variety during play could be beneficial, the question of how much a student’s building should vary from trial to trial in order to be considered appropriate is an empirical question that might be worth investigating. Assessing this would require a definition of the purpose of block play, in terms of the social or developmental benefits it is expected to have for the child. Descriptive analyses of typically developing peers who are considered skilled at the play activity might be useful in developing standards against which the variability in the play of children with autism could be compared.

A final way in which the study may have lacked social validity is in the relatively poor efficiency with which students were taught to vary block and pegboard structures. The study consisted of between 28 and 36 sessions lasting about 15 min each, during which students received one-on-one assistance from the experimenter. It may not be practical to expect special education teachers or parents to devote as much time and effort
to producing the type of changes in behavior accomplished in this study. However, it is encouraging to note that for two participants (Don and Reed) the effects of the lag schedule were noticeable within the first block of trials, and for the third participant (Pete) it took only two blocks of trials under the VAR condition.

**Directions for Future Research**

**Parametric analysis of lag values.** Although Page and Neuringer (1985) conducted an analysis of how differing lag values affected response variability in pigeons, the current study is unique among applied research in its using a lag schedule with a value greater than 1. Larger lag windows should promote higher levels of variation, which may be particularly useful in individuals with autism, for whom baseline levels of variability may tend to be low. However, as the lag window grows progressively larger, the rate of reinforcement may eventually decline as the individual is less and less successful in fulfilling the response requirement; if the lag window is too large, the organism may eventually experience extinction-like conditions in which none of the responses within their repertoire are effective in producing reinforcement. Miller and Neuringer (2000) conceptualized this issue as a need for shaping response variability in this population; in that study, a percentile schedule was used to automate that process of progressively increasing the variability requirement. Taken together, the research by Napolitano et al. (2010) and the current study suggest that children with autism may be responsive to lag schedules with values ranging from 1 to 3 without the use of gradual shaping procedures. An important empirical question that remains unexplored is whether higher levels of variability could be produced by employing larger lag schedules, or
whether doing so would run the risk of extinguishing the response altogether. To evaluate this, it would be interesting to conduct a parametric analysis looking at the degree to which lag schedules of various magnitudes affect response variability in children with autism. If the introduction of larger lag schedules sometimes leads to extinction of responding in this population, it may be useful to also investigate the optimal sequence and schedule for systematically increasing a lag schedule in order to shape increasing levels of variation.

Relevance of procedures to children with ADHD. The stimulus control procedures used in this study may prove useful in treating not only children with autism, but also those with attention deficit hyperactive disorder (ADHD). Unlike children with autism, children with ADHD engage in impulsive and hyperactive behaviors that could be characterized as showing an excess of variability (Barkley, 1990; Castellanos et al., 2005; Saldana & Neuringer, 1998). Individuals diagnosed with ADHD sometimes respond inappropriately in situations in which repetition is required; this could be considered a maladaptive form of variability (Mook & Neuringer, 1994; Neuringer, 2002; Perry et al., 2010). A number of behavioral mechanisms have been proposed to account for the symptoms of ADHD, including relative insensitivity to delayed reinforcement (Catania, 2005) and difficulty related to self-control (Neef et al., 2005; Paloyelis, Asherson, & Kuntsi, 2009). Another potential interpretation of ADHD symptoms is that these children are relatively insensitive to the effects of discriminative stimuli that would normally exert control over variation and repetition (Neuringer, 2009).
There is evidence that individuals with ADHD are sensitive to schedules of reinforcement (such as intermittent reinforcement) that can affect variability. Aase and Sagvolden (2006) investigated variability in children with ADHD who were asked to perform a series of tasks on a computer involving clicking squares on the screen. A multiple schedule was employed, consisting of VI 2 s and VI 20 s components.

Variability was measured along the dimensions of IRT and cursor location. Under the relatively dense VI 2 s schedule, the ADHD and control groups demonstrated comparable levels of variability. However, when reinforcement was more intermittent under the VI 20 s schedule, children with ADHD demonstrated more variability than the children in the comparison group. This finding suggests that children with ADHD may be more sensitive to the phenomenon of schedule-induced variability than other children.

