Assessing Relational Networks: An Evaluation of Derived Relational Responding With Children With ASD and Typically Developing Children

Gianna Delayce Lozano

University of South Florida, glozano@mail.usf.edu

Follow this and additional works at: http://scholarcommons.usf.edu/etd

Part of the American Studies Commons, and the Other Education Commons

Scholar Commons Citation


http://scholarcommons.usf.edu/etd/3217

This Thesis is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact scholarcommons@usf.edu.
Assessing Relational Networks: An Evaluation of Derived Relational Responding

With Children with ASD and Typically Developing Children

by

Gianna D. Lozano

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts
Department of Child and Family Studies
College of Behavioral and Community Sciences
University of South Florida

Major Professor: Timothy Weil, Ph.D.
Raymond Miltenberger, Ph.D.
Danielle Sutton, Ph.D.

Date of Approval:
June 30, 2011

Keywords: Relational Frame Theory, relational framing, derived stimulus relations, derived relational abilities, perspective taking

Copyright © 2011 Gianna D. Lozano
Acknowledgements

I offer my gratitude to my advisor, Dr. Tim Weil for his constant support and guidance throughout this process. I am also grateful for Dr. Danielle Sutton and Dr. Mariann Saurez’s extended assistance and professional direction during this process.
# Table of Contents

List of Tables ......................................................................................................................... iii

List of Figures ........................................................................................................................... iv

Abstract ........................................................................................................................................ v

Introduction ................................................................................................................................. 1
  Relational Frame Theory ............................................................................................................. 2
  Derived Relational Responding ................................................................................................. 3
  Relational Frames ...................................................................................................................... 3
    Mutual Entailment .................................................................................................................... 4
    Combinatorial Entailment ......................................................................................................... 4
  Transfer of Stimulus Function ................................................................................................. 4
  Assessments and Applications of Relational Responses ......................................................... 5
  Basic Relational Ability and Relating as an Operant ............................................................... 6

Method ......................................................................................................................................... 10
  Participants .............................................................................................................................. 10
  Materials ................................................................................................................................ 12
  Dependent Measures and Experimental Design .................................................................. 13
  Interobserver Agreement ........................................................................................................ 14

Procedure .................................................................................................................................. 15
  Initial Contact and Recruitment ............................................................................................... 15
  Formal Relations Pre-test ......................................................................................................... 15
  WISC-IV .................................................................................................................................. 17
  Preference Assessment ............................................................................................................. 17
  Arbitrary Relations .................................................................................................................. 18
    Pre-test ................................................................................................................................. 18
    Training ................................................................................................................................ 19
  Post-Instructional Probes for Mastery of Directly Trained Relations .................................... 20
  Test for Derived Relational Responding .................................................................................. 23

Results ......................................................................................................................................... 25
  Participant 1 ............................................................................................................................. 25
    Number of Trials .................................................................................................................. 25
    Number of Sessions ............................................................................................................. 25
    Derived Relations Post-Instructional Probes ....................................................................... 26
  Participant 2 ............................................................................................................................. 28
Number of Trials .................................................................................................................. 28
Number of Sessions ............................................................................................................. 29
Derived Relations Post-Instructional Probe ................................................................. 29
Participant 3 .......................................................................................................................... 32
  Number of Trials .............................................................................................................. 33
  Number of Sessions .......................................................................................................... 33
  Derived Relations Post-Instructional Probes ............................................................... 34
Participant 4 .......................................................................................................................... 38
  Number of Trials .............................................................................................................. 38
  Number of Sessions .......................................................................................................... 39
  Derived Relations Post-Instructional Probes ............................................................... 39
Typical and AS performances .......................................................................................... 43
Discussion .............................................................................................................................. 46
Limitations ............................................................................................................................. 49
Future Research ..................................................................................................................... 51
References .............................................................................................................................. 55
List of Tables

Table 1: Order of training and testing phases within the curricular assessment ........ 21

Table 2: Total number of training and testing sessions for each relationship between stimuli AB, AC, and CD for participants 1-4 ........................................ 42

Table 3: Percent scores on derived relation probes for each participant ................. 42

Table 4: Performance on derived relation probes grouped by participant and nodal Distance ........................................................................................................ 44

Table 5: Aggregate of scores of each derived relation for each participant by nodal Distance ........................................................................................................ 44
List of Figures

Figure 1: Arbitrary symbols to be used during instruction phases for each relation to be trained ................................................................. 18

Figure 2: Visual representation of the total number of derived relational responses of all arbitrary stimuli involved in training ......................... 22

Figure 3: Graph of participant 1 (AS 1) ......................................................................................................................... 26

Figure 4: Visual representation of the total number of derived relational responses of participant 1 (AS 1) .......................................................... 27

Figure 5: Graph of participant 2 (Typ 1) .......................................................................................................................... 30

Figure 6: Visual representation of the total number of derived relational responses of participant 2 (Typ 1) .......................................................... 31

Figure 7: Graph of participant 3 (AS 2) .......................................................................................................................... 35

Figure 8: Visual representation of the total number of derived relational responses on the first trial of test probes of participant 3 (AS 2) .......... 36

Figure 9: Visual representation of the total number of derived relational responses on second trial of test probes of participant 3 (AS 2) .... 36

Figure 10: Graph of participant 4 (Typ 2) ......................................................................................................................... 40

Figure 11: Visual representation of the total number of derived relational responses on the first trial of test probes of participant 4 (Typ 2) ....... 41

Figure 12: Visual representation of the total number of derived relational responses on the second trial of test probes of participant 4 (Typ 2) .... 41
Abstract

The way in which humans engage in conversation and social interactions is largely due to their ability to form relationships between a wide variety of stimuli. Two people are able to communicate fluently and effectively because each has the capacity to derive meaning during social interactions. Forming relationships is an effortless process that humans engage in daily, however for those individuals with developmental disabilities, the ability to form relationships between various stimuli based on arbitrary properties does not appear to happen in the natural course of development. The purpose of this study was to assess the ability of children to derive relationships between a set of stimuli following training on Same and Opposite for a subset of the possible relations. Four children participated: 2 typically developing children and 2 age matched children diagnosed with Asperger’s Syndrome (AS). Two goals of this study were to identify differences in ability to derive across multiple nodal distances, and, if there was consistency in failures at larger nodal distances. Results indicated typically developing children were able to derive relationships at a greater distance and with a quicker rate of acquisition than those diagnosed with AS.
Introduction

“An essential component of cognition and language involves the formation of new conditional relations between stimuli based upon the history of multiple experiences” (Schlund, Cataldo, & Hoehn-Saric, 2008).

Understanding the mechanisms fueling the generativity of language is paramount for understanding the development of human language (Malott, 2005). Traditional behavioral accounts of language are comprised of direct contingency analysis that explain the emission of behavior as resulting from direct prior experience, induction, or rule following. However there is evidence to suggest that humans are capable of forming novel relations between stimuli based on arbitrary aspects of the stimuli involved. For instance, humans have the ability to derive rules without direct exposure to contingencies or having the rule stated by others.

