Assessing the Effects of Derived Relational Responding on Intraverbal Use of Same-Opposite and More Than-Less Than Relations in Children with Autism

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Assessing the Effects of Derived Relational Responding on Intraverbal Use of Same-Opposite and More Than-Less Than Relations in Children with Autism

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts
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Keywords: Relational Frame Theory, applied behavior analysis, verbal behavior, derived stimulus relations

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# TABLE OF CONTENTS

List of Tables .................................................................................................................................................... iv

List of Figures ........................................................................................................................................................ v

Abstract ................................................................................................................................................................ vii

Chapter One: Introduction ....................................................................................................................................... 1
  Verbal Behavior and RFT ..................................................................................................................................... 3
  Relational Training and Intraverbals ..................................................................................................................... 4
    Relational Skills and Verbal Ability .................................................................................................................. 5
    Teaching Derived Relational Responding ........................................................................................................ 6

Chapter Two: Method ............................................................................................................................................... 10
  Participants .......................................................................................................................................................... 10
  Setting .............................................................................................................................................................. 12
  Materials .......................................................................................................................................................... 12
    Token Economy .......................................................................................................................................... 14
  Dependent Measures and Experimental Design ................................................................................................. 15
  Interobserver Agreement ..................................................................................................................................... 16
  Implementation Fidelity ...................................................................................................................................... 17
  Procedure ........................................................................................................................................................ 18
    Pre-experimental Nonarbitrary Training ......................................................................................................... 19
    Baseline ........................................................................................................................................................ 21
  Experimental Training ....................................................................................................................................... 22
    Same-Opposite ........................................................................................................................................... 23
    More than-Less than .................................................................................................................................... 24
    Derived relational responding probes ........................................................................................................ 24
    Stimulus set re-training .................................................................................................................................. 26
    Training failed derived relations ................................................................................................................... 26
    Mixed trials .................................................................................................................................................... 27
    Grand mixed trials ....................................................................................................................................... 27
    Intraverbal probes of relations ....................................................................................................................... 28

Chapter Three: Results .......................................................................................................................................... 31
  Participant 1 (Adam) .......................................................................................................................................... 31
    Pre-training .................................................................................................................................................... 31
    Baseline ........................................................................................................................................................ 31
    Same-Opposite ............................................................................................................................................. 31
    Set 1 (A-B) .................................................................................................................................................... 31
| Set 2 (A-C) | 32 |
| Set 3 (C-D) | 32 |
| Grand mixed trials | 32 |
| More Than-Less Than | 32 |
| Set 1 (E-F) | 32 |
| Set 2 (E-G) | 32 |
| Set 3 (G-H) | 32 |
| Grand mixed trials | 33 |

**Intraverbal Probes of Relations**

| Participant 2 (Dustin) | 34 |
| Pre-training | 35 |
| Baseline | 35 |
| Same-Opposite | 36 |
| Set 1 (A-B) | 36 |
| Set 2 (A-C) | 36 |
| Set 3 (C-D) | 36 |
| Grand mixed trials | 36 |
| More Than-Less Than | 36 |
| Set 1 (E-F) | 36 |
| Set 2 (E-G) | 37 |
| Set 3 (G-H) | 37 |
| Grand mixed trials | 37 |

**Intraverbal Probes of Relations**

| Participant 3 (Nancy) | 39 |
| Pre-training | 40 |
| Baseline | 41 |
| Same-Opposite | 41 |
| Set 1 (A-B) | 41 |
| Set 2 (A-C) | 41 |
| Set 3 (C-D) | 41 |
| Grand mixed trials | 42 |
| Set 4 (X-Y) | 42 |
| More Than-Less Than | 42 |
| Set 1 (E-F) | 42 |
| Set 2 (E-G) | 44 |
| Set 3 (G-H) | 44 |
| Grand mixed trials | 44 |
| Set 4 (J-K) | 44 |

**Intraverbal Probes of Relations**

| Participant 4 (Paul) | 46 |
| Pre-training | 48 |
| Baseline | 48 |
| Same-Opposite | 48 |
| Set 1 (A-B)                  | 48 |
| Set 2 (A-C)                  | 49 |
| Set 3 (C-D)                  | 49 |
| Grand mixed trials           | 49 |
| Set 4 (X-Y)                  | 49 |
| Set 5 (X-Z)                  | 50 |
| Set 6 (Z-V)                  | 51 |
| Grand mixed trials           | 52 |
| More Than-Less Than          | 52 |
| Set 1 (E-F)                  | 52 |
| Set 2 (E-G)                  | 52 |
| Set 3 (G-H)                  | 53 |
| Grand mixed trials           | 53 |
| Set 4 (J-K)                  | 54 |
| Intraverbal Probes of Relations | 54 |
| Number of Sessions           | 55 |

Chapter Four: Discussion ................................................................. 63
Limitations ............................................................... 68
Future Research ................................................................. 70

References ........................................................................ 73
LIST OF TABLES

Table 1: Trained and derived relations for SAME-OPPOSITE ............................................ 26
Table 2: Trained and derived relations for MORE THAN-LESS THAN ............................. 26
Table 3: Number of sessions, number of trial blocks, and DRR probe scores for each set for Adam ........................................................................................................... 34
Table 4: Adam’s DRR probe scores and DRR training scores for mutually entailed (ME) and combinatorially entailed (CE) relations ................................................ 34
Table 5: Number of sessions, number of trial blocks, and DRR probe scores for each set for Dustin ........................................................................................................ 39
Table 6: Dustin’s DRR probe scores for mutually entailed (ME) and combinatorially entailed (CE) relations ................................................................................. 39
Table 7: Nancy’s DRR probe scores and DRR training scores for mutually entailed (ME) and combinatorially entailed (CE) relations ................................................. 46
Table 8: Number of sessions, number of trial blocks, and DRR probe scores for each set for Nancy ........................................................................................................ 47
Table 9: Paul’s DRR probe scores and DRR training scores for mutually entailed (ME) and combinatorially entailed (CE) relations .................................................... 56
Table 10: Number of sessions, number of trial blocks, and DRR probe scores for each set for Paul ........................................................................................................ 57
Table 11: Total number of sessions, trial blocks, and intra-verbal probe sessions for all participants ...................................................................................................... 58
LIST OF FIGURES

Figure 1: Stimuli used in SAME-OPPOSITE relational network (Sets 1-3) .................. 13
Figure 2: Stimuli used in MORE THAN-LESS THAN relational network (Sets 1-3) ...... 13
Figure 3: Stimuli used for SAME-OPPOSITE relational network (Sets 4-6) .............. 14
Figure 4: Stimuli used for Set 4 MORE THAN-LESS THAN ................................... 14
Figure 5: Outline of training and testing sequence .................................................. 16
Figure 6: Implementation steps during pre-experimental and experimental training phases ................................................................................................................................. 22
Figure 7: Relational network for SAME-OPPOSITE (Sets 1-3) showing trained and derived relations .......................................................................................................... 23
Figure 8: Relational network for MORE THAN-LESS THAN showing trained and derived relations ........................................................................................................... 24
Figure 9: DRR probe scores for Adam ...................................................................... 35
Figure 10: DRR probe scores for Dustin .................................................................. 40
Figure 11: DRR probe scores for Nancy ................................................................. 46
Figure 12: DRR probe scores for Paul ..................................................................... 57
Figure 13: Percentage of correct responses during formal pre-training, baseline, and experimental training for Adam (top panel) and Dustin (bottom panel) .......... 58
Figure 14: Number of relations stated during intraverbal probe sessions for Adam (top panel) and Dustin (bottom panel) ........................................................................ 59
Figure 15: Percentage of correct responses during formal pre-training, baseline, and experimental training for Nancy (top panel) and Paul (bottom panel) ............ 60
Figure 16: Number of relations stated during intraverbal probe sessions for Nancy (top panel) and Paul (bottom panel) ................................................................. 61
Figure 17: Total number of relations stated during intraverbal probe sessions for Adam (squares) and Dustin (diamonds) .................................................................62

Figure 18: Total number of relations stated during intraverbal probe sessions for Nancy (squares) and Paul (diamonds) .................................................................62
ABSTRACT

Relational Frame Theory provides an analysis of verbal behavior involving a focus on the development of relational operants which are seen as a basis for language. From this basis, a framework is provided for establishing relational networks in individuals who lack derived relational ability. Establishment of relational frames may increase the probability of responding relationally to novel instances and use of the specific relational frames during social interactions; therefore, training verbal relations in accordance with an RFT approach may enhance intraverbal responding and facilitate the emergence of untrained responses. The purpose of this study was to evaluate the emergence of specific relationships in the context of intraverbal responding as a collateral effect of training on relational networks in four children with Autism Spectrum Disorder. Two participants demonstrated mastery of derived relational responding (DRR) without training, one participant demonstrated mastery of DRR following training, and a fourth participant demonstrated mutual entailment and some combinatorial entailment. Increases in vocal verbal behavior during generalization probes were observed, although increased use of all target relations was not observed in all participants. Further research is needed to evaluate specific deficits in derived relational responding among individuals with ASD, as well as the correlation between DRR and language ability.

Keywords: Relational Frame Theory, applied behavior analysis, verbal behavior, derived stimulus relations
CHAPTER ONE:
INTRODUCTION

Relational Frame Theory is a behavior analytic approach to human language and cognition which extends Skinner’s (1957) analysis of verbal behavior (Gross & Fox, 2009). According to RFT, verbal behavior involves a history of reinforcement for responding in accordance with contextually controlled, arbitrarily applicable relations referred to as relational frames (Barnes-Holmes, Barnes-Holmes, & Cullinan, 2000). This form of relational responding is viewed as the process of deriving relationships between stimuli and events although there has been no history of training or pairing of the various stimuli involved. This ability allows for more information to be obtained in a given situation than would otherwise be possible if all responding were associative (Blackledge, 2003).

RFT supports the existence of an overarching relational operant in humans which allows countless relations to be derived between seemingly unrelated stimuli. Relational responding can be based on formal similarities between stimuli (i.e., generalization); however, stimuli and events can be related regardless of their physical properties. It is when relational responding is based on the arbitrary aspects of stimuli that have no history together that derived relational responding is said to have occurred. This type of responding is called arbitrarily applicable relational responding, a type of behavior that has only been reliably demonstrated by humans to this point (Blackledge, 2003). From an RFT perspective, arbitrarily applicable relational responding is the
central process involved in human language and advanced cognitive ability (Barnes-Holmes, Barnes-Holmes, & McHugh, 2004).

Relational frames are generalized classes of verbal operants with the defining characteristics of mutual entailment, combinatorial entailment, and transformation of stimulus function. These terms are used to describe the arbitrarily derived relations between two or more stimuli; and through the control of the relational context, results in alteration of stimulus function (Barnes-Holmes, Barnes-Holmes, & McHugh, 2004). Mutual entailment implies a bidirectional relation between two stimuli. In other words, if A is related to B in a particular way, then it can be derived that B is related to A in a corresponding way (Hayes et al., 2001). Combinatorial entailment involves relations between at least three stimuli, where there is a derived reciprocal relationship between two of the stimuli based on how those stimuli are related to an intermediary stimulus (Blackledge, 2003). For example, if A is the same as B and A is the same as C, then it is possible to derive that B and C are also the same. This is a critical feature of how language is acquired according to RFT (Törneke, 2010).

Regarding transformation of function, when an organism behaves in a particular way in relation to a stimulus it can be said that the stimulus has a particular function for the organism’s behavior (Törneke, 2010). In essence, a stimulus functions in different ways depending on the context. A stimulus function may be acquired directly, where the organism experiences consequences following a response; or indirectly, as is seen in derived relational responding. When derived stimulus relations are established, stimulus functions are changed, and as a result, the altered function(s) of the related stimuli impact behavioral regulation accordingly (Törneke, 2010). That is, the function of a stimulus is transformed based on the other stimuli it is related to and how they are related (Blackledge, 2003). Whereas any one of the stimuli may not affect
typical behavioral patterning, due to their participation together in a relational network under the contextual control of both relation and individual function, alterations of behavioral patterns may occur. These altered behavioral patterns may be categorized as adaptive or maladaptive.

The two aspects of context, relational and functional, are referred to as $C_{\text{rel}}$ and $C_{\text{func}}$ respectively. Unlike nonarbitrary relations, which are controlled by physical properties of stimuli, arbitrary relations are governed by the contextual cues which specify relations between stimuli. $C_{\text{rel}}$ establishes the relations between stimuli at a given time, and $C_{\text{func}}$ controls which function of a stimulus is selected based on the relation established by the $C_{\text{rel}}$ (Törneke, 2010). A typically developing individual learns to respond to stimuli based on a variety of different relations between stimuli and through repeated exposure to multiple exemplars (Törneke, 2010). These exemplars are initially based on formal, or nonarbitrary, properties and are then extended to arbitrary aspects of stimuli.