There is also evidence that behavioral variability in this population can be brought under operant control. Saldana and Neuringer (1998) measured the variability of left and right key-presses emitted by children with ADHD during a computer game task. An image of a snake went across the computer screen; when the snake reached a certain point on the screen, children could press one of two keys on the keyboard. In different phases, points were either awarded contingent on unpredictability (in the VARY condition) or independent of variability (in the IND condition). Each response was assessed according to whether or not it was predictable according to a computer algorithm. For both ADHD and non-ADHD groups, variability was higher under the VARY condition than the IND condition. The children with ADHD, however, made a greater number of errors compared to their peers by pressing the buttons before they were
allowed to do so. This study suggests that children with ADHD are sensitive to contingent reinforcement of variation, but also that they may sometimes vary responding in maladaptive ways (i.e., in the temporal locus of the response).

An additional line of research related to ADHD and variability comes from laboratory studies with a specific genetic strand of rat known as the spontaneously hypertensive rat (SHR). These rats display some of the behavioral characteristics of individuals with ADHD such as increased levels of activity and “impulsive” behavior (Hunziker et al., 1996; Perry et al., 2010). Mook and Neuringer (1994) studied operant variability in SHRs and a non-hypertensive comparison group of Wistar-Kyoto (WKY) rats to evaluate the effects of stimulant medications analogous to those commonly used in the treatment of ADHD. Both SHR and WKY rats increased variation of response sequences when placed on a lag 4 schedule. However, in a subsequent phase requiring repetition of a single response, the SHR rats did not emit as many correct sequences as the control group, unless they had been given a dose of d-amphetamine before the session. The un-medicated SHR rats had difficulty learning to repeat responses, but did not have difficulty learning to vary.

A key to teaching individuals with ADHD may be discovering how to arrange environmental contingencies that will promote the learning of specific (non-varied) responses under certain conditions. A potential solution might be to bring repetition and variation under the control of discriminative stimuli. To date, no studies have been conducted in which stimulus control of operant variability was established in children with ADHD. However, the results of the current study and the research described above
suggest that such learning might be possible. In theory, it may be possible for the excessive variability that typifies individuals with ADHD to be brought under the control of a discriminative stimulus; this would be analogous to the way some researchers have decreased stereotypy in individuals with autism by teaching them to engage in that type of responding only under specific stimulus conditions (e.g., Anderson, Doughty, Doughty, Williams, & Saunders, 2010). Given this potential application, it may be interesting to evaluate whether procedures like the ones used in this study could be effective in teaching individuals with ADHD to vary and repeat under specific stimulus conditions.

**Stimulus control and creativity.** The behaviors targeted during the current study (block building, pattern-making on a pegboard, and painting) are all types of activities that are commonly considered as outlets for creativity. Behavior analysts have hypothesized that creativity may be closely related to variability in that behavior that is highly repetitive is typically considered less creative than that which varies (e.g., Chase, 2003; Neuringer, 2003). Although some degree of variation seems essential to what we call creativity, it is important to note that the two concepts are not synonymous. Responses that vary too much from one another, or along the wrong dimensions, may be viewed not as creative, but as aberrant or bizarre (Stokes, 1999). For example, the speech of an individual with schizophrenia may be highly unpredictable, and thus variable, but would not usually be considered a positive example of creativity. It is possible that one key ingredient to creativity is that variability must occur under appropriate conditions (i.e., under stimulus control). To illustrate this, imagine a jazz musician who is
improvising a solo on the piano while playing a familiar song. The extent to which the audience responds favorably to the music hinges in part upon the musician’s decisions to select notes that are unpredictable at certain moments, but also upon the musician staying within the structure of the song at other times. This analogy could easily be extended to other art forms, including painting, writing, and dance; variability may be a desired aspect of responding under certain conditions and within a certain range, while repetition is desired for other aspects of responding. Procedures designed to develop stimulus control of varied responding may be useful in teaching creativity. Future research that investigates stimulus control of variability may be useful in developing a robust behavioral model for creativity; such an approach may prove more fruitful for educators than traditional ways of explaining creative behavior (e.g., describing creativity as an inherent trait). The results of the current study seem to strongly suggest that at least some aspects of creativity can be in fact taught, and can in fact be brought under antecedent stimulus control.