This ability is said to develop from prior experiences where a step is taken in forming relationship based on arbitrary properties of the stimuli involved, and the behavior of relating in the new and untrained ways is reinforced. Following a sufficient number of successful exemplars that are bi-directional and which contact reinforcement, a person is said to develop an overarching class of behavior that permits the formation of new relationships between stimuli and events that have never been related otherwise and does not require explicit reinforcing contingencies (Hayes, Barnes-Holmes, & Roche, 2001). Expression of this overarching repertoire is termed derived relational responding and is said to occur when we form relationships between two or more stimuli in the absence of direct training where the relationship is based on arbitrary properties.
Relational Frame Theory

Relational Frame Theory (RFT) is a behavior analytic approach to language and cognition that attempts to account for the process involved in the meaning of utterances (Weil & Hayes, 2011). The core aspect of RFT attempts to account for behavioral processes that provide individuals the ability to understand and relate a vast number of events and experiences in new and untrained ways that influence the propensity for language (Villatte, Monestes, McHugh, Freixa, & Loas, 2008). For example, a child may learn, by direct training, to say “apple” when shown a picture of an apple and asked “what is the picture?” The use of practical and effective language increases when the child sees an apple at the supermarket and says “apple.” The identification of the picture apple was explicitly taught, however the identification of the object apple was not, and the picture of apple and object do not share similar physical features of size or shape. Within RFT, verbal behavior is defined as the act of relating, in which the action of interest is the derivation of a relation between two or more stimuli. From an RFT perspective, verbal behavior is viewed as a generalized operant that may include a wide variety of relational responses and corresponds to the ability to form relations between stimuli based on varying dimensions, which are governed by the larger social community and contextual cues.

It is important to point out that the generation of individual tacts and/or mands would not count as verbal behavior from this standpoint. The explanation of verbal behavior within RFT extends traditional accounts by emphasizing the behavior of relating two stimuli, which occurs in the absence of direct training. For example, upon learning to tact “car” in the presence of an actual car, given a history of reinforcement for doing
so, the response would not be considered verbal until the individual was able to respond to another person saying “car” by then pointing to a car; seeing a car and saying “car” and seeing the written word “CAR” and emitting the vocalization “car”. In this example, each modality is linked in an equivalence frame with each other (Healy, Barnes-Holmes, & Smeets, 2000; Villatte et al., 2008; Weil & Hayes, 2011). A person’s verbal behavior increases in complexity by forming new relations between the endless interactions with stimuli, and through this, patterns of behavior are formed and reinforced. These patterns are referred to as relational frames (Blackledge, 2003; Villatte et al., 2008).

**Relational Frames**

Relational frames are an analytic unit of RFT and are conceptualized as a three-term contingency in which the contextual cue, as an aggregate of a history of differential reinforcement and the specific context, comprises the first term in the contingency. The relational response is considered the second term and the differential reinforcement from relating stimuli in such ways is considered the third term in the contingency (Healy et al., 2000).

A relational frame is a specific class of arbitrarily applicable relational responding that shows the contextually controlled qualities of mutual entailment, combinatorial mutual entailment and transformation of stimulus functions. Arbitrarily applicable relational responding refers to responses that are under control of environmental and contextual cues that do not share similar properties. In addition, the specific class of responding is initially strengthened by the history of relational responding relevant to the contextual cues involved, and most notably, is not solely based on direct training with regard to formal stimulus characteristics (Weil & Hayes, 2011).
As mentioned previously, a necessary defining feature for stimuli to be considered verbal is their participation in relational networks that show the characteristics of mutual and combinatorial entailment and transformation of stimulus function (Hayes et al., 2001).

**Mutual entailment.** The complementary relationship between two stimuli (A and B) serves as the basis of mutual entailment, where the two stimuli related in some particular way (A to B) are also related in another way (B to A). When the first relation is specified, the second relation is entailed. The natural progression from mutual entailment is how stimuli related mutually can combine with other relational networks and also be related combinatorially.

**Combinatorial entailment.** The relationship between two stimuli can include a relation to a third stimulus, as in A to B and B to C, are each mutually entailed; due to their relation to B, A and C are also related. A to C and C to A are the product of combinatorial entailment (Blackledge, 2003; Weil & Hayes, 2011).

**Transformation of stimulus function.** The third characteristic necessary for a response to be considered verbal is transformation of stimulus function and is defined as the formation of relational responses between sets of stimuli and the physical or psychological functions originally attached to each change as a result of the newly formed relation (Blackledge, 2003). How stimulus functions change is determined by the stimuli involved and the place and direction within the network they are related (Blackledge, 2003). A transfer of function is evident in the example, A is the same as B but B is opposite C, therefore A and C are also related as opposites. Further, if A acquires a reinforcing function, C would be predicted to acquire a punishing function as a
result of C having an opposite relationship with A and B (Weil & Hayes, 2011). An important implication of this is the lack of a conditioning history for the C stimulus. This transformation of stimulus function is not predicted in a Skinnerian account. The culmination of these characteristics of relational responding occurs within the majority of human social interactions and is viewed as being central to the process of language (Blackledge, 2003; Hayes et al., 2001).

To sum up, from a behavior analytic perspective, language is a process largely based on contextual cues that is influenced by a history of relational responding. Relational responding occurs in the form of mutual and combinatorial entailment and leads to subsequent transformation of stimulus functions for the stimuli involved (Weil & Hayes, 2011). Returning to our initial premise, the understanding of language ability has been recognized as one the “greatest challenges in behavior analysis” (Berens & Hayes, 2007). Relating relations (as in analogy) may produce information on multiple sets of responses as they in turn impact other stimulus sets offering an increased and complex network resulting in gains in knowledge and information, which inadvertently influences the propensity of effective communication (Lipkens & Hayes, 2009).

Assessments and Applications of Relational Responses

Research within the realm of RFT has provided an abundance of empirical evidence in favor of an explanation of derived relational responding as a behavioral process accounting for emergent relations. RFT research has been conducted on a wide variety of tasks; however, literature providing evidence of where, in relational networks, the breakdown of relating for language impaired individuals occurs is limited. In spite of this limitation, research of relational responses across a variety of populations with
varying purposes commonly recognizes the benefit of relating stimuli in new and untrained ways in order to maximize language ability (Healy et al., 2000).

**Basic Relational Ability and Relating as an Operant**

In an attempt to show support for viewing DRR as an operant behavior, Steele and Hayes (1991) assessed typically developing high school students’ abilities to respond correctly to relationships of SAME, DIFFERENT, and OPPOSITE. The subjects were trained on each relationship and tested for derived responding on untrained relations, via automated procedures. A computer program was used to display arbitrary symbols and contextual cues of SAME, OPPOSITE, and DIFFERENT. The stimuli used in the Matching-to-Sample (MTS) task consisted of arbitrary symbols to control for prior exposure. The participants were presented with a series of matching tasks with the arbitrary symbols as the comparison stimuli along with the contextual cues (Steele & Hayes, 1991).

The training protocol began with a pre-training phase on relations same, opposite, and different with stimuli that shared similar physical features. There were 16 stimulus sets. One sample stimulus and two comparison stimuli were presented on each trial, which were alternately presented for each of the three relations. For example, a short line (sample stimulus) was presented with a long and medium line (comparison stimuli) with the contextual cue of SAME, OPPOSITE, and DIFFERENT. Within the pre-training phase, the experimental group was trained on the contextual cues, and the control group did not receive training but the MTS tasks across all phases remained constant (Steele & Hayes, 1991). Following pre-training, participants were trained on the same three relations with arbitrary symbols using an arbitrary matching to sample method. The
symbols were presented in the same manner as in pre-training and once participants met criterion on the trained relations with arbitrary stimuli, the two groups were then tested on untrained relations. The tested responses of each group were examined to determine if formal training on contextual cues influenced responding to stimuli based on non-arbitrary and arbitrary properties.

The study provides a method for training and testing of basic relational networks. The subjects were involved in multiple exemplar training and testing of each relationship with the purpose to compare the effects of a pre-training condition that included the training on SAME-OPPOSITE-DIFFERENT relations, to no-pre-training. The two conditions were included to examine responses with previous exposure to stimuli and responses to the same testing stimulus sets, but with no prior training. The results yielded strong support for the ability to shape relating behavior. However, the level of responding and number of trials to reach criterion varied across participants (Steele & Hayes, 1991). The study provides a preliminary step in assessing the ability of relational responding to arbitrary stimuli. Specifically, the researchers mention the need for a behavior analytic investigation of the wider range of stimulus relations formed by individuals, with and without language impairments (Steele & Hayes, 1991).