**Verbal Behavior and RFT**

Verbal behavior is viewed as operant responding that is controlled by antecedents and consequences (Törneke, 2010). According to Skinner (1957), verbal behavior is characterized by indirect interaction with the environment, in which consequences occur as a result of the mediation of a listener. From an RFT perspective, derived stimulus relations are the basis of verbal behavior (Hayes et al., 2001). According to RFT, behaving verbally involves relating events in a particular way, and the ability to respond to arbitrarily applied relations between stimuli is what constitutes verbal behavior (Törneke, 2010). Arbitrarily applicable relational responding is considered a verbal process because it is controlled by contextual aspects of the
environment, rather than by formal features of the stimuli and events that are being related (Barnes-Holmes, Barnes-Holmes, & McHugh, 2004).

RFT distinguishes between verbal and nonverbal response forms. Verbal responses are based on arbitrarily applicable relational responding, whereas nonverbal responses are based on contingencies of reinforcement that have been directly experienced (Barnes-Holmes et al., 2000). The latter type of responding is considered nonverbal because it does not possess the referential and symbolic characteristics typically associated with verbal events. In order for a stimulus to be considered verbal, it must participate in a relational frame with at least two other stimuli. This distinction may be a useful step towards identifying specific behavioral processes involved in the production of generative language (Barnes-Holmes et al., 2000).

**Relational Training and Intraverbals**

It has been suggested that learning relations between responses may facilitate the emergence of untrained responses (Perez-Gonzalez, Garcia-Asenjo, Williams, & Carnerero, 2007). Many intraverbal stimuli and responses may participate in relations that can be derived (i.e., can emerge) without additional training (Perez-Gonzalez et al., 2007). One such relation is reversibility, or when two responses are interchangeable. For example, the words “big” and “small” are interchangeable as either verbal stimuli or responses when presented with the contextual cue “Name the opposite of ---”. Perez-Gonzalez et al. examined the emergence of intraverbal antonyms in two children (ages 6 and 8 years old) diagnosed with Pervasive Developmental Disorder (PDD). Neither of the participants showed emergence of untrained intraverbals until both the original and reverse relations were taught. Emergent relations were demonstrated by both participants after learning several pairs of opposite concepts, suggesting
that learning relations between intraverbal responses may facilitate the emergence of additional responses. The authors indicate that by training multiple exemplars of opposite pairs, the phrase “the opposite of” was established as a contextual cue which occasioned the derived relational response.

May, Hawkins, and Dymond (2013) evaluated the emergence of intraverbal responses following tact training in three adolescents with autism. Training and testing materials consisted of two pictures, each showing a fictitious character. A-B relations were trained with the question “What is this monster’s name?” along with the presentation of the picture of the corresponding monster (i.e., tact prompt). A-C relations were trained with the presentation of the question “What does this monster eat?” in addition to the tact prompt (i.e., the picture of the corresponding monster was presented but not the name of the monster). Emergent responses were tested without the visual stimulus present and by asking “What food does (monster’s name) eat?” (B-C) and “Which monster eats (food)?” (C-B). All three participants demonstrated emergence of correct untrained intraverbal responses following tact training. The authors suggest that because the A stimuli (character pictures) participated in training both B stimuli (character names) and C stimuli (food names) this facilitated the emergence of B-C and C-B relations.

**Relational Skills and Verbal Ability**

RFT suggests that an increased ability to respond relationally contributes to greater proficiency of verbal skills. According to Barnes-Holmes et al. (2001), “it is the relational skills that are key, not merely verbal content in a formal sense” (p. 160). The ability to comprehend sentences and participate in conversation requires a variety of relational responses in order to derive relations between verbal stimuli (Cassidy, Roche, & Hayes, 2011). It is also important for
children to learn to evaluate relations between events based solely on social attribution of characteristics (Berens & Hayes, 2007). Derived relational responding is a generalized contextually controlled operant which allows for a technical approach to the investigation of underlying processes involved in language generativity (Stewart, McElwee, & Ming, 2013). Research suggests that the acquisition of verbal relational abilities correlates with various cognitive skills, as well as educational success (Barnes-Holmes et al., 2001). An essential component of the establishment of these skills and the formation of a flexible repertoire of responding involves the use of multiple exemplar training (Barnes-Holmes, Barnes-Holmes, & McHugh, 2004).

**Teaching Derived Relational Responding**

The development of relational frames involves explicit training of multiple exemplars, followed by testing for derived responses using novel stimuli (Luciano et al., 2009). Additionally, Luciano and colleagues recommend training bidirectional relations and programming the transfer from formal to arbitrary stimulus relations. Several studies have successfully demonstrated the acquisition of derived relational responding in children using multiple exemplar training (e.g., Barnes-Holmes, Barnes-Holmes, & Smeets, 2004; Barnes-Holmes, Barnes-Holmes, Smeets, Strand, & Friman, 2004; Berens & Hayes, 2007; Gorham, Barnes-Holmes, Barnes-Holmes, & Berens, 2009). Participants in these studies learned to relate stimuli based on arbitrary properties in accordance with frames of comparison (more than and less than) and/or opposition.

The relational frame of opposition involves the abstraction of a dimension along which stimuli can be ordered and distinguished from a point of reference (Barnes-Holmes, Barnes-
Holmes, & Murphy, 2004; Luciano et al., 2009). Coordination (i.e., equivalence) should be taught before opposition because opposition involves combinatorially entailed relations that are coordinated with one another; that is, the opposite of an opposite is the same (Barnes-Holmes, Barnes-Holmes, & Murphy, 2004). The relational frame of comparison involves responding to one stimulus in terms of a qualitative or quantitative relation along a specific dimension with another stimulus (Luciano et al., 2009).

Barnes-Holmes, Barnes-Holmes, and Smeets (2004) taught three typically developing children (ages 4 to 6) to respond in accordance with arbitrarily applied opposite relations among paper coins. The children were presented with a horizontal array of two or more coins and were told that one of the coins bought many or few sweets. Pointing to one coin at a time, the experimenter said, “If this coin (A) buys many/few, and this coin (B) is the opposite, which would you pick to buy the most sweets?” For trials involving four or more coins and for certain trials involving three coins, the participant was required to select at least two coins in order for the response to be considered correct. For example, in a trial where A buys many, B is opposite A, and C is opposite B, the correct response would be both A and C (an opposite of an opposite is the same).

In a similar study, Barnes-Holmes, Barnes-Holmes, Smeets, Strand, et al. (2004) taught three typically developing children to derive arbitrary comparative relations between two and three paper coins. Participants were trained to respond in accordance with arbitrarily specified relations of more than and less than. The experimenter designated the relative value of each coin prior to every trial and instructed the participant to select the coin that would “buy as many sweets as possible.” Participants failed initial baseline tests but demonstrated acquisition of target relational responses following multiple exemplar training.
The authors acknowledge that a limitation of both studies described above is that the relational responses were not actually derived because the children were exposed to the same four types of trials involving two or three coins. It could be argued that over multiple trials, children learned that if \( A > B > C \), then \( A > C \) and \( C < A \). In order to test for truly derived responding in this context it is necessary to evaluate comparative relations that have not been directly trained (Gorham et al., 2009).

Consider a four-element relational sequence where \( A > B \), \( B > C \), and \( C > D \); it is then possible to ask children about the untrained relationship between \( B \) and \( D \). A related study by Gorham et al. (2009) compared performances of typically developing children and children with autism on problem-solving tasks involving arbitrary more than and less than relations involving identically sized paper coins. Two of the three participants with autism demonstrated similar performances as the typically developing children; however, the third participant with autism was dropped from the study because he failed to demonstrate nonarbitrary more than and less than relations, even with supplementary training. A second experiment involving the same participants trained and tested more than and less than \( B-D \) relations with four-coin and five-coin sequences. Six of the seven children were unable to derive the transitive \( B-D \) relations during baseline testing, despite passing relational responding tests of four-coin sequences during the first study. The children with autism demonstrated greater difficulty during training of \( B-D \) relations than the typically developing children.

The effectiveness of training multiple exemplars to establish derived relational responding is well documented in typically developing children; however, more research in this area is needed with children with autism spectrum disorders in order to identify specific deficits in relational abilities, as well as the relation between verbal ability and DRR (Moore, 2009).
Additionally, the acquisition of derived relational responding may have collateral benefits that have not yet been assessed, particularly in individuals who show deficits in relational ability.

The purpose of the proposed study was to assess the impact of derived relational responding on intraverbal ability during naturalistic probes (i.e., intraverbal probes). Specifically, this study evaluated whether novel intraverbal responding involving same-opposite and more than-less than relations would emerge collateral to the establishment of derived relational ability involving these same relations. This study was conducted with children diagnosed with autism who were able to identify same-opposite and more than-less than concepts based on formal features, but showed deficits in deriving same-opposite, and more than-less than relations based on arbitrary properties.
CHAPTER TWO:

METHOD

Participants

Participants were four children diagnosed with Autism Spectrum Disorder (ASD) who were between ages 6 and 10 and who demonstrated similar verbal ability. Participant 1 (Adam) was 10.0 years old at the beginning of his participation in the study. Adam was in fifth grade and had consistently received ABA services since age 3. Participant 2 (Dustin) was 10.2 years old at the beginning of the study. He was in fourth grade and had never received ABA services. Participant 3 (Nancy) was 8.9 years old when she began the study and was in third grade at a school for children with autism. She had never received ABA services. Participant 4 (Paul) was 6.0 years old and was in kindergarten when he began the study. Paul had been receiving ABA services since age 4.

Attempts were made to select similar-age participants in order to control for potential extraneous factors (i.e., maturation, history); however the primary determining factor was each participant’s language ability. Language ability was determined through participants’ clinical records and assessments, and through direct observation. All participants were able to communicate using complete sentences and demonstrated the use of autoclitic frames. An autoclitic is a verbal operant that modifies the function or strength of other verbal behavior (Skinner, 1957), and is relevant to the vocal verbal relational responses of interest. Autoclitics are frequently involved in the production of intraverbal speech. Additionally, when comparing
two or more items or events the suffix *er* is often added to state the relation (e.g., bigger, smaller, faster, slower).

Other inclusion characteristics included: the ability to identify same, opposite, more than, and less than relations based on formal properties, deficits in relating items based on arbitrary properties, the ability to respond to yes/no questions and open-ended questions (i.e., intraverbal behavior), demonstration of joint attention, low rates of problem behaviors (fewer than 3 instances per hour and duration of less than 3 min per occurrence), and the ability to remain seated and on-task for at least 10 min at a time. Additionally, it was determined that during their involvement in the study that participants would not be exposed to clinical programming of the target relations outside of the study. These factors were determined through an initial phone interview with parents and validated during the initial pre-experimental meeting. Formal pre-training with nonarbitrary stimuli also served as a pre-test to assess inclusion characteristics based on relational abilities. Initial probes of intraverbal relations assessed participants’ abilities to relate items based on arbitrary properties, and also provided language samples for each of the participants.

Participants were recruited through fliers displayed at USF and through emails sent to agencies within the community. Participant characteristics were listed and a brief description of the study was provided. A consent form was distributed to parents who responded with an interest in allowing their child to participate in the study. In addition to written parental consent, verbal assent from each participant was obtained prior to his or her involvement in the study. A verbal assent script was read to each participant during the pre-experimental meeting and participants were encouraged to ask questions. Pre-experimental training began after obtaining both written parental consent and participant verbal assent.
Pseudonyms or initials were used to identify participant information. Any records containing potentially identifiable information have been and will be kept in a secure location in the possession of the experimenter (i.e., in sealed manila envelopes in a locked file cabinet, on a password protected computer or hard drive). Research data and records will be kept for at least 5 years after the final report has been submitted.

**Setting**

Sessions were conducted in participants’ homes approximately 2 to 3 times per week. All sessions were conducted at a table with the exception of Dustin, with whom most sessions were conducted on the floor of his bedroom. Sessions lasted 30 min to one hour and took place in a quiet room with minimal distractions. Only the necessary materials for the current training session were within close proximity of the experimenter and participant. Intraverbal probes of relations took place in the same setting as baseline and training sessions and in the same format (i.e., seated at table with experimenter).

**Materials**

Data were collected using paper and pencil and all sessions were video recorded. Stimuli for pre-experimental training and experimental training were displayed on 8.5x11 inch sheets of white paper. Sheets were oriented horizontally and each sheet displayed 3 images. The sample stimulus was centered 1 inch from the top of the sheet and the two comparison stimuli were approximately 3 inches below the sample stimulus and approximately 5 inches apart. Stimulus sheets were placed in transparent sheet protectors and arranged by order of trial presentation in 3-ring binders.
Stimuli for pre-experimental training consisted of two sets of 20 stimulus sheets (one set for SAME-OPPOSITE, one set for MORE THAN-LESS THAN). The stimuli used during the pre-experimental phase had salient, formal features upon which the relational response was based. Ten SAME-OPPOSITE concepts were presented during pre-training: day/night, hot/cold, up/down, black/white, big/small, on/off, happy/sad, full/empty, open/closed, and left/right. Stimuli used for MORE THAN-LESS THAN included pictures of quantities and numerals.