Promoting generalization of variability. The study’s failure to produce stimulus generalization points to the importance of additional research on the conditions under which varied responding will generalize. In spite of using a common antecedent stimulus across the training and generalization settings, the variable pattern of responding that occurred in the training task (block building or pegboard) did not occur during the generalization task (painting). One way of promoting greater generalization might be to establish stimulus control of variability across multiple tasks using the same S<sub>d</sub>. The use of multiple exemplars during training has been shown to promote generalization across
settings or behaviors within the context of teaching other skills (e.g., Ducharme & Holborn, 1997; Reeve, Reeve, Townsend, & Poulson, 2007; Sprague & Horner, 1984). It is possible that a similar strategy might be effective in promoting variability across situations. If a child were explicitly taught to engage in varied responding when told to do something “different” during painting, block building, and drawing, variability might be more likely to occur when asked to do something “different” when playing a piano.

Another strategy for promoting generalization is to teach responses that will come into contact with natural contingencies (Stokes & Baer, 1977). In the case of variability, it would be essential to determine what natural reinforcers might be associated with the desired outcome (e.g., increased social engagement with peers during play or improved feedback during an art lesson), and then programming contingencies that would increase the level of variability to a sufficient degree that these natural consequences would occur.

A third approach to improving generalization that might be effective is the use of indiscriminable contingencies (Stokes & Baer, 1977). Research has demonstrated that consequences that are somewhat unpredictable (as in delayed reinforcement or a randomly changing schedule) can promote maintenance and generalization (e.g., Baer, Williams, Osnes, & Stokes, 1984; Guevremont, Osnes, & Stokes, 1986). In the case of operant variability, one way that the contingencies might be made indiscriminable would be to implement a variable lag schedule (Lee et al., 2007). Under such a schedule, the value of the lag schedule would vary around a fixed \( n \) from trial to trial, so that under a variable lag 3, one response might be required to vary from the previous 2, while the next response might be required to vary from the previous 4, etc. In this way a variable lag
schedule would be analogous to a VR or VI schedule in which the response requirements vary from one response to the next, but average out to some predetermined value. To date, no research has been done on the effects of such a schedule on response variability, but it is possible that such schedules could promote maintenance and generalization.

Another consideration related to stimulus generalization of operant variability that might be worthy of future study is the relevance of similarity between the training and generalization environments. It would be expected that if response variability functions in a similar manner to other dimensions of behavior, generalization would be most likely when generalization stimuli closely resemble training stimuli (Stokes & Baer, 1977). Generalization can also be promoted through the establishment of an artificial stimulus class that includes a range of stimuli (either similar or dissimilar) that should all control the target response (e.g., Salmon, Pear, & Kuhn, 1986). In promoting generalization of variability, it might prove useful to establish a stimulus class related to varied responding by using a variety of antecedent stimuli during instruction (e.g., instructions to do “Different,” “New,” or “Something else”). Given the range of antecedent stimuli that might occur in the natural environment (e.g., during block play with a peer), establishing a stimulus class of this kind may prove useful in promoting generalization. This could be conceptualized as an example of “training loosely” to promote generalization (Stokes & Baer, 1977).

Response generalization may be another fruitful area for future research on this topic. If an individual learns to vary one aspect of behavior through operant procedures, it is not necessary for one to assume that other (untargeted) aspects of behavior would
also change. Variation in the topography of block building may become varied under a lag schedule targeting that aspect of the response, but other aspects of block building (e.g., the position of the structure on the table, or the height of the structure) may not be affected at all. As demonstrated in the study by Ross and Neuringer (2002), various dimensions of a response can be manipulated independently by contingencies requiring their repetition or variation. Taken together the results of the current study, and those reported by others (Holman et al., 1977; Napolitano et al., 2010) seem to suggest that generalization may occur only across situations involving similar responses. It would be interesting to evaluate whether generalization of variability could also be achieved across dimensions, such that an individual learns to vary one aspect of the response, and can then more readily vary another aspect. This is an empirical question that might be worth investigating.