Berens and Hayes (2007) utilized multiple exemplar training with typically developing females to assess its effectiveness in facilitating the development of DRR with vocabulary words. Through this evaluation, the researchers sought to evaluate the efficacy of the procedure in treating relational responding as an operant and to strengthen the evidence and practical application of RFT. The protocol included comparative relations more than/less than, and assessed acquisition within an arbitrary game to
determine if relational responding ability was acquired as a result of training with multiple exemplars (Berens & Hayes, 2007). The arbitrary game consisted of using stickers with acquired amounts trained to each in order to purchase more or less of a highly preferred item. The game was presented to the children and they were instructed to “pick the picture that would buy the most candy” where the pictures designated varied amounts and each picture’s amount varied from trial to trial (Berens & Hayes, 2007).

Following the initial game sequence, participants were trained on the relations between stimuli, which indicated relationships of “more than/less than”. The stimuli were trained via verbal instructions and pointing, as in “stimulus A is more than stimulus B” while simultaneously pointing to the corresponding stimuli. The training process was repeated across multiple trials with multiple exemplars that acquired the function of varying amounts of “more than/less than” (Berens & Hayes, 2007). Researchers used the game format as a means to train and test multiple trials in an efficient manner and provide a method for adequately testing the participants’ ability to select stickers with varying amounts that were not directly trained, i.e. derive relations.

Results indicate that DRR emerged following training of the comparative relational frames. The study provided support for the teaching of relational operants as well as the successful emergence of derived relations via behavioral procedures. Researchers encouraged additional empirical efforts to focus on the application and validation of relational operants as an extension of applied behavior analysis (Berens & Hayes, 2007).

As mentioned by Steele and Hayes (1991), research with individuals with autism and related disorders is limited (Steele & Hayes, 1991). Rehfeldt, Dillen, Ziomek and
Kowalchuk (2007) addressed the limitation and signified the importance of assessing what has become known about relational learning to facilitate language ability with children with high functioning ASD’s in an attempt to surpass commonly shared social deficits (Rehfeldt, Dillen, Ziomek, & Kowalchuk, 2007). There is still much to know about language ability of individuals diagnosed with ASD’s. In addition, if the literature supporting the importance of DRR for advanced cognitive ability is correct, it will be important to both assess relational deficits with children diagnosed with ASD’s and to program effectively to remediate those deficits in hopes of closing any gaps in cognitive performance.

The purpose of this study was to assess derived relational responding ability with children diagnosed with AS as compared to performance on the same tasks with typically developing children.
Method

Participants and Setting

There were four children in the study, two diagnosed with Asperger’s Syndrome (AS), as assessed by a local area psychologist, and two children who were not diagnosed with a developmental disability and were considered on grade level in their academics (i.e., typically developing). Participants 1 (Mike) and 2 (Ryan) were diagnosed with AS and were 9 years of age. Participants 3 (Mark) and 4 (Sara) were typically (typ) developing and were also 9 years of age. The children were aged matched within 3 months and the children with developmental disabilities were the older one in each dyad. The children were matched in dyads that included one child diagnosed with AS and one typically developing child.

Each participant underwent an evaluation of intelligence, which provided additional background information on his or her intellectual abilities. The intelligence scale used was the Wechsler Intelligence Scale for Children (Grice, Krohn, & Logerquist, 1999) and was administered by the lead researcher, trained by a local area psychologist, at each of the participants’ homes. Participant 1 (AS 1) scored in the 84th percentile in the verbal similarities subtest (high average); the 16th percentile in the vocabulary subtest (low average); and, the 37th percentile in the comprehension subtest (average). Participant 2 (typ 1) scored in the 16th percentile in the verbal similarities subtest (low average); the 2nd percentile in the vocabulary subtest (borderline); and, the 16th percentile in the comprehension subtest (low average). Participant 3 (AS 2) scored in the 84th
percentile in the verbal similarities subtest (high average); the 16\textsuperscript{th} percentile in the vocabulary subtest (low average); and, the 63\textsuperscript{rd} percentile in the comprehension subtest (average). Participant 4 (typ 2) scored in the 50\textsuperscript{th} percentile in the verbal similarities subtest (average); in the 2\textsuperscript{nd} percentile in the vocabulary subtest (borderline); and, in the 5\textsuperscript{th} percentile on the comprehension subtest (borderline).

The initial requirement for inclusion in this study was the children’s ability to discriminate the relationships of same and opposite based on formal properties. Additional, selection criteria for participants include limited instances of problem behaviors (0-3 per 1 hour period, with a short duration of 0-3 minutes) and the ability to remain seated and on-task for at least 10 minutes at a time. These abilities were assessed through an initial phone interview with the parents. If the parents indicated the child did possess the ability, a short verification test was conducted during the first session to validate the parental report.

Following selection, primary inclusion criteria for the children diagnosed with AS was the ability to engage in vocal verbal behavior that included a variety of the verbal operants described by Skinner (1957). A focus was the identification of a generalized mand repertoire, a large tact repertoire (at least 100 items), and the ability to engage in intraverbal interactions (otherwise known as reciprocal interactions) in a conversational setting. In addition, there must have been a demonstrated ability to engage in joint attention behaviors and vocal verbal initiations. These repertoires were assessed largely by parental report and verified by direct observation upon meeting each participant. Direct observation consisted of observing behaviors as they naturally occurred and/or probing skills in the natural setting to verify abilities.
Sessions were conducted within the participants’ homes 1-3 times per week with sessions lasting no more than 30 minutes. The sessions took place in a quiet room, void of major distractions such as toys or stimuli that could potentially divert attention. Training took place at a table with two chairs set opposite each other. Only the necessary materials for particular training sequences were present close by.

Participants were recruited utilizing various behavior analysis agencies within the community. Interested families contacted the researcher and a phone interview was conducted to screen the child for basic requirements. If results from the phone interview indicated that the selection criteria described above were met, an in home meeting was scheduled to verify that the children could score 80% or better on stimulus relations based on formal properties with various stimuli (to be described).

Materials

The materials used in the study were based on the advantages of “table top” procedures highlighted by (Dymond, Rehfeldt, & Schenk, 2005). Materials consisted of 8x10 white paper with two comparison stimuli printed on the pages. The stimuli were placed in the lower third of the page (layout orientation). The comparison stimuli were centered horizontally and equal distance from each other. A third stimulus was centered horizontally in the top third of the page. This stimulus served as the contextual cue for relational responding. Sample stimuli were printed on 3x5 white index cards. Secondary reinforcers in the form of tokens on a token board were used to deliver immediate reinforcement contingent on correct responding on a fixed-ratio 1 schedule. Backup tangible reinforcers were provided if all tokens were earned within each sessions.
Specific reinforcers varied on the results of each child’s preference assessments. Data sheets, pencils, and a video recorder were the materials used for recording responses.

**Dependent Measures and Experimental Design**

The Dependent Measures consisted of correct verbal responses to the trained relationships in each phase A-B, A-C, and C-D. The specific response form was measured as the accurate placement of the sample stimulus on the corresponding comparison stimulus, given a particular contextual cue along with the vocal cue “match to same/opposite.” The dependent measure was the physical placement of the sample stimulus and not in the form of vocal behavior. Each trial was recorded as correct or incorrect and a percent score was computed at the completion of each training session.

The study was conducted in a concurrent multiple baseline across behaviors design that included a dyad of one child diagnosed with AS and one typically developing child. It is important to note, a direct comparison between groups was considered a secondary analysis to provide information on the number of responses of the two groups required during training to acquisition, as well as the performance on each probe in the relational network. The formal pretest phases were run non-concurrently across all four participants as inclusion dates varied, but the training phases of the study were run concurrently.