Materials used for training arbitrary relations consisted of 36 different arrangements of stimuli (i.e., six different arrangements of stimuli for each of the six stimulus sets), with six copies of each sheet. A total of 14 symbols (adapted from Steele & Hayes, 1991) were divided into two sets of seven stimuli (see Figures 1 and 2). These two sets of seven stimuli served as relational networks for SAME-OPPOSITE and MORE THAN-LESS THAN. Each stimulus was designated alphanumerically (e.g., A1,
B1, B2) and participants did not have knowledge of these labels. Two additional sets of three stimuli (one for SAME-OPPOSITE and one for MORE THAN-LESS THAN) were created using novel symbols and used with Participants 3 and 4 for supplementary training and testing (see Figures 3 and 4).

Picture cards of common items were used during intraverbal probe trials. Five cards were presented at a time and were only presented one time for each participant. The same sets of pictures were presented to each participant in the same order. A total of 24 sets of five picture cards were compiled by the experimenter. The experimenter attempted to select items that children were likely to be familiar with and asked participants to identify the items at the beginning of each intraverbal probe session to ensure they knew what the items were. If a participant was unable to tact an item in a picture the experimenter told the participant what the item was and described it before continuing the session. This only occurred a few times throughout the course of the study.

**Token Economy**

A token system was created specifically for participants to use in this study in order to control for any history with previous token boards, and the token system was taught during the pretesting phase. During baseline and probe trials, tokens were delivered on a VI 30-s schedule.
During training trials tokens were delivered on an FR1 schedule. Participants were required to earn 20 tokens before gaining approximately 5 min of access to a preferred item or activity. Backup reinforcers were provided in exchange for tokens earned, and participants’ preferences were determined through parent or therapist report or through participant self-report. Reinforcers used depended on what participants selected during sessions. For Adam, preferred activities were tablet games and nature books. Dustin’s preferred activity was playing games on a tablet. For Nancy, games or videos on a tablet were preferred activities. Paul’s preferred activity was watching videos on a tablet.

**Dependent Measures and Experimental Design**

The primary dependent measure consisted of vocally stating the arbitrarily specified relation between the designated stimuli in each trial. Secondary dependent measures involved structured probe trials to evaluate participants’ ability to draw relations between various items. This study contained several phases: formal pre-training, baseline, experimental training of stimulus sets, DRR probes, training of failed relations, presentation of initially trained relations intermixed with derived relations (i.e., mixed trials), and presentation and random rotation of the originally trained stimulus sets (i.e., grand mixed trials) (see Figure 5).

A multiple baseline design across participant dyads was used to examine acquisition of trained stimulus sets and derived stimulus relations. With respect to intraverbal responses, probes were conducted to examine the impact of the experimental training on intraverbal behavior and the use of relations. These data were displayed using a continuous probe design.
Interobserver Agreement

All sessions were video recorded for Inter-Observer Agreement (IOA) to be collected. IOA observations were conducted by research assistants who were trained by the experimenter. IOA was collected for 38.5% of relational training and testing trials overall with 99.6% agreement, and was collected for 43% of intraverbal probe sessions with 97.7% agreement. Trial-by-trial IOA was calculated for experimental training and testing trials by dividing the number of trials in which the experimenter and a second observer agreed on the outcome by the
total number of trials conducted during the observation and multiplied by 100. For example, IOA for a trial block with 10 trials in which the second observer and the experimenter agree on 9 trials would be calculated as follows: \((9/10) \times 100\), with a result of 90% agreement. IOA for Adam was 100% for 50% of sessions, IOA for Dustin was 99.5% for 33.3% of sessions, IOA for Nancy was 99.3% for 35.7% of sessions, and IOA for Paul was 99.6% for 35% of sessions.

IOA for intraverbal probes was calculated based on frequency-within-interval recording. Observation time was divided into 1-min intervals, and the percentage of agreement between observers was calculated for each interval by dividing the smaller frequency by the larger frequency. The percentages from all intervals were summed and divided by the total number of intervals in each observation period. Intraverbal probe IOA for Adam was 97.2% for 50% of sessions, IOA for Dustin was 98.8% for 50% of sessions, IOA for Nancy was 100% for 33% of sessions, and IOA for Paul was 94.6% for 39% of sessions.

**Implementation Fidelity**

Implementation fidelity data was collected for 42.6% of relational training and testing trials, with a score of 99.6%, and for 43% of intraverbal probe sessions, with a score of 99.7%. Research assistants collected implementation fidelity data by viewing video recordings of sessions and filling out a checklist provided by the experimenter. The checklist outlined each step of implementation and the research assistant placed tally marks for each opportunity and whether each step was implemented correctly. The percentage of correct steps during each session was calculated by dividing the number of steps completed correctly by the number of steps in the checklist. Separate checklists were created to reflect implementation steps for each phase and for intraverbal probes as well. For relational training and testing, a second observer
independently scored 50% of Adam’s sessions with an overall score of 100%, 50% of sessions for Dustin with an overall score of 99.9%, 35.7% of Nancy’s sessions with an overall score of 98.6%, and 35% of Paul’s sessions with an overall score of 100%. For intraverbal probes, a second observer independently scored 50% of sessions for Adam and Dustin with an overall score of 100% for both, 33% of Nancy’s sessions with an overall score of 100%, and 39% of Paul’s sessions with an overall score of 98.9%.

Procedure

Training was conducted using nonautomated procedures, in which each stimulus was delivered, arranged, and recorded, and responses were consequated by an experimenter who was present in the experimental setting with the participant at all times (Dymond, Rehfeldt, & Schenk, 2005). According to Dymond et al., there are several advantages to using nonautomated procedures, including interaction between instructor and participant, flexibility, and correlation with participants’ usual instruction.

Prior to each session, the experimenter asked the participant, “Do you want to look at pictures with me?” If the participant provided verbal assent the session began. If the participant said “no” the experimenter said “Alright” and proceeded to appear busy (e.g., making notes, organizing materials) for the next 5 min. During this time the participant was permitted to play in the room but did not have access to reinforcers that were to be used for training. After 5 min passed, the experimenter re-presented the question and the protocol would be repeated if the participant said “no” a second time. If the participant said “no” a third time the session would end and would resume at the next scheduled session. There was only one instance in which a
participant (Dustin) did not provide verbal assent when asked the first time. The outlined protocol was followed and he provided assent the second time he was asked.

**Pre-experimental Nonarbitrary Training**

The pre-experimental phase functioned as a test for inclusion criteria and was administered in order to determine whether participants demonstrated the ability to relate stimuli as SAME, OPPOSITE, MORE THAN, and LESS THAN based on formal properties. Additionally, the pre-experimental training phase served to teach participants the format in which to respond during experimental training. Pre-experimental training consisted of 40 trials per block (20 trials of SAME-OPPOSITE and 20 trials of MORE THAN-LESS THAN), with trials for SAME-OPPOSITE and MORE THAN-LESS THAN presented separately.

Reinforcement in the form of tokens was provided on an FR1 schedule during this phase, in which participants earned tokens for each correct response. After participants earned 20 tokens they were permitted to gain access to the preferred item or activity of their choice for a designated amount of time.

The experimenter and the participant were seated at a table together. Stimulus sheets were presented one at a time and one stimulus sheet was presented for each trial. On the first presentation of each relational type, the experimenter stated the correct relation while pointing to the comparison stimulus, then to the sample stimulus (e.g., “This (pointing to comparison) is SAME/OPPOSITE/MORE THAN/LESS THAN this (pointing to sample)”). The S^D presented for each trial was the question: “How is this (pointing to comparison) related to this (pointing to sample)?” On the first presentation of each type of relation the experimenter immediately prompted the correct response (i.e., “Say ‘this is [SAME/OPPOSITE/MORE THAN/LESS THAN this (pointing to sample)]’.”)
THAN] this’’ while pointing) after presenting the $S^D$. This initial presentation for each type of relation during pre-training served as an example (not a prompted response) and was not calculated with the remaining trials in that trial block.

Participants were required to vocally state the relationship between the designated comparison stimulus and the sample stimulus for each trial. Participants were allowed 10 sec to respond for each trial during pre-training and experimental training trials. It was important to give this 10 second time allowance and for this time to remain consistent when probing derived stimulus relations to allow participants to engage in verbal behavior (either covert or overt) in order to arrive at the correct response. For example, if participants are taught that $B_1$ is the same as $A_1$, and $B_2$ is opposite $A_1$, it is possible to derive that $B_1$ is opposite $B_2$ and $B_2$ is opposite $B_1$, but only following the necessary verbal responses that allow for this derived relational response to occur.

If the participant did not provide a correct response within 10 sec of the experimenter’s initial instruction for that trial, or responded incorrectly, the experimenter re-presented the $S^D$ and immediately prompted the correct response (i.e., “Say ‘this is [SAME/OPPOSITE/MORE THAN/LESS THAN] this’’ while pointing). If the participant responded correctly following the experimenter’s prompting the experimenter acknowledged the correct response (e.g., “That’s right”). If the participant did not respond correctly following the experimenter’s prompting the experimenter modeled the correct response. Following either a correct or incorrect prompted response the experimenter presented the $S^D$ a third time and allowed 10 sec for the participant to respond independently. If the participant responded correctly the experimenter provided differential praise but no token and the trial ended. If the participant responded incorrectly following the third presentation of the instruction the experimenter modeled the correct response.
and the trial ended. The same prompting and error correction procedures outlined here were utilized during experimental training (see Figure 6).

Participants were required to respond correctly on 9 out of 10 trials for each relational type (SAME, OPPOSITE, MORE THAN, or LESS THAN), or 36 out of 40 trials for each trial block, across at least two trial blocks in order to meet inclusion criteria. Participants were only permitted to make one error per relational type and required to respond correctly to the first trial of each relation.

**Baseline**

The format of baseline trials was similar to pre-experimental training trials, except experimental stimuli were used and no prompting or corrective feedback was provided. Verbal praise and tokens were provided contingent upon appropriate behaviors, such as attending, being on-task, and remaining seated, to ensure that participants were responding with their best ability and to minimize any potential discomfort resulting from extended probe trials. Prior to beginning baseline, the experimenter told each participant, “I’m going to show you some pictures and ask you some questions. Even though I won’t be telling you if you are right or wrong yet, just try your best.”

All six stimulus sets were presented during baseline. SAME-OPPOSITE and MORE THAN-LESS THAN trials were presented separately but combined into trial blocks. There were six trial types presented for SAME-OPPOSITE and six trial types for MORE THAN-LESS THAN. Each trial type was presented two times for a total of 24 trials per trial block (12 SAME-OPPOSITE trials, 12 MORE THAN-LESS THAN trials), and percentage of correct responses
was calculated by dividing the number of correct responses by the total number of trials.

Experimental training for SAME-OPPOSITE relations began following stability during baseline

**Figure 6.** Implementation steps during pre-experimental and experimental training phases.

**Experimental Training**

Three sets of SAME-OPPOSITE relations were trained, followed by training of three sets of MORE THAN-LESS THAN relations. Additional stimulus sets were added and used with Participants 3 and 4 (Nancy and Paul), for whom training of additional exemplars was necessary.
**Same-Opposite.** Seven different stimuli were used for SAME-OPPOSITE (designated A1, B1, B2, C1, C2, D1, and D2), and stimuli were divided into three sets of three stimuli for training purposes (Set 1: A1-B1-B2, Set 2: A1-C1-C2, Set 3: C2-D1-D2; see Figure 7). A second relational network composed of seven stimuli and divided into three sets was used with Nancy and Paul. Stimulus sets were trained sequentially. The first stimulus listed in each set served as the sample stimulus during training.

Training SAME-OPPOSITE began with Set 1, for which two relations were taught (A1 **SAME AS** B1, A1 **OPPOSITE** B2). There were a total of 10 trials during each training block, with 5 trials of SAME and 5 trials of OPPOSITE. In order to meet mastery criteria, participants were required to respond correctly on 9 out of 10 trials (90%) and respond correctly on the first trial of each relational type, across two consecutive training blocks.

The experimenter presented one stimulus sheet for each trial. On the first presentation of each stimulus set the experimenter stated the arbitrarily applied relations between each stimulus. For example, during the first presentation of Set 1 SAME-OPPOSITE, participants were oriented to the stimuli, and following an observing response the experimenter said, “This (pointing to B1)
is the same as this (pointing to A1), and this (pointing to B2) is opposite this (pointing to A1)”.

The experimenter then turned to the next stimulus sheet and presented the $S^D$ (i.e., “How is this (pointing to B1 or B2) related to this (pointing to A1)?”). If the participant provided the correct response within 10 sec of the instruction the experimenter delivered reinforcement in the form of a token and praise. If the participant responded incorrectly the experimenter followed the error correction and prompting procedure outlined above for pre-training. This constituted the first trial for that trial block. The experimenter then presented nine more trials of SAME-OPPOSITE with Set 1 stimuli. This procedure was repeated with the remaining stimulus sets.