**Conclusion**

The results of this study seem to suggest that operant variability procedures, particularly those that include a stimulus control component, have the potential to change the behavior of individuals with autism. However, it remains to be seen whether these procedures can be translated into a viable applied technology. To achieve this, the contingencies would need to be implemented efficiently by teachers and other practitioners, and to change socially significant behavior (such as play) to a meaningful degree. Given the relatively weak stimulus control established with the students in this study, and the lack of generalization they exhibited, it is clear that additional work will be needed to develop these procedures into effective tools for classrooms or clinical settings.
Nonetheless, the potential benefits of such procedures in improving the lives of children with autism and children with ADHD, and teaching creativity make this a fertile area for future study and much remains to be learned about the phenomenon of operant variability.
References


Dear Parent/Guardian,

My name is Neal Miller. I am a doctoral student studying special education at The Ohio State University. I am currently conducting research on the topic of teaching creative block play to children with autism, and I am writing to ask permission to have your son or daughter participate in this study. The research is designed to investigate teaching methods designed to increase novelty and creativity during play. The research will involve 15-minute sessions of block play conducted daily over the course of 6 weeks. All research activities will take place at Haugland Learning Center. I will be coordinating with your child’s teacher to schedule these sessions in a way that will not interfere with any other academic activities. Please read the attached document, that describes the procedures in more detail. If you wish to have your child participate, please sign the form and return it to me. If you have questions about the procedures described, or want further information about this project, you may contact me by phone at 503-349-6388 or by email at miller.5107@buckeyemail.osu.edu.

Thanks,

Neal Miller
The Ohio State University Parental Permission
For Child’s Participation in Research

Study Title:  

Stimulus Control of Operant Variability in Children with Autism

Researcher:  

Nancy Neef

Sponsor:  

This is a parental permission form for research participation. It contains important information about this study and what to expect if you permit your child to participate.

Your child’s participation is voluntary.

Please consider the information carefully. Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to permit your child to participate. If you permit your child to participate, you will be asked to sign this form and will receive a copy of the form.

Purpose:

Many children with autism have restricted interests or repetitive behaviors that interfere with their learning. This study is evaluating a teaching procedure designed to help children with autism learn to engage in appropriate behavior that is varied and unpredictable, rather than rote and repetitive. This will be taught within the context of the commonplace play activity of building with blocks. Using methods developed in laboratory research on the principles of learning and behavior, the experimenter will attempt to establish specific stimuli (verbal cues) that will indicate the availability of praise and preferred items for either varying or repeating specific types of block structures during play. A subsequent phase will examine whether these same cues will generalize to a novel activity (using colored stamps or playing a xylophone), in which variability is also possible. The instructional methods being studied may have important implications for the teaching of creativity, play, and social behavior to individuals with autism in the future.

Procedures/Tasks:

Prior to any teaching, the experimenter will conduct procedures to determine highly preferred items to use during subsequent instruction. This will involve presenting a variety of toys or food items to the student, and determining the order in which they are selected. This preference assessment will be used to select items that can be used during teaching trials to reinforce the target response. During experimental sessions, students
will be asked to build a structure out of simple wooden building blocks, and given up to 2 minutes to do so. Based on the form of the structure, the experimenter will sometimes deliver reinforcers (i.e., food or leisure items). If the student does not respond correctly, prompting will be used to teach an appropriate block building response. After an initial phase in which all block structures will produce reinforcement, a series of phases will be run in which the experimenter will either ask the student to “Build the same” (in which case repeating one of the structures they recently made will produce reinforcement) or to “Build different” (in which case the current block structure would need to differ from the previous 3 in order to produce reinforcement). Following a series of training trials using these cues, a block of trials will be run without the “different” and “same” cues, to determine if they were exerting control over responding. Next, the student will be presented with a novel task (either playing a keyboard or placing colored stamps on a paper), in order to test whether the “different” and “same” cues will also affect variability in this context. During sessions, data will be collected by the experimenter regarding the type of structures that are built, and the type of prompts, instructions, and consequences that the experimenter delivers. In addition, digital photos will be taken of the block structures, and sessions will be digitally recorded on video for data collection purposes. These digital pictures and video files will be used only for the purposes of data collection during this study, and will be erased following the completion of the project.