Following the formal pre-test, a baseline phase (pre-instructional probe) prior to each training sequence was conducted to verify an absence of ability with the target relational operants. The design permits within- and between-subjects analysis of changes in performance levels as well as comparisons between the children following probe tests for derived relational responding.
Interobserver Agreement

Interobserver agreement was assessed by having 2 observers’ simultaneously but independently record data during a minimum of 50% of sessions for all four participants and across all phases. Agreement percentages resulted by comparing observers’ data of recording each participant’s response as correct or incorrect to the principal investigators data. If all trials were recorded the exact same way the agreement percentage for that session was 100% IOA. IOA was 100% for all recorded sessions.
Procedure

Initial Contact and Recruitment

All participants’ were referred to the study by the community outlets and the participants’ parents contact information was forwarded via email to the principal investigator. Following the referral information the principal investigator contacted the parents by phone and conducted a brief interview to gather preliminary information regarding child’s age, diagnosis (if any), and ability to recognize things as “same” or “opposite.” Parents who indicated their child did have the ability to recognize the relationship of “same” and “opposite” were invited to participate in the study and an initial meeting was then scheduled to conduct the formal pretest as a verification of the parental report.

Formal Relations Pre-test

The pre-test functioned as a test for the inclusion criterion for the study in which the ability to relate things as same and opposite based on formal properties was verified. The pretest consisted of 20 trials, including 10 trials of SAME and 10 trials of OPPOSITE. The stimuli for the pretest had salient, formal features of sameness or opposition of which the relational response was based. A total of ten stimulus sets, were used for testing of relations based non-arbitrary properties. The stimulus sets included comparisons of black/white, few/many, tall/short, big/little, left/right, up/down, thick/thin, male/female, fat/skinny, and open/closed. Each trial included two distinct
comparison stimuli and a sample stimulus that is a perfect (formal) match to one of the comparisons.

Participants were presented with the laminated 8x10 sheet of paper with the comparison stimuli and the contextual cue of SAME or OPPOSITE positioned as described earlier. The child was presented with an index card with the sample stimulus and told to match accordingly. All children were presented with the verbal cue “put with SAME/OPPOSITE” in addition to the contextual cue. The trials for each relation were presented randomly to assess flexibility in responding.

The trainer and participant sat at a table facing each other with the stimuli in the center of the table. The participant was presented with the verbal cue “put with SAME/OPPOSITE” and handed the sample stimulus at the same time. The participant was permitted 10 seconds to match the sample item/object to one of the comparison stimuli. If no response occurred within 10 seconds of the delivery of the sample card, the trial was considered incorrect. The use of prompts, feedback or specific reinforcement was not provided during the initial phase. Percentage data were recorded on correct responses and mastery was 80% or better on each relation without prompts or reinforcement in order to be eligible for inclusion in the study. Verbal praise was provided contingent on appropriate learning behaviors, such as attending, on-task behavior, and appropriate sitting at table. If a participant could not respond at 80% or better on the test of formal relations he or she was dropped from the study. Six participants were presented with the formal pre-test, two of which did not meet inclusion criteria.
Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV)

A portion of the WISC was administered for all participants immediately after the formal pre-test scores met criterion of 80% or better. The WISC was administered to serve as an initial basis of reasoning ability of each participant and to provide information on how the participants ranked among each other and other children their age on the same verbal tasks of similarities, vocabulary, and comprehension.

Three subtests of the verbal portion of the WISC were administered. The verbal subtests included questions of similarities, which are how two things are alike; vocabulary, which asks to define a word; and comprehension, which are questions about social situations (Wechsler, 2004). The test was administered with the participant and principal investigator in each participant’s home. Each question was given verbally and the investigator wrote down each response verbatim. The responses were kept on record to be scored by the local psychologist.

Preference Assessment

The preference assessment was initially conducted by an informal questionnaire with the participants, in which a list of preferred activities was compiled and used at the end of each session as reinforcement for appropriate behavior. Activities included various household games and electronic gaming devices in which the participant and researcher engaged.

A second preference assessment was conducted in a similar manner except the list included various edibles and items all ranging from $.50 to $1.00. A token board was implemented during the time of assessment to facilitate higher percentage scores during
training and the selected items were delivered only after earning 20 out of 20 tokens for correct responses.

Arbitrary Relations

**Pre-test.** Prior to training for each 3-stimulus sets, a pre-instructional baseline probe was conducted on the relations to be directly trained (see Table 1 for order of training and testing stimuli). The pretest consisted of 10 trials of each of the two relations (5 for *SAME* and 5 for *OPPOSITE*). The “to be trained” relation between the A and B stimuli was: A1 *SAME AS* B1 and A1 *OPPOSITE* B2. The additional arbitrary relations between A and C stimuli and C and D stimuli was similarly pre-tested with the same form (A1 *SAME AS* C1, A1 *OPPOSITE* C2, C2 *SAME AS* D2, and C2 *OPPOSITE* D1). Each of the three stimulus sets (A-B; A-C; C-D) were tested and trained in sequential order (see figure 1 for a diagram of stimuli).

All pretests were conducted using discrete trials in a standard “match to sample” procedure in which the participants were provided with the materials, previously mentioned, and were verbally prompted by the trainer to “match to same/opposite or put with same/opposite.” There were no prompts or reinforcement of responses given during the pre-instructional baseline probes. The participants’ responses were recorded and percentage of correct responses was calculated and later compared to responses during and after training of each arbitrary relation. Three pre-tests were conducted within the
arbitrary relation phase of the study. Each pretest was conducted identically with the only variation being the actual relation to be trained (A-B, A-C, or C-D).

**Training.**

Following the pre-instructional probe for A-B relations, training on same and opposite began. At the early stage, it was necessary to establish an additional 3 member relational class to use as distracters in the matching to sample procedure. These were designated as Y-X relations and the stimuli were used as distracter comparisons throughout training on all stimulus sets. The distracter sets were necessary to avoid exclusion type responding where the participants respond based on what has not been experienced within previous training during probe trials (choosing a novel stimulus given a lack of stimulus control for the correct response).

There were 20 trials in each trial block of the instruction phase per relation AB, AC, and CD. The trial blocks contained both same (10 trials of A1B1, A1C1, and C2D2)
and opposite (10 trials of A1B2, A1C2, and C2D1) relations. Relations were taught using prompts and feedback and the relations based on arbitrary properties were most likely foreign to the participants, which required the use of prompts to facilitate correct responses. The level of prompts began with most to least to ensure the correct response on the first prompted trial; and was quickly faded to least to most prompts as independent responses occurred regularly. The highest level of prompt necessary for all participants was a gestural prompt consisting of the researcher pointing to the correct stimuli. Therefore, the prompt allowed for immediate access to correct responses and decreased the risk of reinforcing or chaining incorrect responses. In addition, basing the level of prompt used on the individual child assisted in decreasing the probability of prompt dependency. Reinforcement in the form of tokens and praise for correct responses was used in conjunction with prompts and prompt fading for incorrect responses. Simply stated, prompted responses did not receive a token, but only corrective feedback and lower magnitude of praise, and as the children initiated independent responses, tokens and a higher magnitude praise was delivered.