**More than-Less than.** As with SAME-OPPOSITE, seven different stimuli were used for MORE THAN-LESS THAN (designated E1, F1, F2, G1, G2, H1, and H2), and stimuli were divided into three sets of three stimuli for training purposes (Set 1: E1-F1-F2, Set 2: E1-G1-G2, Set 3: G2-H1-H2; see Figure 8). A fourth stimulus set was added for training and testing with Nancy and Paul. The first stimulus listed in each set served as the sample stimulus during training. Mastery criteria for MORE THAN-LESS THAN relations was the same as for SAME-OPPOSITE relations.

**Derived relational responding probes.**

When mastery criteria for a particular stimulus set was met, a series of probe trials were conducted for the derived stimulus relations.

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**Figure 8.** Relational network for MORE THAN-LESS THAN showing trained and derived relations. Solid lines indicate directly trained relations and dashed lines indicate derived relations to be tested. Arrows indicate the direction of training/testing.
Stimuli were re-arranged on stimulus sheets, such that the sample stimulus during training (e.g., A1) was one of the two comparison stimuli, and each of the comparison stimuli during training (e.g., B1 and B2) were tested as a sample stimulus during DRR probes. A total of four derived relations (two mutually entailed, two combinatorially entailed) for each stimulus set were tested (see Tables 1 and 2). Each relation was tested three times during each trial block for a total of 12 trials and no reinforcement or corrective feedback was provided for responses. Similar to baseline, at the beginning each DRR probe session the participants were informed that they would be asked some questions but that they would not be told whether their answers were right or wrong yet. The experimenter presented a stimulus sheet for each trial and asked participants to vocally state the relation between two designated stimuli (i.e., “How is this (pointing to comparison stimulus) related to this (pointing to sample stimulus)?”). Participants were given 10 sec to respond following the presentation of the $S^D$.

Mastery criteria for DRR probes was 11 out of 12 responses correct (91.7%) with a correct response on the first presentation of each relation across two trial blocks, separated by one trial block of re-training of the original relations. In other words, if a participant scored 91.7% during a DRR trial block for a stimulus set, the original relations will be re-trained; if the participant scored 90% or above during the re-training trial block the derived relations were probed again to determine whether mastery criteria was met. The purpose of conducting DRR probes and stimulus set re-training in this format was to avoid exposing participants to extended trials under extinction conditions. If a participant scored below 91.7% on the first trial block of DRR probes for that stimulus set the original relations were re-trained, followed by a second trial block of DRR probes.
Table 1. Trained and derived relations for SAME-OPPOSITE.

<table>
<thead>
<tr>
<th>Set</th>
<th>Trained Relations</th>
<th>Derived Relations</th>
<th>Mutual Entailment</th>
<th>Combinatorial Entailment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1 S B1; A1 O B2</td>
<td>B1 S A1; B2 O A1</td>
<td>B1 O B2; B2 O B1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A1 S C1; A1 O C2</td>
<td>C1 S A1; C2 O A1</td>
<td>C1 O C2; C2 O C1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>C2 O D1; C2 S D2</td>
<td>D1 O C2; D2 S C2</td>
<td>D1 O D2; D2 O D1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>X1 S Y1; X1 O Y2</td>
<td>Y1 S X1; Y2 O X1</td>
<td>Y1 O Y2; Y2 O Y1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>X1 S Z1; X1 O Z2</td>
<td>Z1 S X1; Z2 O X1</td>
<td>Z1 O Z2; Z2 O Z1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Z2 S V2; Z2 O V1</td>
<td>V2 S Z2; V1 O Z2</td>
<td>V2 O V1; V1 O V2</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Trained and derived relations for MORE THAN-LESS THAN.

<table>
<thead>
<tr>
<th>Set</th>
<th>Trained Relations</th>
<th>Derived Relations</th>
<th>Mutual Entailment</th>
<th>Combinatorial Entailment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F1 &lt; E1; F2 &gt; E1</td>
<td>E1 &gt; F1; E1 &lt; F2</td>
<td>F1 &lt; F2; F2 &gt; F1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>G1 &lt; E1; G2 &gt; E1</td>
<td>E1 &gt; G1; E1 &lt; G2</td>
<td>G1 &lt; G2; G2 &gt; G1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>H1 &lt; G2; H2 &gt; G2</td>
<td>G2 &gt; H1; G2 &lt; H2</td>
<td>H1 &lt; H2; H2 &gt; H1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>K1 &lt; J1; K2 &gt; J1</td>
<td>J1 &gt; K1; J1 &lt; K2</td>
<td>K1 &lt; K2; K2 &gt; K1</td>
<td></td>
</tr>
</tbody>
</table>

Stimulus set re-training. The experimenter presented 10 trials (5 per relation) for the stimulus set being re-trained. Re-training trials were conducted in a similar format as trials during the initial training phase. Following correct responding on 9 out of 10 trials (90%), probes of the previously failed derived relations were conducted again. If a participant failed to reach mastery criteria (11 out of 12 trials, or 91.7%) following stimulus re-training, training was conducted for the failed relations.

Training failed derived relations. As with DRR probes, each training block during this phase consisted of 3 trials for each derived relation (12 trials total). Stimuli were presented in a similar format as during DRR probe trials; however, prompting and feedback were used to teach the derived relations and reinforcement was provided for correct unprompted responses. During the first presentation of each failed derived relation to be trained, the experimenter stated the
originally trained relation, followed by the derived relation. The experimenter then immediately presented the $S^D$ (i.e., “How is this (pointing to comparison) related to this (pointing to sample)?”). Participants were required to meet mastery criteria (11 out of 12 trials, or 91.7%) for the derived relations across two consecutive trial blocks, with no more than one error per relation and a correct response on the first presentation of each relation before advancing to mixed trials. Modifications to DRR training for individual participants are described in the Results section.

**Mixed trials.** After reaching mastery criteria—on either DRR probes or training the failed derived relations—participants were exposed to a series of mixed trials in which the originally trained relations for each set were combined with the derived relations and interspersed within each trial block. Trial blocks consisted of 18 trials, with six trials of initially trained relations (two relations each presented three times) and 12 trials of derived relations (four relations each presented three times). Mastery criteria was 17 out of 18 trials correct (94.4%) across two consecutive trial blocks, with no more than one error per trial type and a correct response of the first presentation of each relation.

**Grand mixed trials.** Following mastery of all three sets in each relational network, including the derived relations, the originally trained relations in each stimulus set were presented in random rotation. Grand mixed trials for SAME-OPPOSITE were conducted following mastery of the derived relations for Set 3 of SAME-OPPOSITE; grand mixed trials for MORE THAN-LESS THAN were conducted following mastery of the derived relations for Set 3 of MORE THAN-LESS THAN.

Three different stimulus sets were presented during each grand mixed trial block (three sets of SAME-OPPOSITE, or three sets of MORE THAN-LESS THAN), and each set involved two trial types. Trial blocks consisted of 18 trials (six trial types, each presented three times). On
the first presentation of each set, the experimenter stated both relations while pointing (e.g., “This (B1) is SAME as this (A1) and this (B2) is OPPOSITE this (A1)” and then tested the two relations (e.g., B1 and B2) on the next two trials. This was repeated for all three stimulus sets. Feedback was provided in the form of reinforcement or error correction. In order to reach mastery criteria during this phase participants were required to respond correctly on 17 out of 18 trials (94.4%) across two consecutive trial blocks, with no more than one error per trial type and a correct response of the first presentation of each relation. According to the original protocol, once a participant met mastery criteria on grand mixed trials for MORE THAN-LESS THAN relations, his or her involvement in the study was considered complete; however, two participants underwent training and testing of an additional stimulus set.

Intraverbal probes of relations. Research on intraverbals often involves generalization probes to test for emergence of untrained responses that are directly related to skills being taught, such as testing for the ability to name untrained members of a category. In the current study, structured probe trials were conducted throughout the study (at least one time per phase and stimulus set) to assess the effects of training on participants’ use of same-opposite or more than-less than relations when asked to relate pictures of common items. All intraverbal probe sessions were video recorded and transcribed in order to qualitatively analyze and quantify the relations described (i.e., based on nonarbitrary or arbitrary properties, types of relations used).

Intraverbal probes were conducted in the same setting as training, with the experimenter and the participant seated at a table. Five pictures were placed on the table in an array, with none of the pictures in a set belonging to the same class. The same picture sets were used for all participants and pictures in sets were not repeated within participants. The experimenter instructed the participant: “Tell me all the ways you think any of these could be related” and told
the participant that there was no wrong response for this part. Participants were asked to describe as many relations as possible and there was no time limit.

If a participant stopped responding for 15 sec, or made a statement such as “I don’t know” the experimenter encouraged him or her to continue. If the participant paused for longer than 15 sec following the experimenter’s second prompt to continue, or made a second statement indicating that he or she was done responding (e.g., “I can’t think of anything else”) the session ended. If a participant did not state any relations between pictures he or she was given a score of 0 on that probe trial. Feedback was provided in the form of neutral responses (e.g., “Alright”, “Ok”) and prompts to continue stating relations (e.g., “What else?”, “Can you think of any more?”), as well as reciprocal comments to some of the participants’ statements (e.g., “Yeah, that is a dog. I like dogs”). Reinforcement in the form of praise and tokens was provided for on task behaviors but not for specific responses.

The dependent measure for relational probes was total number of relational statements made by the participant for each presentation of picture sets (i.e., each trial block). Each relational statement was counted separately and classified by type of relation and (when possible) whether that relation was based on formal or arbitrary properties. If an increase in level was not observed for intraverbal probe data following mastery of the second set of stimuli (including the derived relations) for SAME-OPPOSITE the experimenter provided examples of relations between pictures of items and more intrusive prompting during one trial block. During the next trial block of intraverbal probes the experimenter resumed minimal prompting to evaluate whether the number of stated relations increased following more intrusive prompting and experimenter modeling of responses. Prompting was provided following mastery of the second set of derived relations for MORE THAN-LESS THAN as well if no increase in level
was observed regarding comparative relations. Specific prompting procedures for each participant are described in the Results section.
CHAPTER THREE:

RESULTS

Participant 1 (Adam)

Pre-training

Adam scored 100% on both SAME-OPPOSITE and MORE THAN-LESS THAN relations across two consecutive trial blocks. Pre-training for Adam was conducted during one session.

Baseline

Adam’s baseline scores were 0.4% and 0% across two trial blocks. Baseline for Adam was completed during one session.

Same-Opposite

Adam completed training and testing for SAME-OPPOSITE in four sessions (23 trial blocks). No training was necessary for derived relations based on SAME-OPPOSITE (see Figure 13).

Set 1 (A-B). Adam scored 100% across all training blocks for Set 1. DRR probes scores were 91.7% and 100% (see Tables 3 and 4). He scored 100% and 94.4% on mixed trial blocks for Set 1.
Set 2 (A-C). For Set 2, Adam scored 100% across all training blocks, DRR probe blocks, and mixed trial blocks.

Set 3 (C-D). Adam scored 100% across all training blocks, DRR probe blocks, and mixed trial blocks for Set 3.

Grand mixed trials. Adam met mastery criteria for grand mixed trials within one session, scoring 94.4%, 100%, and 100% across three trial blocks.

More Than-Less Than

Adam completed the MORE THAN-LESS THAN phase in four sessions (25 trial blocks). He required training of derived relations for the first set of comparative relations and demonstrated mastery of DRR on subsequent sets (see Figure 13).

Set 1 (E-F). Adam scored 100% across all training blocks for the initially trained relations in Set 1. DRR probe scores were 25% and 41.6% (see Tables 3 and 4). Failed derived relations were trained across four trial blocks, with scores ranging from 91.7% to 100%. Adam scored 100% across two mixed trial blocks.

Set 2 (E-G). Adam scored 80% on the first training trial block and scored 100% on all subsequent training blocks for this set. He scored 75% on the first DRR probe trial block. Stimulus relations were retrained and he scored 100% across two more DRR probe trial blocks, reaching mastery criteria for Set 2 derived relations with no direct training. He scored 100% across two mixed trial blocks.

Set 3 (G-H). Adam scored 100% across all training and probe trials for Set 3; therefore no DRR training was necessary. He met mastery criteria for mixed trials within two trial blocks, scoring 94.4% and 100%.
Grand mixed trials. Adam met mastery criteria on grand mixed trials for MORE THAN-LESS THAN relations in two trial blocks, scoring 100% across both trial blocks.

Intraverbal Probes of Relations

A total of 12 intraverbal probe sessions were conducted with Adam (see Figures 14 and 17). During baseline and pre-training, he demonstrated some use of SAME relations, mainly based on formal properties; however, several relations based on arbitrary properties were stated as well (e.g., “This is a picture of children. And this is a picture of plants. They are both related because they are both living things. They’re also related because they have the same colors. The kid’s shirt and the flowers are the same color”). The experimenter introduced prompting during the sixth probe session in which several relations based on SAME or OPPOSITE were provided. No prompting was provided during the following two sessions (Sets 7 and 8) and an increase or change in relations stated was not observed. The experimenter introduced prompting of MORE THAN-LESS THAN relations with Set 9; however, an overall increase in level of target relations stated during probe sessions was not observed with Adam during the last two sessions.