Duration:

The experimental sessions will last approximately 15 minutes, and will take place in a classroom at Haugland Learning Center. The experimenter will run sessions 3-4 times per week, for approximately 6 weeks. Your child may leave the study at any time. If you or your child decides to stop participation in the study, there will be no penalty and neither you nor your child will lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

Risks and Benefits:

If your child participates in this study, he or she will receive instruction and practice related to playing with blocks, as well as with responding appropriately to the verbal cues “same” and “different.” These are potentially important skills. Your child will also gain access to preferred items during the teaching trials. There are no anticipated risks of the procedures being used in this study. If a child does not wish to participate in the experiment at any point (as indicated by verbal or non-verbal communication), he or she will be free to terminate that session, or withdraw from the experiment. The experimenter will coordinate with your child’s teacher to ensure that the 15-minute sessions are conducted at a time that does not interfere with the one-on-one instruction your child typically receives.
Confidentiality:

Efforts will be made to keep your child’s study-related information confidential. Digital and physical files related to your child’s performance will be kept on a password-protected computer or in a locked file cabinet, and these files will be coded so that they do not contain the names of the participants. However, there may be circumstances where some information must be released. For example, personal information regarding your child’s participation in this study may be disclosed if required by state law. Also, your child’s records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

Incentives:

During experimental sessions, your child will be able to access preferred items such as foods and toys.

Participant Rights:

You or your child may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you or your child is a student or employee at Ohio State, your decision will not affect your grades or employment status.

If you and your child choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights your child may have as a participant in this study.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

Contacts and Questions:

For questions, concerns, or complaints about the study you may contact Neal Miller by phone at 503-349-6388 or by email at miller.5107@buckeyemail.osu.edu.
For questions about your child’s rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If your child is injured as a result of participating in this study or for questions about a study-related injury, you may contact Neal Miller by phone at 503-349-6388 or by email at miller.5107@buckeyemail.osu.edu.

**Signing the parental permission form**

I have read (or someone has read to me) this form and I am aware that I am being asked to provide permission for my child to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to permit my child to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

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**Investigator/Research Staff**

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

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172
I am doing a study on how children learn to play. If you agree to take part in this study, I am going to ask you to build with blocks. After you make a building with the blocks, you will sometimes get a toy or a snack. We will play with the blocks for about 15 minutes a day, in a room here at your school. The study will last for a few weeks. You can ask me any questions you have about what we are going to do before we start. It will be OK to say “No” if you don’t want to do this – you won’t get in trouble for saying that. If you say “Yes,” you can still change your mind if you decide to stop being in the study. So, do you want to take part in this study? (Yes or no?)
Appendix B: Sample Datasheet
Primary Datasheet

Date:___________________________
Participant # __________________
Phase of Experiment __________

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<th>Instruction</th>
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Appendix C: Photos of Block Structure Forms
1. Balance

2. I

3. Post

4. Single Stack

5. Post & Balance

6. Double Wide Stack
7. Enclosure

8. Arch

9. Fence

10. Floor

11. Multi Stack

12. Multi Stack & Balance
13. Multi Stack & Balance & I

14. Multi Stack & I

15. Multi Stack & Post

16. Multi Stack & Post & Balance

17. Multi Stack & Post & I
Appendix D: Diagrams of Peg Forms
7. $3 + 1$

8. $2 + 2$

9. Angle

10. Diamond

11. T

12. Zig Zag
13. Scatter

14. Curve

15. Y

16. U

17. Bumpy Line
Treatment Integrity Datasheet

Date: ______________________

Participant ______________

Phase: _____________________

<table>
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<tr>
<th>Trial #</th>
<th>Did teacher present the correct instruction?</th>
<th>Did teacher wait for student to complete the form?</th>
<th>Did teacher present the correct consequence?</th>
<th>Did teacher start the next trial within 60 seconds?</th>
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