Post-instructional probe for mastery of directly trained relations. Once the participants completed training and met performance criterion of 80% or higher for each of the two relations, a post-instructional probe was conducted to assess mastery of each of the two relations. The post-instructional probe was conducted identically as the pre-instructional probe with the same number of trials, random presentation of stimuli, and no prompts or reinforcement for responses. The post-instructional probe was a test of the directly trained relations within the training phase and was conducted on relations A-B; A-C; C-D to verify the participants’ ability to correctly respond to stimuli with relations
SAME and OPPOSITE, based on arbitrary properties and without feedback. There was one opportunity for the participants to perform at 80% or higher on the post-instruction probe for each stimulus set to be considered mastered and enter the testing phase for derived relations. If the participants failed to achieve criterion for the post-instruction probe, they returned to the instruction phase of the stimulus set. An illustration of the training and testing order can be viewed in Table 1.
**PRETRAINING**

<table>
<thead>
<tr>
<th>Opposite</th>
<th>Same</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Black</td>
</tr>
<tr>
<td>White</td>
<td>White</td>
</tr>
</tbody>
</table>

**EXPERIMENT**

*Train A-B and Y-X relations*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>S</td>
</tr>
<tr>
<td>A1</td>
<td>A1</td>
</tr>
<tr>
<td>B1</td>
<td>B2</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>S</td>
<td>X1</td>
<td>X2</td>
</tr>
<tr>
<td>Y1</td>
<td>Y1</td>
<td>X1</td>
<td>X2</td>
</tr>
</tbody>
</table>

**Probes**

*Mutual entailment*

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7P</td>
<td>C2</td>
<td>C1</td>
</tr>
<tr>
<td>A1</td>
<td>X2</td>
<td>A1</td>
</tr>
</tbody>
</table>

*Combinatorial entailment*

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9P</td>
<td>C2</td>
<td>C1</td>
</tr>
<tr>
<td>B1</td>
<td>B2</td>
<td>C2</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>B2</td>
<td>C1</td>
<td>C2</td>
</tr>
</tbody>
</table>

**Train A-C relations**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5P</td>
<td>B1</td>
</tr>
<tr>
<td>B2</td>
<td>B2</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>13P</td>
<td>D1</td>
<td>D2</td>
<td>C1</td>
</tr>
<tr>
<td>C2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15P</td>
<td>D1</td>
<td>D1</td>
<td>B1</td>
</tr>
<tr>
<td>B2</td>
<td>B1</td>
<td>B2</td>
<td></td>
</tr>
</tbody>
</table>

**Train C-D relations**

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>17P</td>
<td>A1</td>
<td>A1</td>
<td>D1</td>
</tr>
<tr>
<td>D2</td>
<td>D1</td>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Order of training and testing phases within the curricular assessment. The order of training sequences is separated by eighteen “probe” phases (indicated by red numbers1P-18P) where participants were tested on derived relations to verify ability to meet criterion and progression to the next training sequence was permitted.
Tests for derived relational responding. Once the participants met mastery criterion of 80% or higher on each stimulus set, they were tested for derived relational ability. For instance, after mastering A1 is \textit{SAME AS} B1 and A1 is \textit{OPPOSITE} B2, the child was tested on the following derived responses: B1 is \textit{SAME AS} A1; B2 is \textit{OPPOSITE} A1; B2 is \textit{OPPOSITE} B1; B1 is \textit{OPPOSITE} B2. Each of these relations was presented five times resulting in 20 trials for each probe that was conducted. All trials were conducted in the same manner as trials during the instructional phase with the exception of no prompting and no reinforcement for correct responses. The child was provided praise on a VR3 schedule for attending behavior and participation, generally.

Reinforcement was not provided for correct responses and non-contingent praise was provided every two to four responses. Participants had to score four out five correct on each derived relation in order to meet the mastery criterion of 80% or better (for each derived relation) \textit{and} respond correctly on the first presentation of each relation.

Inclusion of the rigorous mastery criterion was utilized to ensure that an error on the first
trial of each relation did not serve as a prompt for subsequent correct responding. If a derived relation probe did not indicate mastery, it was directly trained using the same instructional procedure as reviewed above. An exception to this was with participants 3 and 4 who underwent a second testing phases on the same derived relations to examine an increase (if any) in responses to untrained relations after completing a second round of training and testing for the trained relations of the failed derived relations. A final test for mastery of the directly trained relation occurred as in the instructional phase (no prompts and no reinforcement) prior to moving on to the pre-instructional baseline for the next 2-member stimulus set (A-C and then C-D).
Results

Participant 1 (Mike-AS 1)

Mike’s ability to derive mutually and combinatorial entailed relations was variable (figure 3). He was able to derive 1 out of 2 mutually and combinatorial entailed relations for section AB, 1 mutually entailed and zero combinatorial entailed relations for section AC and zero mutual and combinatorial entailed relations for section CD. The graph also displays his ability to meet mastery criterion of 100% for all failed relations with 1-2 training sessions.

Number of trials. Each training sequence consisted of 20 trials of the relation to be trained, AB, AC, and CD. Training sequences were considered mastered after two consecutive 100% scores on relations SAME and OPPOSITE. Participant 1 needed 180 trials to complete the three training sequences. Relationships between A and B stimuli (SAME and OPPOSITE) totaled 60 trials. Relationships between A and C stimuli (SAME and OPPOSITE) totaled 60 trials and relationships between C and D stimuli totaled 60 trials.

Number of sessions. Mastery criterion for each session was 90-100% correct responses for each trained relationship. The total number of sessions to reach mastery on trained relationships between stimuli AB, AC and CD was 9 sessions. The total number of sessions to complete section AB was 3 sessions with 100% correct responses each session. The total number of sessions to complete section AC was 3 sessions with an average score of 95% correct responses each session. The total number of sessions to
complete section CD was 3 sessions with 100% each session. See Table 2 for total number of sessions per relation for each participant.

**Derived relations post-instructional probe.** Post-instructional probes were conducted with 20 trials (A→B) and 30 trials (A→C, C→D). Scores were required to reach 100% on all untrained relationships in order to pass each of the post-instruction probe sessions (AB, AC, and CD). If scores did not meet criteria, the failed relations were subsequently trained to 100%. With section AB, Mike scored 100% on mutually entailed relations B2A1 and 20% on B1A1. Combinatorially entailed relations were recorded at 100% for B2B1 and 0% on relation B1B2. Within section AC, mutually entailed responses reached 80% for relation C1A1 and 40% on relation C2A1. Combinatorially entailed relational responses were at 40% on relation C1C2, 0% on relation C2B2, 20% on relation B1C2, and 40% on relation C1B2. Within section CD, mutually entailed responses D1C1 and D2C2 were recorded at 60% and 40% respectively. Combinatorial entailed relations, D1B1, A1D1, D1B2 and A1D2 reached 60%, 0%, 60% and 0% respectively. See Table 3 for percent scores of each participant and Figure 4 for the complete relational networks described above.
Figure 3. Graph of participant 1 (AS 1) performance during baseline, instruction, and post-instruction phases. Performance on test probes of derived relations are also indicated.
Participant 2 (Sara-Typ 1)

Sara’s performance during test probes was variable across sections AB, AC, and CD (figure 5). Her ability to form 1 out of 2 mutually entailed relations and zero combinatorial entailed relations for section AB, 2 out 2 mutually entailed and 2 out of 4 combinatorial entailed relations in section AC, and 2 out of 2 mutually entailed and 1 out of 4 combinatorial entailed relations within section CD. The graph in figure 5 also indicates she was able to meet criterion of 100% for all failed relations in 1-2 training sessions.

Number of trials. Each training sequence consisted of 20 trials of the relation to be trained, AB and CD. Training sequences were considered mastered after two
consecutive 100% scores on relations SAME and OPPOSITE. Participant 2 needed 120
trials to complete the training sequences. Relationships between A and C stimuli (SAME
and OPPOSITE) did not require training trials, as participant 2 scored 100% on baseline
probes and was expedited directly to derived relational probes. Relationships between A
and B stimuli (SAME and OPPOSITE) totaled 60 trials to reach criteria and relationships
between C and D stimuli (SAME and OPPOSITE) totaled 60 trials to reach mastery
criteria.