During probe sessions Adam often began talking about preferred topics (e.g., animals, television, computer games). Generally, he segued into these topics based on a statement made by the experimenter or based on one of the pictures; although some topic changes had no observable relation to the context of probe sessions. The experimenter would provide several reciprocal statements following Adam’s topic changes and then direct him back to the pictures.

The total number of relations stated during probe sessions ranged from 1 to 7, with an average of 4. The duration of intraverbal probe sessions for Adam ranged from 1 min 47 sec to 12 min, with an average of 5 min 36 sec.
Number of Sessions

Adam completed the study in 12 sessions with approximately two sessions per week, with a total of 57 trials blocks (including pre-training and baseline). There were 12 intraverbal probe sessions conducted with Adam, including one post-training session (see Table 11).

Table 3. Number of sessions, number of trial blocks, and DRR probe scores for each set for Adam.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Number of Sessions</th>
<th>Number of Trial Blocks</th>
<th>DRR Probe Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same-Opposite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1 (A-B)</td>
<td>1</td>
<td>7</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>Set 2 (A-C)</td>
<td>1</td>
<td>7</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>Set 3 (C-D)</td>
<td>1</td>
<td>7</td>
<td>100%, 91.7%</td>
</tr>
<tr>
<td>More-Less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1 (E-F)</td>
<td>2</td>
<td>11</td>
<td>25%, 41.6%</td>
</tr>
<tr>
<td>Set 2 (E-G)</td>
<td>2</td>
<td>10</td>
<td>75%, 100%, 100%</td>
</tr>
<tr>
<td>Set 3 (G-H)</td>
<td>1</td>
<td>7</td>
<td>100%, 100%</td>
</tr>
</tbody>
</table>

Table 4. Adam’s DRR probe scores and DRR training scores for mutually entailed (ME) and combinatorially entailed (CE) relations. Blacked out cells indicate where no training was conducted due to mastery on DRR probes.

<table>
<thead>
<tr>
<th>Phase</th>
<th>DRR Probe Scores</th>
<th>DRR Training Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ME</td>
<td>CE</td>
</tr>
<tr>
<td>Same-Opposite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>100%, 100%</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>Set 2</td>
<td>100%, 100%</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>Set 3</td>
<td>100%, 83%</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>More-Less</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>0%, 16%</td>
<td>50%, 66%</td>
</tr>
<tr>
<td>Set 2</td>
<td>50%, 100%, 100%</td>
<td>100%, 100%, 100%</td>
</tr>
<tr>
<td>Set 3</td>
<td>100%, 100%</td>
<td>100%, 100%</td>
</tr>
</tbody>
</table>
**Participant 2 (Dustin)**

**Pre-training**

Dustin scored 100% both SAME-OPPOSITE and MORE THAN-LESS THAN relations across two consecutive trial blocks. Pre-training for Dustin was conducted across two sessions.

**Baseline**

During baseline, Dustin scored between 0% and 0.4% across four trial blocks. He scored 0.4% (1/24 correct) during two non-consecutive trial blocks; correct responses were for different relations (one for SAME, one for OPPOSITE) and were not repeated. Baseline for Dustin took place over two sessions.

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**Figure 9.** DRR probe scores for Adam. Circles represent mutual entailment scores, triangles represent combinatorial entailment scores.
**Same-Opposite**

Dustin completed training and testing for SAME-OPPOSITE in three sessions (24 trial blocks). No training of derived relations was necessary for SAME-OPPOSITE relations (see Figure 13).

**Set 1 (A-B).** Dustin scored 100% across all training blocks for Set 1. DRR probe scores were 91.7% and 100% (see Tables 5 and 6). He scored 100% and 94.4% on mixed trial blocks for Set 1.

**Set 2 (A-C).** For Set 2, Dustin scored 100% across all training blocks, DRR probe blocks, and mixed trial blocks.

**Set 3 (C-D).** Dustin demonstrated a similar performance with Set 3, scoring 100% across all training blocks, DRR probe blocks, and mixed trial blocks.

**Grand mixed trials.** Dustin met mastery criteria for grand mixed trials within two trial blocks, scoring 94.4% on the first trial block and 100% on the second trial block.

**More Than-Less Than**

Dustin completed the MORE THAN-LESS THAN phase in four sessions (25 trial blocks). He met mastery criteria on DRR probes for all three sets and did not require training of derived comparative relations (see Figure 13).

**Set 1 (E-F).** Dustin scored 100% on all stimulus set training blocks for Set 1. DRR probe scores were 91.6% and 100% (see Tables 5 and 6). Scores on mixed trial blocks were 94.4% and 100%.
Set 2 (E-G). Dustin’s scores on training blocks were 100%. DRR probe scores were 83.3% and 100%. An additional DRR probe trial block was then presented in which Dustin was asked to state the opposite, or reversed, relation. The experimenter began by asking, “What is the opposite of MORE?” and “What is the opposite of LESS?” Dustin responded correctly to these two questions; the experimenter provided praise and said “So if it’s MORE you would say…” (Dustin responded “LESS”) and “If it’s LESS you would say…” (Dustin responded “MORE). Derived relations for Set 2 were probed again, except this time the experimenter asked Dustin to state the “opposite answer” for each trial. No feedback was provided during the reversal probe. He scored 91.7% on the reversal probe. For Set 2 mixed trials, the experimenter asked Dustin to state “the real answers” (i.e., the originally trained relations) for the first mixed trial block, and asked him to state “the opposite answers” (i.e., the reversed relations) for the second mixed trial block. Scores on both mixed trial blocks were 100%.

Set 3 (G-H). Dustin scored 100% across all training and probe trials for Set 3. After scoring 100% on the second DRR probe, a reversal probe was conducted and Dustin scored 100%. Scores on mixed trial blocks were 100%.

Grand mixed trials. Dustin met mastery criteria on grand mixed trials for MORE THAN-LESS THAN relations in two trial blocks. During the first trial block the experimenter asked Dustin to state the originally trained relations and he scored 100%. During the second trial block the experimenter asked Dustin to state the reversed relations and he scored 100%.

Intraverbal Probes of Relations

A total of 11 intraverbal probe sessions were conducted with Dustin (see Figures 14 and 17). For the first five picture sets he stated between 1 and 3 relations per session. The
experimenter introduced prompting during the sixth probe session and provided examples of SAME and OPPOSITE relations between the items in the pictures. An increase in stated relations was not observed during the following session (Set 7) and the experimenter provided additional examples for Set 8. During this session Dustin stated 10 relations scored as SAME, most of which pertained to the colors or shapes of the items (e.g., “The tambourine is the same color as the cat though, and the minute hand is red just like the ketchup and the maracas”; “These could both be shapes (soap dish and clock) and the plate’s round like the clock”). Similar responding was observed with Set 9. For this set, Dustin initially stated six SAME relations which pertained to colors; the experimenter then prompted him to think about the functions of the items and asked if any of the items could be related based on “what they do, or what you can do with them.” Dustin did not state any additional relations following prompting with Set 9.

Prompting was provided in a similar format during the following two sessions. An overall increase in the number of relations stated was observed from pre-training to post-training, mainly observed with Formal/Same relations. A slight increase in Arbitrary/Same relations was observed during Set 10 following the experimenter’s prompt to relate the items functionally, although no Arbitrary/Same relations were stated for the following set.

The total number of relations stated per session for Dustin ranged from 1 to 11, with an average of 3.9. The duration of intraverbal probe sessions ranged from 1 min 15 sec to 10 min 20 sec, with an average duration of 4 min 42 sec.
Number of Sessions

Dustin participated in the study for 12 sessions with approximately two sessions per week, with a total of 55 trial blocks (including pre-training and baseline). Intraverbal probes were conducted during 11 sessions, including one post-training session (see Table 11).

Table 5. Number of sessions, number of trial blocks, and DRR probe scores for each set for Dustin.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Number of Sessions</th>
<th>Number of Trial Blocks</th>
<th>DRR Probe Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same-Opposite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1 (A-B)</td>
<td>1</td>
<td>7</td>
<td>91.7%, 100%</td>
</tr>
<tr>
<td>Set 2 (A-C)</td>
<td>1</td>
<td>7</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>Set 3 (C-D)</td>
<td>1</td>
<td>7</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>More-Less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1 (E-F)</td>
<td>1</td>
<td>7</td>
<td>91.7%, 100%</td>
</tr>
<tr>
<td>Set 2 (E-G)</td>
<td>1</td>
<td>8</td>
<td>83.3%, 100%, 91.7% (Reversed)</td>
</tr>
<tr>
<td>Set 3 (G-H)</td>
<td>1</td>
<td>8</td>
<td>100%, 100%, 100% (Reversed)</td>
</tr>
</tbody>
</table>

Table 6. Dustin’s DRR probe scores for mutually entailed (ME) and combinatorially entailed (CE) relations. Blacked out cells indicate where no training was conducted due to mastery on DRR probes.

<table>
<thead>
<tr>
<th>Phase</th>
<th>DRR Probe Scores ME</th>
<th>DRR Probe Scores CE</th>
<th>DRR Training Scores ME</th>
<th>DRR Training Scores CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same-Opposite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>100%, 100%</td>
<td>83%, 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 2</td>
<td>100%, 100%</td>
<td>100%, 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 3</td>
<td>100%, 100%</td>
<td>100%, 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More-Less</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>83%, 100%</td>
<td>100%, 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 2</td>
<td>66%, 100%, 83%</td>
<td>100%, 100%, 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 3</td>
<td>100%, 100%, 100%</td>
<td>100%, 100%, 100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Participant 3 (Nancy)

Pre-training

During the pre-training phase, Nancy scored 90% (18/20 correct) on MORE THAN-LESS THAN and 90% on SAME-OPPOSITE during the first trial block. She scored 90% on MORE THAN-LESS THAN and 100% on SAME-OPPOSITE during the second pre-training trial block. Pre-training for Nancy was conducted across two sessions.

Figure 10. DRR probe scores for Dustin. Circles represent mutual entailment scores, triangles represent combinatorial entailment scores.
Baseline

Nancy scored 0% on all baseline probes. When responding during baseline, she counted the lines on each of the symbols she was asked to relate. Baseline for Nancy was conducted across two sessions.

Same-Opposite

Nancy completed training and testing for the SAME-OPPOSITE phase in 10 sessions (50 trial blocks; see Figure 15).

Set 1 (A-B). Nancy scored 40% on the first trial block, followed by an increase to 100% across the next two trials blocks. She scored 0% both trial blocks of DRR probes (see Tables 7 and 8). Failed derived relations were trained over 5 trial blocks, with scores ranging from 50% to 100%, with an average of 74.9%. Scores on mixed trial blocks for Set 1 were 100%.

Set 2 (A-C). Nancy scored 100% across all training blocks for the initially trained relations. She scored 0% on the first DRR probe, followed by an increase to 66.7% on the second DRR probe. Scores on all DRR training blocks and mixed trial blocks were 100%.

Set 3 (C-D). Scores on all training blocks for Set 3 were 90% above. Nancy scored 0% on the first DRR probe and 100% on the subsequent DRR probe following re-training. Stimulus set re-training was conducted again, followed by a third DRR probe. On the first trial of the third block of DRR probes, Nancy responded correctly and looked at the experimenter for feedback. The experimenter provided a neutral response and asked Nancy to just try her best. Nancy resumed baseline responding (i.e., counting lines of the symbols) and did not respond correctly on any of the following trials in this block, resulting in a score of 0.8%. Training was conducted for the failed derived relations, followed by mixed trials, on which Nancy’s scores ranged from
91.6% to 100%, with an average of 97.9%. The experimenter introduced a priming condition, in which pictures of known items were presented and Nancy was asked to name the items but no feedback was provided. The experimenter presented 10 consecutive priming trials and Nancy responded correctly on each trial. Set 3 was re-trained with scores of 100% across two trial blocks, followed by probes of the previously failed derived relations (i.e., although relations had been trained, no feedback was provided). Nancy scored 91.7% and 100% when no feedback was provided for responding. The experimenter continued to incorporate priming during Nancy’s sessions throughout the remainder of the study.

**Grand mixed trials.** Nancy met mastery criteria for SAME-OPPOSITE grand mixed trials within three trial blocks with an average of 94.4%.

**Set 4 (X-Y).** Based on Nancy’s responding on Set 3, a fourth stimulus set was added to continue to evaluate the emergence of DRR. Nancy scored between 90% and 100% on stimulus set training and re-training, and 100% on both DRR probes. Scores on mixed trial blocks were 94.4% and 100%.

**More Than-Less Than**

Nancy completed training and testing for the MORE THAN-LESS THAN phase in 15 sessions (66 trial blocks; see Figure 15).