**Number of sessions.** Mastery criterion for each session was 90-100% correct
responses for each trained relationship. The total number of sessions to reach mastery on
trained relations AB, AC and CD was 9 sessions. The total number of sessions to
complete section AB was 3 sessions with an average of 90% correct responses each
session. The total number of sessions to complete section AC was 3 sessions consisting
of baseline probes with an average score of 100% correct responses each session. The
total number of sessions to complete section CD was 3 sessions with an average score of
95% each session. See Table 2 for total number of sessions per relation for each
participant.

**Derived relations post-instructional probe.** Post-instructional probes were
conducted with 20 trials (A→B) and 30 trials (A→C, C→D). Scores were required to
reach 100% on all untrained relationships in order to pass each of the post-instruction
probe sessions (AB, AC, and CD). If scores did not meet criteria, the failed relations
were subsequently trained to 100%. With section AB, Sara scored 20% on mutually
entailed relations B2A1 and 80% on B1A1. Combinatorially entailed relations were
recorded at 0% for B2B1 and relation B1B2. Within section AC, mutually entailed
responses reached 100% for relations C1A1, C2A1 and combinatorially entailed relations C1C2 and B1C2. The remaining combinatorial relations C2B2 and C1B2 were recorded at 0%. Within section CD, mutually entailed responses D1C2 and D2C2 were recorded at 100% and 80% respectively. Combinatorial entailed relations, D1B1, A1D1, D1B2 and A1D2 reached 40%, 100%, 20% and 20% respectively. See Table 3 for percent scores of each participant and Figure 6 for the complete relational networks described above.
Figure 5. Graph of participant 2 (typ 1) performance during baseline, instruction, and post-instruction phases. Performance on test probes of derived relations are also indicated.
Figure 6. Visual representation of the total number of derived relational responses of participant 2 (Typ 1). The network represents the untrained, tested derived relations, both mutually and combinatorially entailed, for all arbitrary stimuli involved in training. Black lines designate correct derived responding.

**Participant 3 (Ryan-AS 2)**

Ryan displayed variable performance on derived relation test probes in terms of failing all mutual and combinatorial entailed relations for section AB, however he was able to derive 1 out of 2 mutually entailed and 2 out of 4 combinatorial entailed relations in section AC (figure 7). He was able to derive both mutually entailed relations and 1 out 4 combinatorial entailed relations within section CD. Ryan was the first participant to undergo a second training phase and data suggest better performance on the same test probes during the second exposure. Variability can also be seen in his performance during the second administration of test probes where he increased scores to 1 out 2 mutual entailed relations in section AB, decreased scores to only 1 out 4 combinatorial
relations in section AC, and increased performance in section CD to 3 out 4 combinatorial entailed relations. Ryan required additional training trials in section AC at 3 training sessions to meet 100% for the failed derived relations.

**Number of trials.** Each training sequence consisted of 20 trials of the relation to be trained, AB, AC, and CD. Training sequences were considered mastered after two consecutive 100% scores on relations SAME and OPPOSITE. Participant 3 needed 180 trials to complete the three training sequences and was the first to undergo a second training phase within in each relation following the first administration of derived relation probes. The second training phases of relationships between stimuli AB, AC, and CD (SAME and OPPOSITE) totaled 120 additional trials. Relationships between stimuli A and B totaled 60 trials to reach criteria and move forward to derived relations followed by 40 trials of the second training phase of section AB. Relationships between stimuli A and C; and C and D both totaled 60 trials for the first training phase followed by 40 trials to reach mastery criteria.

**Number of sessions.** Mastery criterion for each session was 90-100% correct responses for each trained relationship. The total number of sessions to reach mastery on trained relationships between stimuli AB, AC and CD (SAME and OPPOSITE) was 15 sessions, including the second training phases of each section. The total number of sessions to complete section AB was 4 sessions with an average of 20-100% correct responses each session. The second training phase of relationships between stimuli A and B totaled 2 sessions with an average of 90% correct responses each session. The total number of sessions to complete section AC was 2 sessions in the first phase and 2 sessions in the second training phase, both phases with an average score of 100% correct
responses each session. The total number of sessions to complete the first phase of section CD was 3 sessions with an average score of 90% each session followed by the second phase with 2 sessions and an average score of 100% correct responses each session. See Table 3 for total number of sessions per relation for each participant.

Derived relations post-instructional probes. Post-instructional probes were conducted with 20 trials (A→B) and 30 trials (A→C, C→D). Scores were required to reach 100% on all untrained relationships in order to pass each of the post-instruction probe sessions (AB, AC, and CD). If scores did not meet criteria, the failed relations were subsequently trained to 100%. With sections AB, AC, and CD there were two administrations of derived relation probes yielding 2 sets of percentage scores. Within section AB, first test probes, Ryan scored 40% on mutually entailed relations B2A1 and B1A1. Combinatorial entailed relations were recorded at 60% for B2B1 and 40% on relation B1B2. The second test scores were 80% on mutually entailed relations B1A1 and 0% for B2A1. The second test scores of combinatorial entailed relations were recorded at 0% for B2B1 and 100% on relation B1B2. Within the first test of AC, mutually entailed responses reached 80% for relation C1A1 and 40% on relation C2A1. Combinatorial entailed relational responses were at 20% on relation C1C2, 0% on relation C2B2, 100% on relation B1C2, and 100% on relation C1B2. The second test phase for mutually entailed relations reached 100% for relation C1A1 and 80% for relation C2A1. The second set of scores for combinatorial entailed relations were 80% on B1C2, 0% on C1C2, 20% on C2B2 and 60% on C1B2. Within section CD, the first set of mutually entailed responses D1C1 and D2C2 were recorded at 100%. Combinatorial entailed relations, D1B1, A1D1, D1B2 and A1D2 reached 100%, 60%,
0% and 20% respectively. The second set of mutually entailed probes was 100% for D1C1 and D2C2. The second test phase for combinatorial entailed relations D1B1, A1D1, D1B2 and A1D2 were 100%, 100%, 80%, and 60% respectively. See Table 3 for percent scores of each participant and Figure 8 and 9 for the complete relational networks described above.
Figure 7. Graph of participant 3 (AS 2) performance during baseline, instruction, and post-instruction phases. Performance on test probes of derived relations are also indicated.
Figure 8. Visual representation of the total number of derived relational responses of participant 3 (AS 2) on the first test probe session. The network represents the untrained, tested derived relations, both mutually and combinatorially entailed, for all arbitrary stimuli involved in training. Black lines designate correct derived responding.

Figure 9. Visual representation of the total number of derived relational responses of participant 3 (AS 2) on the second test probe session. The network represents the untrained, tested derived relations, both mutually and combinatorially entailed, for all arbitrary stimuli involved in training. Black lines designate correct derived responding.
Participant 4 (Mark-Typ 2)

Mark displayed slight variability in responses after the train-test sequence of section AB (figure 10). He was able to derive both mutually and combinatorial entailed relations in section AB, however was unable to derive any mutually and combinatorial entailed relations during the first test probe of section AC. His performance increased following the second test probe session and was able to derive one mutual and one combinatorial entailed relation for section AC. The graph illustrates he able to derive 1 out 2 mutually entailed and 2 out of 4 combinatorial entailed relations during the first test probe session of section CD and responses increased to 2 out 2 mutually entailed and 3 out of 4 combinatorial entailed relations during the second test probes. Data indicates Mark required only one training session to meet criterion of failed derived relations across the three train-test sequences.