**Set 1 (E-F).** Nancy scored 100% on stimulus set training and re-training. DRR probe scores were 25% and 50% (see Tables 7 and 8). Failed derived relations were initially trained over 11 trial blocks (trial blocks 60-70), with an average score of 54.5%. In trial block 67, each of the four target relations was presented in massed trial format (each presented three times totaling 12 trials); Nancy scored 66.7% on this trial block and 58.3% on the next trial block.
Prior to trial block 69, the experimenter conducted formal MORE THAN-LESS THAN training using pre-training stimuli, as well as cards showing numerals and quantities. Nancy scored 95% on formal training and scored 41.6% and 58.3% across the next two DRR training blocks (trial blocks 69 and 70). Stimulus set re-training was conducted for a second time with an added component of bidirectional training, in which the experimenter stated both the target relation and the derived relation for each trial (trial block 71), and then prompted Nancy to state both the target relation as well as the derived relation as an intraverbal fill-in (trial block 72). For example, the experimenter presented the SD “How is this (comparison) related to this (sample)?” and following a correct response the experimenter would say “Right, so this (sample) is….” and Nancy would complete the statement. Nancy scored 100% on the target relations as well as the derived relations during this trial block and began to independently state both relations after several prompted trials (e.g., “This is more than this and this is less than this”). The experimenter then immediately resumed DRR training and Nancy scored 50% on trial block 73. Prior to trial block 74, the experimenter presented three cards showing numerals 1 through 3 and asked Nancy to identify most and least. The experimenter placed the number cards on the stimulus sheet next to the corresponding symbols (1 with F1, 2 with E1, 3 with F2) and asked Nancy to state each comparative relation. DRR training was then conducted and Nancy scored 83.3% (trial block 74).

The experimenter continued to conduct formal training of more/less and most/least (separate from DRR training) during sessions until mastery criteria was reached for Set 1. A pattern of responding emerged in which Nancy consistently missed F1-F2 and F2-F1 (combinatorially entailed) relations. Prior to trial block 80 the experimenter presented 10 trials of F1-F2 and 10 trials of F2-F1; Nancy scored 100% on F1-F2 and 60% on F2-F1. The
experimenter repeated this procedure prior to trial block 84 and Nancy scored 100% on both
relations. Nancy scored 100% on DRR training during trial blocks 84 and 85 and reached
mastery criteria, for a total of 23 trial blocks (276 trials) to mastery. She met mastery criteria for
mixed trials within three trial blocks, with an average score of 94.4%.

**Set 2 (E-G).** Nancy scored 100% on all training trial blocks for Set 2, including DRR
training and mixed trials. She scored 25% on both DRR probe trial blocks for this set. After the
second DRR probe, an additional trial block of re-training was conducted in which the
experimenter conducted bidirectional training (as with Set 1). Nancy correctly stated each target
relation and derived relation during re-training. Nancy scored 25% on a third trial block of DRR
probes conducted immediately following bidirectional re-training.

**Set 3 (G-H).** Nancy scored 100% on training trial blocks for Set 3. As with Sets 1 and 2,
an additional re-training trial block was conducted in which Nancy was prompted to state the
bidirectional relations. She scored 58.3% on the first DRR probe, 25% following the first re-
training, and 25% following bidirectional re-training. She met mastery criteria for DRR training
within three trial blocks with an average score of 97.2%, and met mastery criteria for mixed trials
within two trial blocks, scoring 100% across both.

**Grand mixed trials.** Nancy scored 100% across two trial blocks of grand mixed trials for
MORE THAN-LESS THAN relations.

**Set 4 (J-K).** A fourth set of stimuli were added following grand mixed trials in order to
determine if DRR would emerge for MORE THAN-LESS THAN relations with additional
training. Nancy scored 100% across all trial blocks for Set 4, including 100% on both DRR
probes.
Intraverbal Probe of Relations

A total of 24 intraverbal probe sessions were conducted with Nancy (see Figures 16 and 18). Her responses consisted mostly of tacting items and stating various features, functions, or classes to which items belonged. She stated no relations during the first six probe sessions. During the seventh probe session the experimenter provided a series of examples relating the items as same or opposite. Nancy repeated several of the experimenter’s statements but did not provide any novel examples stating relations between items. During the next probe session and subsequent probe sessions the experimenter provided an opportunity for Nancy to talk about the items before prompting. When Nancy did not state any relations between items, the experimenter asked if she thought any of the items could be the same or opposite (indicated by open arrows; see Figure 12). Nancy selected two pictures (clock and musical instruments) and stated that they were the same but did not say why. It was noted that both pictures had red borders. During the following probe sessions Nancy often related the colors of the picture borders as same or opposite, despite prompting to talk about “the things inside the borders”. Although she did state several relations between the actual items, these relations were mainly unspecified and therefore difficult to determine the properties upon which they were based. In order to eliminate differences in the picture borders, two sets of pictures (Sets 20 and 22) were presented which all had black borders. Nancy commented that they were all “black ones”, and selected several pictures as “same” because they were “black ones”. For Set 21, the borders were cut off the pictures and she did not state any relations for this set. A similar prompting procedure was followed with more than-less than relations, starting with Set 21.
The total number of relations stated per session for Nancy ranged between 0 and 3, with an average of 1. The duration of intraverbal probes sessions for Nancy ranged between 1 min 16 sec to just over 6 min, with an average of 4 min 3 sec.

**Number of Sessions**

Nancy participated in the study for a total of 28 sessions with approximately three sessions per week, amounting to 120 trial blocks (including pre-training and baseline). Intraverbal probes were conducted during 24 sessions (see Table 11).

![Figure 11. DRR probe scores for Nancy. Circles represent mutual entailment scores, triangles represent combinatorial entailment scores.](image_url)
Table 7. Nancy’s DRR probe scores and DRR training scores for mutually entailed (ME) and combinatorially entailed (CE) relations. Averages are shown bold in parentheses. Blacked out cells indicate where no training was conducted due to mastery on DRR probes.

<table>
<thead>
<tr>
<th>Phase</th>
<th>DRR Probe Scores (Average)</th>
<th>DRR Training Scores (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ME</td>
<td>CE</td>
</tr>
<tr>
<td>Same-Opposite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>0%, 0%</td>
<td>0%, 0%</td>
</tr>
<tr>
<td>Set 2</td>
<td>0%, 83%</td>
<td>0%, 50%</td>
</tr>
<tr>
<td>Set 3</td>
<td>0%, 100%, 0% (33%)</td>
<td>0%, 100%, 16% (38%)</td>
</tr>
<tr>
<td>Set 4</td>
<td>100%, 100%</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>More-Less</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>0%, 0%</td>
<td>50%, 83%</td>
</tr>
<tr>
<td>Set 2</td>
<td>0%, 16%, 0% (5%)</td>
<td>50%, 33%, 50% (44%)</td>
</tr>
<tr>
<td>Set 3</td>
<td>66%, 0%, 16% (27%)</td>
<td>50%, 50%, 33% (44%)</td>
</tr>
<tr>
<td>Set 4</td>
<td>100%, 100%</td>
<td>100%, 100%</td>
</tr>
</tbody>
</table>

Table 8. Number of sessions, number of trial blocks, and DRR probe scores for each set for Nancy.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Number of Sessions</th>
<th>Number of Trial Blocks</th>
<th>DRR Probe Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same-Opposite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1 (A-B)</td>
<td>3</td>
<td>13</td>
<td>0%, 0%</td>
</tr>
<tr>
<td>Set 2 (A-C)</td>
<td>3</td>
<td>9</td>
<td>0%, 66.7%</td>
</tr>
<tr>
<td>Set 3 (C-D)</td>
<td>3</td>
<td>18</td>
<td>0%, 100%, 0.8%</td>
</tr>
<tr>
<td>Set 4 (X-Y)</td>
<td>1</td>
<td>7</td>
<td>100%, 100%</td>
</tr>
<tr>
<td>More-Less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1 (E-F)</td>
<td>8</td>
<td>34</td>
<td>25%, 50%</td>
</tr>
<tr>
<td>Set 2 (E-G)</td>
<td>2</td>
<td>11</td>
<td>25%, 25%, 25%</td>
</tr>
<tr>
<td>Set 3 (G-H)</td>
<td>2</td>
<td>12</td>
<td>58.3%, 25%, 25%</td>
</tr>
<tr>
<td>Set 4 (J-K)</td>
<td>2</td>
<td>7</td>
<td>100%, 100%</td>
</tr>
</tbody>
</table>
Participant 4 (Paul)

Pre-training

Paul scored 95% overall on the first pre-training trial block (95% on both SAME-OPPOSITE and MORE THAN-LESS THAN) and scored 87.5% overall on the second trial block (90% on SAME-OPPOSITE, 85% on MORE THAN-LESS THAN). A third pre-training session was conducted and he scored 100% on SAME-OPPOSITE and 95% on MORE THAN-LESS THAN.

Baseline

Four baseline trial blocks were conducted with Paul over two sessions. Baseline scores ranged from 20% to 29%, with an average score of 23.9%. Correct responses did not occur consistently.

Same-Opposite

Paul completed the SAME-OPPOSITE phase in 18 sessions (96 trial blocks). A total of six sets of SAME-OPPOSITE training were conducted with Paul (see Figure 15).

Set 1 (A-B). Paul met mastery criteria within four training blocks with an average score of 85%. DRR probe scores were 50% and 75% (see Tables 9 and 10). During both probe trial blocks he missed all B2-B1 relations; on the second probe 9 out of 12 responses were correct and all three incorrect responses were B2-B1. Paul met mastery criteria for DRR training within four
trial blocks with an average score of 85.4% (see Table 10 for mutual and combinatorial entailment scores on DRR probe and training blocks). He mastered mixed training over two trial blocks, scoring 94.4% and 100%.

**Set 2 (A-C).** Paul scored 100% across all training blocks for the two initially trained relations in Set 2. He scored 75% on both DRR probes; all incorrect responses were C2-C1. DRR training was conducted over seven trial blocks with an average score of 82.8%. Mastery criteria for mixed trials were met within six trial blocks with an average score of 90.7%.

**Set 3 (C-D).** Paul mastered the initially trained relations for Set 3 within three trial blocks with an average score of 96.7%. Scores on DRR probes were 50% and 66.7%. He responded incorrectly on all D1-D2 trials (the same relation as B2-B1 and C2-C1, in which the stimulus trained as OPPOSITE of the sample is presented as the sample during probe trials and the combinatorially entailed relation is tested). Failed relations were trained across seven trial blocks with an average score of 77.4%. Paul scored 100% across two trial blocks of mixed trials.

**Grand mixed trials.** Paul met mastery criteria for grand mixed trials of Sets 1-3 within two trial blocks, scoring 100% on both.

**Set 4 (X-Y).** Three additional stimulus sets (Sets 4-6) were introduced with Paul to continue to evaluate the emergence of DRR and specific patterns of responding. Paul scored 100% across two training blocks and scored 75% on both DRR probes. He missed 5 out of 6 Y2-Y1 trials. Failed relations were trained across eight trial blocks with an average score of 85.4%. Due to repeated errors on Y2-Y1 trials, two blocks of massed trial training were conducted with this relation prior to trial block 65. Paul scored 91% across the following two trial blocks, meeting mastery criteria for DRR training. Massed trials of Y2-Y1 were conducted prior to the first mixed trial block, and immediate access to Paul’s highest preferred reinforcer (watching
videos on his tablet) was provided on an FR1 schedule following each correct response. Additionally, correct Y2-Y1 responses were reinforced on an FR1 schedule within mixed trial blocks with access to approximately 15 sec of a video. He met mastery criteria for mixed trials within three trial blocks, scoring 88.9%, 100%, and 100%.

**Set 5 (X-Z).** Paul scored 100% and 90% on training blocks for Set 5. He scored 58.3% on the first DRR probe, missing all Z2-Z1 relations. He scored 91.7% (11 out of 12 correct) on the second DRR probe, with one incorrect response on the first presentation of Z2-Z1. Stimulus set re-training was conducted and derived relations were probed a third time. Paul scored 83.3% (10 out of 12 correct) on this trial block, missing two trials of Z2-Z1. One more block of re-training was conducted as well as a final DRR probe for this set, on which Paul scored 75% (9 out of 12 correct), missing two trials of Z2-Z1. DRR training was conducted with the addition of formal SAME-OPPOSITE training. Pictures used in pre-training were re-introduced in an attempt to facilitate the transition from formal to arbitrary relational responding. The experimenter used several sets of three pictures showing SAME-OPPOSITE (e.g., open/closed, empty/full) and placed each of the pictures with the corresponding symbols as they were arranged during the initial stimulus set training (i.e., with X1 as the sample) Open boxes were placed with X1 and Z1, and a closed box was placed with Z2. Paul was then asked to state the relation with the formal pictures present, and then again when the pictures were removed. The experimenter then turned to the stimulus sheets used for DRR probes, in which stimuli were rearranged (Z1 or Z2 as the sample) and asked Paul to rearrange the formal stimuli to match the experimental stimuli and state the relations. Paul initially required some assistance but following prompting was able to complete the task independently.
DRR training for Set 5 along with formal training took place over two sessions (trial blocks 83-88). Correct responses on Z2-Z1 trials were reinforced on an FR1 schedule, as with Set 4, during both DRR training and mixed trials. During the first training session, Paul appeared distracted by other events occurring in the training environment that were beyond the experimenter’s control, mainly people entering and leaving the house. This may have contributed to an increased number of errors that occurred during trial blocks 83-86, for which his average score was 64.5%. During the following session the environment was free of distractions and Paul scored 100% across two trial blocks of DRR training, meeting mastery criteria. Paul met mastery criteria for mixed trials within two trial blocks, scoring 100% and 94.4%.