**Number of trials.** Each training sequence consisted of 20 trials of the relations to be trained, AB, AC, and CD. Training sequences were considered mastered after two consecutive 100% scores on relations SAME and OPPOSITE. Participant 4 needed 160 trials to complete the three training sequences and was the other participant to undergo a second training phase within in each relation following the first administration of derived relation probes. The second training phases of sections AB, AC, and CD totaled 80 additional trials of relationships between stimuli AB, AC, and CD (SAME and OPPOSITE). Relationships between stimuli A and B totaled 20 trials to reach criteria and move forward to derived relations. The modified procedure went into place after Mark’s first training phase of AB, which resulted in only 1 training exposure of relation AB. Relationships between stimuli A and C (SAME and OPPOSITE) were trained with
20 trials for the first training phase followed by 40 trials to reach mastery criteria. Relationships between stimuli C and D (SAME and OPPOSITE) had a total of 40 trials for both training and re-training phases.

**Number of sessions.** Mastery criterion for each session was 90-100% correct responses for each trained relationship. The total number of sessions to reach mastery on trained relationships between stimuli AB, AC and CD (SAME and OPPOSITE) was 8 sessions, including the second training phases of each relation. The total number of sessions to complete section AB was 1 session with an average 100% correct responses each session. The total number of sessions to complete section AC was 1 session in the first phase and 2 sessions in the second training phase, both phases had an average score of 100% correct responses each session. The total number of sessions to complete the first phase of section CD was 2 sessions with an average score of 100% each session followed by the second phase with 2 sessions and an average score of 100% correct responses each session. See Table 2 for total number of sessions per relation for each participant.

**Derived relations post-instructional probe.** Post-instructional probes were conducted with 20 trials (A→B) and 30 trials (A→C, C→D). Scores were required to reach 100% on all untrained relationships in order to pass each of the post-instruction probe sessions (AB, AC, and CD). If scores did not meet criteria, the failed relations were subsequently trained to 100%. With sections AC and CD there were two administrations of derived relation probes yielding 2 sets of percentage scores. Within section AB test probes, Mark scored 100% on mutually and combinatorial entailed relations B2A1, B1A1, B2B1, and B1B2. Within the first test of AC, mutually entailed
responses were at 50% for relation C1A1 and 0% on relation C2A1. Combinatorial entailed relational responses were at 0% on relation C1C2, 10% on relation C2B2, 0% on relation B1C2, and 0% on relation C1B2. The second test phase for mutually entailed relations reached 100% for relation C1A1 and 20% for relation C2A1. The second set of scores for combinatorial entailed relations were 60% on B1C2, 20% on C1C2, 100% on C2B2 and 0% on C1B2. Within relation CD, the first set of mutually entailed responses D1C1 was recorded at 0% and D2C2 were recorded at 80%. Combinatorial entailed relations, D1B1, A1D1, D1B2 and A1D2 reached 100%, 0%, 100% and 20% respectively. The second set of mutually entailed probes was 100% for D1C1 and D2C2. The second test phase for combinatorial entailed relations D1B1, A1D1, D1B2 and A1D2 were 100%, 100%, 60%, and 80% respectively. See Table 3 for percent scores of each participant and Figure 11 and 12 for the complete relational networks described above.
Figure 10. Graph of participant 4 (typ 2) performance during baseline, instruction and post-instruction phases. Performance on test probes of derived relations are also indicated.
Figure 11. Visual representation of the total number of derived relational responses of participant 4 (Typ 2) on the first test probe session. The network represents the untrained, tested derived relations, both mutually and combinatorially entailed, for all arbitrary stimuli involved in training. Black lines designate correct derived responding.

Figure 12. Visual representation of the total number of derived relational responses of participant 4 (Typ 2) on the second test probe session. The network represents the untrained, tested derived relations, both mutually and combinatorially entailed, for all arbitrary stimuli involved in training. Black lines designate correct derived responding.
Table 2. Total number of training and testing sessions for each relationship between stimuli AB, AC, and CD for participants 1-4

<table>
<thead>
<tr>
<th>Participants</th>
<th>AB Train</th>
<th>BA Test</th>
<th>AC Train</th>
<th>CA Test</th>
<th>CD Train</th>
<th>DC Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (AS 1)</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2 (Typ 1)</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 (AS 2)</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>4 (Typ 2)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 3. Percent scores on derived relation probes for each participant.

**BA TEST**

<table>
<thead>
<tr>
<th>Participants</th>
<th>ME</th>
<th>ME</th>
<th>CE</th>
<th>CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (Typ 1)</td>
<td>20</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3 (AS 2)</td>
<td>80</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 (Typ 2)</td>
<td>40/80</td>
<td>40/0</td>
<td>60/0</td>
<td>40/100</td>
</tr>
</tbody>
</table>

**CA TEST**

<table>
<thead>
<tr>
<th>Participants</th>
<th>ME</th>
<th>ME</th>
<th>CE</th>
<th>CE</th>
<th>CE</th>
<th>CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (Typ 1)</td>
<td>80</td>
<td>40</td>
<td>40</td>
<td>0</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>3 (AS 2)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 (Typ 2)</td>
<td>100/100</td>
<td>40/80</td>
<td>100/80</td>
<td>20/0</td>
<td>0/20</td>
<td>100/60</td>
</tr>
</tbody>
</table>

**DC TEST**

<table>
<thead>
<tr>
<th>Participants</th>
<th>ME</th>
<th>ME</th>
<th>CE</th>
<th>CE</th>
<th>CE</th>
<th>CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (AS 1)</td>
<td>D1C2</td>
<td>D2C2</td>
<td>D1B1</td>
<td>A1D1</td>
<td>D1B2</td>
<td>A1D2</td>
</tr>
<tr>
<td>2 (Typ 1)</td>
<td>60</td>
<td>40</td>
<td>60</td>
<td>0</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>3 (AS 2)</td>
<td>100/100</td>
<td>100/100</td>
<td>100/100</td>
<td>60/100</td>
<td>0/80</td>
<td>20/60</td>
</tr>
<tr>
<td>4 (Typ 2)</td>
<td>0/100</td>
<td>80/100</td>
<td>100/100</td>
<td>0/100</td>
<td>100/60</td>
<td>20/80</td>
</tr>
</tbody>
</table>

**Typical and AS Performances**

The typically developing participants averaged higher percentage scores on most of the post-instructional probes with the exception of a few low scores in each section.

Sara (typ 1) scored an average of 25%, 67%, and 60% on post-instructional probes for
relationships between stimuli AB, AC, and CD (SAME and OPPOSITE) respectively and Mark (typ 2) scored an average of 100%, 10%, and 50% on the first set post instructional probes for relationships between stimuli AB, AC, and CD (SAME and OPPOSITE).

Mike (AS 1) scored an average of 55%, 37% and 37% on post-instructional probes for relationships between stimuli AB, AC, and CD (SAME and OPPOSITE). Ryan (AS 2) scored an average of 45%, 57%, and 63% on the first set of post-instructional probes for relationships between stimuli AB, AC, and CD (SAME and OPPOSITE). Individual percent scores on each relation are listed in Table 4.

A secondary analysis was conducted by taking an aggregate of performances on each derived relation, broken down by nodal distance. The aggregate was composited by adding percent scores for each relation tested and divided by the total number of relations for the given section for each participant. The analysis was necessary to assist in understanding how and under what relations the results differed. See Table 5 below for exact scores per participant.