**Set 6 (Z-V).** On the first presentation of Set 6, prior to the experimenter stating the target relations, Paul attempted to guess (incorrectly) the two relations. The experimenter immediately corrected him and began training. Initial relations for Set 6 were trained across two trial blocks, with scores of 90% and 100%. Paul scored 58.3% on the first two DRR probes, separated by two trial blocks of re-training (Paul scored 80% on the first re-training trial block so an additional re-training trial block was conducted, on which he scored 100%). On the first DRR probe he missed 2 out of 3 V1-V2 trials; on the second DRR probe he missed 3 out of 3 V1-V2 trials (the same relation as Y2-Y1 and Z2-Z1, in which the stimulus trained as OPPOSITE of the sample is presented as the sample during probe trials and the combinatorially entailed relation is tested). Stimulus set re-training was conducted again, during which Paul was asked to place pictures of SAME and OPPOSITE based on formal features with the corresponding symbols, which he was able to do correctly and independently 4 out of 4 times. A third DRR probe for Set 6 was conducted immediately following formal training and Paul’s score increased slightly to 75%; 2 out of 3 incorrect responses were V1-V2. DRR training was conducted across two trial blocks,
with scores of 100% on both. Paul scored 100% and 94.4% on mixed training and met mastery
criteria within two trial blocks.

**Grand mixed trials.** Grand mixed trials of the initially trained relations for sets 4-6 were
carried out with Paul. He met mastery criteria within two trial blocks, scoring 100% and 94.4%.

**More Than-Less Than**

Paul completed training and testing of comparative relations in 12 sessions (67 trial
blocks). As with Nancy, training and testing of Set 4 was conducted with Paul (see Figure 15).

**Set 1 (E-F).** Paul met mastery criteria for the initially trained relations within three trial
blocks, scoring 60%, 90%, and 100%. Scores on DRR probes were 41.7% and 58.3%, with
scores of 83.3% and 100% on combinatorially entailed relations (see Tables 9 and 10). This
finding was of interest given Paul’s performance on mutually and combinatorially entailed
relations during SAME-OPPOSITE training, in which he consistently scored higher on mutual
entailment probes. DRR training for Set 1 was conducted across 11 trial blocks, with an average
score of 83.3%. Mixed trials were conducted over four trial blocks, with an average score of
95.8%.

**Set 2 (E-G).** Initial relations for Set 2 were trained over two trial blocks, with scores of
90% and 100%. Scores on DRR probes were 41.7% and 50%; again, Paul scored higher on
combinatorially entailed relations (83.3% on both DRR probes). At the start of both blocks of
DRR probes Paul said he did not know the answers and asked the experimenter to tell him the
answers. This was the first time this behavior was observed with Paul during the study. The
experimenter encouraged him to just try his best, and provided descriptive praise for response
attempts (e.g., “Thank you for answering the questions”). A third block of stimulus set re-
training was conducted, during which the experimenter asked Paul to state the bidirectional relations. Paul was first asked to state the target relation and following a correct response he was asked to state the derived relation, prompted as an intraverbal fill-in (e.g., “Right, if this is less than this, then this is…” and Paul completed the statement). Immediately following bidirectional re-training a third block of DRR probes was conducted, on which Paul scored 50% (100% on combinatorial entailment trials).

DRR training for Set 2 involved training of bidirectional relations, as well as formal training using number cards. Prior to trial blocks 133 and 136 the experimenter presented three cards showing numerals 1 through 3 and placed the number cards on the stimulus sheet used to train the initial relations next to the corresponding symbols (1 with G1, 2 with E1, 3 with G2) and asked Paul to state each comparative relation, as well as the bidirectional relation. The experimenter then turned to the stimulus sheets used for DRR probes, in which stimuli were rearranged (G1 or G2 as the sample) and prompted Paul to rearrange the formal stimuli to match the experimental stimuli and state the relations. DRR training for Set 2 was conducted across five trial blocks with an average score of 88.3%. Paul met mastery criteria for mixed trials within two trial blocks, scoring 94.4% and 100%.

**Set 3 (G-H).** Paul met mastery criteria on stimulus set training within two trial blocks, scoring 100% and 90%. He scored 33% on the first DRR probe, 50% on the second DRR probe following re-training, and 75% on the third DRR probe following bidirectional retraining. DRR training was conducted across two trial blocks, with scores of 91.7% on both. Scores on mixed trial blocks were 83.3%, 94.4%, and 94.4%.

**Grand mixed trials.** Scores on grand mixed trials were 94.4% across two trial blocks.
**Set 4 (J-K).** Paul scored 100% on training trial blocks for Set 4. As with Sets 2 and 3, an additional re-training trial block was conducted in which Paul was prompted to state the bidirectional relations. He scored 41.6% on the first DRR probe, 50% following the first re-training, and 41.6% following bidirectional re-training. DRR training was conducted over eight trial blocks, with an average score of 75%. Mixed trials were conducted over four trial blocks, with an average score of 91.6%.

**Intraverbal Probes of Relations**

A total of 23 intraverbal probe sessions were conducted with Paul (see Figures 16 and 18). He did not state any relations during the first probe session, and an increase to three stated relations was seen during the following three probe sessions, prior to DRR training. Starting with Picture Set 3, Paul related some or all of the items in a temporal sequence, a response that was not observed with the other participants (e.g., “Okay, first you ride on the bicycle, then you see the panda, then you mop the floor, then put the movie in, then pop some popcorn”). This was scored as one relation, and scored again as a separate relation if he re-ordered the pictures into a different temporal sequence within the session. Paul also stated spatial and hierarchical relations, and related items based on their functions; he did not demonstrate use of the relations same, opposite, or comparison. The experimenter provided examples of same and opposite relations starting with Set 10. After several sessions of experimenter provided examples and no observed use of the target relations, the prompt of “Do you think any of these could be same/opposite?” was added with Set 14 (see Figure 16). With Sets 15 and 21, Paul related several items as opposite, but did not identify any features upon which these relations were based. The
experimenter gave Paul an opportunity to elaborate on the stated relations, and provided examples of opposite relations following no response. For example:

Paul: These look so opposite (table and teddy bear)

_Experimenter:_ They look so opposite? Why do you think that?

Paul: (No response)

_Experimenter:_ One way I think they could be opposite is that the table is hard and the bear is soft. That’s an opposite.

An overall increase in the total number of relations stated was observed over the course of the study and following the addition of prompting; however, when no prompting was provided during the last three sessions the total number of stated relations decreased but was still slightly above baseline level. The total number of relations stated per session for Paul ranged between 0 and 8, with an average of 3.8. The duration of intraverbal probe sessions ranged from 1 min 50 sec to 11 min 30 sec, with an average duration of 5 min 30 sec.

**Number of Sessions**

Paul participated in the study for a total of 35 sessions with two to three sessions per week, amounting to 173 trial blocks (including pre-training and baseline). Intraverbal probes were conducted during 23 sessions (see Table 11).
Table 9. Paul’s DRR probe scores and DRR training scores for mutually entailed (ME) and combinatorially entailed (CE) relations. Average scores are shown bold in parentheses.

<table>
<thead>
<tr>
<th>Phase</th>
<th>DRR Probe Scores (Average)</th>
<th>DRR Training Scores (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ME</td>
<td>CE</td>
</tr>
<tr>
<td><strong>Same-Opposite</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>50%, 100% (75%)</td>
<td>50%, 50% (50%)</td>
</tr>
<tr>
<td>Set 2</td>
<td>100%, 100% (100%)</td>
<td>50%, 50% (50%)</td>
</tr>
<tr>
<td>Set 3</td>
<td>50%, 83% (61.5%)</td>
<td>50%, 50% (50%)</td>
</tr>
<tr>
<td>Set 4</td>
<td>100%, 83% (91.5%)</td>
<td>50%, 66% (58%)</td>
</tr>
<tr>
<td>Set 5</td>
<td>66%, 100%, 100%, 83% (87%)</td>
<td>50%, 83%, 66%, 66% (66%)</td>
</tr>
<tr>
<td>Set 6</td>
<td>66%, 66%, 83% (71.6%)</td>
<td>50%, 50%, 66% (55.3%)</td>
</tr>
<tr>
<td><strong>More-Less</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>0%, 16% (8%)</td>
<td>83%, 100% (91.5%)</td>
</tr>
<tr>
<td>Set 2</td>
<td>0%, 16%, 0% (5%)</td>
<td>83%, 83%, 100% (88.6%)</td>
</tr>
<tr>
<td>Set 3</td>
<td>33%, 50%, 50% (44.3%)</td>
<td>33%, 50%, 100% (61%)</td>
</tr>
<tr>
<td>Set 4</td>
<td>33%, 33%, 50% (38.6%)</td>
<td>50%, 66.7%, 33% (49.9%)</td>
</tr>
</tbody>
</table>
Table 10. Number of sessions, number of trial blocks, and DRR probe scores for each set for Paul.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Number of Sessions</th>
<th>Number of Trial Blocks</th>
<th>DRR Probe Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same-Opposite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1 (A-B)</td>
<td>2</td>
<td>13</td>
<td>50%, 75%</td>
</tr>
<tr>
<td>Set 2 (A-C)</td>
<td>4</td>
<td>18</td>
<td>75%, 75%</td>
</tr>
<tr>
<td>Set 3 (C-D)</td>
<td>4</td>
<td>15</td>
<td>50%, 66.7%</td>
</tr>
<tr>
<td>Set 4 (X-Y)</td>
<td>3</td>
<td>16</td>
<td>75%, 75%</td>
</tr>
<tr>
<td>Set 5 (X-Z)</td>
<td>4</td>
<td>18</td>
<td>58.3%, 91.7%, 83.3%, 75%</td>
</tr>
<tr>
<td>Set 6 (Z-V)</td>
<td>2</td>
<td>11</td>
<td>58.3%, 58.3%, 75%</td>
</tr>
<tr>
<td>More-Less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set 1 (E-F)</td>
<td>4</td>
<td>21</td>
<td>41.7%, 58.3%</td>
</tr>
<tr>
<td>Set 2 (E-G)</td>
<td>3</td>
<td>14</td>
<td>41.7%, 50%, 50%</td>
</tr>
<tr>
<td>Set 3 (G-H)</td>
<td>2</td>
<td>12</td>
<td>33%, 50%, 75%</td>
</tr>
<tr>
<td>Set 4 (J-K)</td>
<td>3</td>
<td>19</td>
<td>41.7%, 50%, 41.7%</td>
</tr>
</tbody>
</table>

Figure 12. DRR probe scores for Paul. Circles represent mutual entailment scores, triangles represent combinatorial entailment scores.
Table 11. Total number of sessions, trial blocks, and intraverbal probe sessions for all participants.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Total Number of Sessions</th>
<th>Total Number of Trial Blocks</th>
<th>Intraverbal Probe Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nancy</td>
<td>28</td>
<td>120</td>
<td>24</td>
</tr>
<tr>
<td>Dustin</td>
<td>12</td>
<td>55</td>
<td>11</td>
</tr>
<tr>
<td>Adam</td>
<td>12</td>
<td>57</td>
<td>12</td>
</tr>
<tr>
<td>Paul</td>
<td>35</td>
<td>173</td>
<td>23</td>
</tr>
</tbody>
</table>

Figure 13. Percentage of correct responses during formal pre-training, baseline, and experimental training for Adam (top panel) and Dustin (bottom panel). Open triangles represent DRR probe scores, closed triangles represent DRR training scores.
Figure 14. Number of relations stated during intraverbal probe sessions for Adam (top panel) and Dustin (bottom panel). Triangles represent SAME, circles represent OPPOSITE, squares represent MORE, diamonds represent LESS, X’s represent other relational frames; dark symbols indicate formal relations, gray scale symbols indicate arbitrary relations. Arrows indicate sessions in which prompting was provided.
Figure 15. Percentage of correct responses during formal pre-training, baseline, and experimental training for Nancy (top panel) and Paul (bottom panel). Open triangles represent DRR probe scores, closed triangles represent DRR training scores.
Figure 16. Number of relations stated during intraverbal probe sessions for Nancy (top panel) and Paul (bottom panel). Triangles represent SAME, circles represent OPPOSITE, squares represent MORE, diamonds represent LESS, X’s represent other relational frames; dark symbols indicate formal relations, gray scale symbols indicate arbitrary relations. Arrows indicate sessions in which prompting was provided, open arrows indicate sessions in which the experimenter provided more specific prompting of target relations.
Figure 17. Total number of relations stated during intraverbal probe sessions for Adam (squares) and Dustin (diamonds). Arrows indicate sessions in which prompting was provided.

Figure 18. Total number of relations stated during intraverbal probe sessions for Nancy (squares) and Paul (diamonds). Arrows indicate sessions in which prompting was provided, open arrows indicate sessions in which more specific prompting of target relations was provided.
CHAPTER FOUR:
DISCUSSION

This study evaluated the effects of training derived relational responding on intraverbal ability in four children with autism. It was hypothesized that multiple exemplar training of derived stimulus relations would facilitate the acquisition of DRR across stimulus sets. In addition, it was hypothesized that the acquisition of targeted relational frames of coordination, opposition, and comparison would result in generalized use of these relations during naturalistic (i.e., intraverbal) probes. Results showed differences among participants in both areas; however, it was observed that with generalization to the naturalistic probes all children showed an increase in multiple relational frames, in addition to the target relational frames.

Regarding the establishment of DRR with relational training and testing, three of the four participants demonstrated mastery of DRR on at least one set of SAME-OPPOSITIVE and one set of MORE THAN-LESS THAN. For two participants, Adam and Dustin, similar performances were observed in terms of DRR ability and responding on intraverbal probes. Dustin demonstrated mastery on all DRR probes with no training, including reversal probes. An increased use of SAME relations was observed with Dustin following experimenter prompting. Adam met mastery criteria on all DRR probes for SAME-OPPOSITIVE without additional training; he required training on the Set 1 of MORE THAN-LESS THAN and demonstrated mastery on DRR probes for Sets 2 and 3. A slight increase in use of SAME relations on intraverbal probes was observed with Adam, as well as an overall increase in the use of other
Participant 3, Nancy did not demonstrate any DRR ability at the beginning of the study and did not state any relations during intraverbal probes until the experimenter provided examples along with additional prompting of asking for specific relations. Over-selective responding was observed with Nancy on intraverbal probes in that she began to relate the pictures based on the colors of the borders, and continued to primarily relate the items based on the border colors even with prompting and modifications to the materials. Despite these deficits, Nancy demonstrated improvements in DRR ability starting with Set 2 of SAME-OPPOSITE (from 0% to 67%), and scored 100% on the second DRR probe for Set 3. She demonstrated mastery on DRR probes for Set 4 of both SAME-OPPOSITE and MORE THAN-LESS THAN. The fourth participant, Paul, did not meet mastery criteria on any DRR probes for SAME-OPPOSITE or MORE THAN-LESS THAN relations, despite training additional exemplars and non-arbitrary training, although some improvement in DRR scores was seen over the course of the study. Additionally, while generalized use of target relations on intraverbal probes was not observed with Paul, he demonstrated the use of several relational frames (i.e., temporal, spatial, hierarchy) and an overall increase in relational statements was observed from pre-training and baseline.

Although Paul did not meet mastery criteria on any DRR probe trial blocks for SAME-OPPOSITE, he demonstrated mastery of three of the four derived relations. Despite several procedural modifications (e.g., additional formal training, denser reinforcement schedules) one combinatorially entailed (CE) relation did not emerge for Paul. It was determined that this could not be attributed to issues with participant motivation or attending. Paul identified a highly preferred activity (watching videos on a tablet) at the beginning of the study, and this selection was also validated by caregivers. The acquisition of trained relations suggests that the preferred
activity functioned as a reinforcer, and his behavior prior to and during sessions indicated that sufficient motivating operations were in place (e.g., manding for videos). Paul was not observed engaging in behavior that indicated lack of attending during sessions, such as off-task behavior or latency in responding. It was also determined that Paul’s failure to acquire one of the CE relations could not be attributed to over-selective responding based on formal features given that six different sets of stimuli were used and the same errors occurred across stimulus sets. This interesting, although unanticipated, finding is certainly in need of further investigation with other individuals with ASD.

It is possible that some of Paul’s errors on DRR probes, at least initially, were a result of a learning history in which response allocation remains consistent across training and testing. During training there were an equal number of SAME and OPPOSITE responses (5 per trial block); during DRR probe trial blocks there were 3 trials with the answer SAME and 9 trials with the answer OPPOSITE. Both combinatorially entailed relations were opposition. Paul consistently failed to respond correctly on one combinatorially entailed OPPOSITE relation, which resulted in an approximately equal distribution of SAME and OPPOSITE responses on DRR probes. Another possible explanation for Paul’s repeated failure of one particular CE relation is potentially the result of reinforcer blocking effect (Williams, 1975). The blocking of reinforcement control suggests that temporal contiguity between a stimulus and the delivery of reinforcement may not necessarily be sufficient to build stimulus control for a new response when there is a history of reinforcement for another response (Williams, 1975). It may be the case that the noncontingent reinforcement provided during DRR probes strengthened the occurrence of incorrect responses and that, in light of this, the explicit reinforcement provided during training was not adequate to gain stimulus control over the correct response. Additionally,
it is possible that Paul simply failed to acquire one type of relation due to a history of errors established over the course of the study.

Another interesting and unanticipated finding pertains to DRR probe scores for MORE THAN-LESS THAN relations. An analysis of participants’ mutual entailment (ME) and combinatorial entailment (CE) scores on DRR probes indicates that for all participants, CE scores were higher than ME scores on comparative relations (see Figures 9 through 12). It is possible that this was due to the format of the procedure, in which participants were required to reverse the trained relations in order to respond correctly on the ME relations but not the CE relations. For example, if F2 is trained as more than E1, testing E1 to F2 (ME) requires the participant to state the reverse relation (E1 is less than F2); however, when testing a CE comparative relation (e.g., F2 to F1), a correct response requires stating the same relation that was trained (e.g., when F2 is the comparison stimulus, say “more than”). The order of training (SAME-OPPOSITE before MORE THAN-LESS THAN) may also be a factor in this finding; that is, participants learned to derive SAME-OPPOSITE relations first, in which the bidirectional relations are the same (e.g., if A is opposite B, then B is opposite A).

A second focus of this study was to evaluate the effects of a DRR training protocol on participants’ ability to draw relations between common items. According to RFT, derived relational responding is a contextually controlled generalized overarching operant that is the underlying process involved in language (Barnes-Holmes, Barnes-Holmes, & McHugh, 2004). Based on this account, training and acquisition of DRR should promote relational skills; therefore, it was expected that this type of training would result in an increased ability to draw relations between items presented as picture sets. As recommended by Luciano et al. (2009), the target relational repertoire should be brought into other contexts and training environments as
soon as possible. According to Luciano and colleagues, a broad training approach enhances coherence of the arbitrary relations and promotes the use of such relations in an individual’s naturally occurring language interactions. Therefore, the purpose of the intraverbal probes was twofold; to evaluate generalized use of the target relations, as well as to provide additional training to facilitate this transfer. Although an increased use of the target relations was not observed in all participants, an overall increase in the total number of relations stated could be seen with all participants, particularly following the addition of prompting and during sessions in which prompting was provided.

Adam demonstrated mastery on all DRR probes for all three sets of SAME-OPPOSITE, and for 2 out of 3 sets of MORE THAN-LESS THAN, and some generalized use of SAME relations was seen on intraverbal probes. It was observed that Dustin, who required no DRR training for any stimulus set, showed more generalized use of SAME relations during intraverbal probes than the other participants. Although an increase in the overall number of relations was observed with both of these individuals, an overall shift from formal to arbitrary relations was not observed, nor an increase in the use of other target relations. Nancy demonstrated acquisition of DRR, as well as an increased use of target relations following training, although this increase was only observed after specific prompting of the relations, and responses were limited by over-selective responding based on the borders of the pictures. Paul did not reach mastery on any DRR probes, and generalized use of target relations on intraverbal probes was minimal, and occurred only following specific prompting of relations; however, Paul demonstrated an increased use of several other relational frames during intraverbal probes.

Specific social validity measures were not included; however, anecdotal reports from parents, as well as participant behavior, support the social validity of this study. Parents were
pleased with the nature of the study and the structure of the sessions, particularly intraverbal probes, where the focus was essentially engaging the participant in conversation. Additionally, there were no issues gaining vocal verbal assent or compliance from participants prior to each session.

Limitations

Several limitations were encountered throughout the process of this study. Sessions were conducted in the participants’ homes and although every attempt was made to control environmental variables, it was not always possible to limit all potential distractions. It is possible that this contributed to some variability in data, particularly for Paul. A second possible limitation pertains to participant characteristics. Although participants were carefully selected based on a number of inclusion criteria, lack of standardized assessment scores for each of the participants could be seen as a limitation; however, the intraverbal probes conducted essentially allowed us to obtain language samples for the participants throughout the study and provided a qualitative measure of participants’ verbal ability. Additionally, Paul was several years younger than the other participants. He turned 6 just prior to beginning the study, while Nancy turned 9 about halfway through the study, and Adam and Dustin were both 10 years old. It is not known whether this was a contributing factor in Paul’s performance; however, in light of the fact that equivalence relations have been demonstrated in preschool-age children and younger (e.g., Devany, Hayes, & Nelson, 1985; Lipkens, Hayes, & Hayes, 1993; Luciano, Gomez Becerra, & Rodriguez-Valverde, 2007) it is unlikely that Paul’s difficulties could be simply accounted for as a matter of age.
Another limitation involves the $S^D$ used for intraverbal probes in which participants were asked how common items could be related. A less specific instruction was used in order to determine whether the use of these relations would transfer when a similar $S^D$ was used for training target relations; however, it is possible that one reason we failed to see an emergence of the use of the trained relations was due to participants’ history of relating items based only on congruence, as well as participants’ learning history surrounding the term “related”. For example:

*Experimenter:* “Alarm clocks make sounds to alert you, kind of like boats make sounds with their horns.”

Adam: “Yeah, but these are not related because alarm clocks sounds are quieter than boat sounds.”

*Experimenter:* “Yeah, boats are definitely louder than alarm clocks. But that’s one way they can be related.”

Adam: “Ok. HONK!”

An additional limitation encountered with the intraverbal probe procedure pertains to the colored borders of the pictures, as well as very small text on the pictures; however, over-selective responding based on these features was only observed with Nancy, and she was the only participant to comment on the picture borders. Attempts to control for this (e.g., removing the borders, using all the same color borders) did not result in an increase in responding based on the pictures themselves.

One other limitation involves the training procedure for failed relations, particularly comparative relations, in which pre-training stimuli were incorporated into the training procedure. When presented with subsequent stimulus sets for more than-less than relations, Adam identified the symbols as “one, two, and three”, an effect that was not anticipated or seen with other participants. Although it could be argued that participants’ scores on subsequent DRR
probes were artifacts of this procedure, we contend their responses were still derived, and if anything, the symbols came to participate in frames of coordination with the numbers. Additionally, given that DRR emerges through transfer of stimulus control from formal to arbitrarily specified relations it is likely that this component is necessary in the development of DRR itself (Luciano et al., 2009).

**Future Research**

The results of this study contribute to a growing body of literature concerned with clinical applications of an RFT-based approach. Much more research is needed in the area of RFT and derived relational responding, particularly its application to education and individuals with developmental disabilities, and the correlation between relational skills and verbal ability. More research on the development of DRR in typically developing children would greatly enhance this line of research. For example, what does DRR performance and acquisition look like in typically developing children? Would greater generalization on intraverbal probes be observed in typically developing children, compared with children with ASD?

Future studies should also evaluate the effects of relational training in the absence of DRR training, in which participants are presented with common objects or pictures and asked to relate the items to one another, to determine whether this alone would enhance relational ability. In addition, future research should examine whether the use of specific contextual cues would occasion more relational responding and facilitate this transfer. For example, providing participants with only two pictures at a time and asking for a specific relation (e.g., “How could these be the same?”) or asking “How could this one be related to this one?” as done in training.
Additionally, this area of research would benefit from an investigation of the number of exemplars required for the acquisition of DRR. It is possible that younger children (e.g., Paul) can acquire this ability, but need training of more exemplars than children who are older to compensate for naturally occurring learning opportunities.

Another area in need of investigation is the training format used to teach DRR ability; for example, evaluating the use of receptive or expressive responses in DRR training and testing protocols (i.e., targeting listener or speaker repertoires). This study required participants to vocally state relations between stimuli on each trial, while prior research in derived stimulus relations has mainly involved receptive responses (e.g., pointing, matching to sample). It is not known whether the response form has any effect of the acquisition of DRR or performance when testing for the emergence of DRR. The current study incorporated the use of vocal verbal responses, partly to evaluate whether participants would engage in overt verbal behavior that would indicate the development of derived stimulus relations; however, this type of collateral vocal verbal behavior was not observed with participants. It is of interest whether explicit prompting of additional verbal responses would promote acquisition of DRR.

It is also of interest whether the frequency and distribution of training sessions has an effect on acquisition. Learning derived stimulus relations may be enhanced by shorter, more frequent sessions, and may more closely resemble naturally occurring exposures to multiple exemplars, compared with longer sessions spread out over the course of several weeks. Additionally, discrete trial training (DTT) may not be the most appropriate format for teaching DRR. Fluency based training and measurement, as used in precision teaching (PT), may yield quicker acquisition and improved performance (Kubina & Yurich, 2012); however, the use of PT strategies to teach DRR has not been evaluated. These are only a few possibilities of potential
applications for an RFT-based approach to language training, and the results of this study support its value.
REFERENCES