Overall, performances on derived relation test probes do not indicate the typical dyad scored higher across all relations. It appears the scores for the typical dyad are highest under the mutual entailed relations but that is the only section where a large difference in scores can be drawn. All other derived relations were split between high scores for participants with AS and high scores for typically developing participants.
Table 4. Performance on derived relation probes grouped by participant and nodal distance

<table>
<thead>
<tr>
<th>ME 0 nodal distance</th>
<th>AB</th>
<th>AC</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B1A1 B2A1</td>
<td>C1A1 C2A1</td>
<td>D1C2 D2C2</td>
</tr>
<tr>
<td>AS1</td>
<td>20 100</td>
<td>80 40</td>
<td>60 40</td>
</tr>
<tr>
<td>AS2</td>
<td>40/80 40/0</td>
<td>80/100 40/80</td>
<td>100/100 100/100</td>
</tr>
<tr>
<td>TYP1</td>
<td>80 20</td>
<td>100 100</td>
<td>100 80</td>
</tr>
<tr>
<td>TYP2</td>
<td>100 100</td>
<td>50/100 0/20</td>
<td>0/100 80/100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CE 1 nodal distance</th>
<th>AB</th>
<th>AC</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS1</td>
<td>0 100</td>
<td>40 0 20 40</td>
<td>60 60</td>
</tr>
<tr>
<td>AS2</td>
<td>60 40</td>
<td>100 20 0 100</td>
<td>40 20</td>
</tr>
<tr>
<td>TYP1</td>
<td>0 0</td>
<td>100 20 0 100</td>
<td>100 0</td>
</tr>
<tr>
<td>TYP2</td>
<td>100 100</td>
<td>10 0 0 0</td>
<td>100 100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CE 2 nodal distances</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1D1 A1D2</td>
</tr>
<tr>
<td>AS1</td>
<td>0 0</td>
</tr>
<tr>
<td>AS2</td>
<td>60 20</td>
</tr>
<tr>
<td>TYP1</td>
<td>60 20</td>
</tr>
<tr>
<td>TYP2</td>
<td>0 20</td>
</tr>
</tbody>
</table>

Table 5. Aggregate of scores of each derived relation for each participant by nodal distance

<table>
<thead>
<tr>
<th>Participants</th>
<th>ME 0</th>
<th>CE 1</th>
<th>CE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mike (AS 1)</td>
<td>57</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Sara (Typ 1)</td>
<td>80</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Ryan (AS 2)</td>
<td>67</td>
<td>48</td>
<td>40</td>
</tr>
<tr>
<td>Mark (Typ 2)</td>
<td>55</td>
<td>51</td>
<td>10</td>
</tr>
</tbody>
</table>
Discussion

The ability to derive relations has a profound impact on language ability. The behavior analytic view of derived stimulus relations is a cornerstone of advanced language and communication.

This study aimed, primarily, to test children’s ability to derive relations and examine the nodal distances at which relationships were formed. An additional analysis was attempted comparing the ability to derive stimulus relations between the children who are considered typically developing and the children diagnosed with AS. The results of the study indicated both typically developing children and children diagnosed with AS were able to relate stimuli based on arbitrary properties at 0, 1, & 2 nodal distances in the trained relational network. The typical children were able to form the mutual and combinatorial entailed relationships during the test probes at a higher percentage (averaging 50%) than the children diagnosed with AS (averaging 40%). While the mean difference (10%) is not very impressive, the significance of this difference is found in the relational diagrams (figures 4, 6, 8, 9, 11, 12).

It was hypothesized that all children would derive mutually entailed relations regardless of which relation was tested. This was not the case, however, with poor performances across three of the four children. Each of these children responded correctly on three out of six mutually entailed relations. The fourth child responded correctly on five out of six mutually entailed relations. The additional training trials experienced by AS 2 and Typ 2 appear to have strengthened responding on mutually
entailed relations as their performances improved to five out of six correct. This begs the question of how performances may have been impacted had all children received a greater number of training trials? It is impossible to say in this instance for sure, as this additional procedure seen here represents more than just additional trials. Rather, it is a sequence of training--testing--training where exposure to the test probes may have provided an advantage in returning to the second round of training trials.

While not anticipated, it would have been interesting if relational ability was found to weaken as nodal distance increased more so for children diagnosed with AS. If it was found to be so, there would be evidence that a deficit in relational ability across one and two nodal distances may hinder the social behaviors of initiations and reciprocity as fewer stimuli could participate in any response. However, this was not seen to be the case. There is little discernable difference in performance between children when derived relational ability increased to one and two nodal distances. In fact, there is also no pattern observed between children at these distances regardless if a frame of coordination or opposition. Overall, all children performed poorly when probing for derived relational responding at greater distances.

The largest difference was found in training performance of each dyad. Participants 1 and 3 (AS 1 and 2) required a greater number of training sessions to meet criteria for the failed derived relations of AC and CD at five to six training sessions as compared to the typically developing participants who required three to five training sessions to reach mastery. The increased training sessions also resulted in the greatest improvement of acquisition scores with the AS participants, likely due to increased
exposures to training stimuli with prompts and reinforcement. Data do not indicate large differences in performances on actual test probes of the untrained relations.

Participants Sara and Mark (typically developing) displayed variability between responses within each training and testing phase. Mark scored 100% during training and testing of relation AB; however whereas Sara was able to perform at 100% during training, her derived performance was quite low. Sara did not require training on relation A1C2 and A1C1 due to three 100% scores during baseline, therefore, she was moved to the testing phase of AC and scored considerably higher than Mark, who received additional training on the relation AC to assess if repeated exposures to the relation would result in a higher percentage during the re-test of the derived relations.

The correct responses on baseline AC of Sara was likely due to chance, given the conditions of no prompts or reinforcement, however it was decided to adhere to study’s protocol as well as typical training strategies in verbal behavior which state 100% baseline performance requires no training and indicates the behavior is ready to test. Although Sara did not receive consequences for correct responding with AC relations during baseline, her performance on mutually entailed derived relations was 3 out of 3 correct. Thus, it is safe to assume that a rule was established during the initial exposures in baseline.

Participants Mike and Ryan (AS) showed less variability, than the typical dyad, between responses within each training phase. Both individuals were unable to derive the relations for all relationships between stimuli AB, AC, and CD (SAME and OPPOSITE) and both individuals showed difficulty with the testing of derived relations C2B2, B1C2,
C1C2, and C1B2 under section AC. The number of sessions and trials to reach criteria was similar for both individuals during section AC.

Other similarities of responding behavior between the Mike and Ryan were their selecting responses, in that, both individuals appeared uncertain during various matching exercises by placing the sample stimulus card down on the comparison stimuli and sliding the card back and forth until their hand rested on the answer. The behavior did not occur every session or trial, however these two participants were the only ones observed to engage in that response topography. Additionally, Ryan engaged in vocal-verbal behavior of arbitrarily set rules, while simultaneously sliding the sample stimulus card over comparison stimuli. It appears that he derived ineffective rules, which proved to have a negative effect on correct responding.

For example, Ryan occasionally looked at the two comparison stimuli and would verbalize aloud “this is opposite this, and same as that” prior to making his response, when in actuality one of the comparison stimuli was a distracter, therefore having no relation to the sample stimulus in his hand. Ryan was the only individual to engage in this type of overt rule-governed behavior during the course of the study.

**Limitations**

Throughout the course of the study, limitations presented themselves in the following areas. In the initial stages of the study, participants were only seen once a week, which was agreed upon by parents at the onset of the study. This may have resulted in requiring more training sessions overall, and may have had an adverse effect on the children's ability to derive as the network expanded. Following the start of the third participant, sessions were scheduled two to three times per week to assist in
facilitation of acquisition of the relations. All participants missed at least one but no more than four sessions throughout the course of the study. Each of these was due to parental cancelations. Additional sessions were requested for all participants, but only the parents of participants 2 and 4 gave consent.

At the onset of training the contingency of working on the “matching game” and then having the opportunity to select a preferred activity to play with the trainer was in place. The contingency was successful in that all participants completed the training sequences and appeared to enjoy the interaction with the trainer during a game the participants selected. However performance was not at 100%, so to help facilitate scores each session a preference assessment was conducted with novel items and edibles. All four participants were able to request preferred items, which were then brought to the sessions for potential earning. The novel items were presented alongside a token board and tokens were delivered immediately following each response of the 20 trial training task. The participants were presented with the contingency of earning all 20 tokens resulted in obtaining the preferred item selected for that session. The participants vocally expressed interest and motivation to obtain the preferred items. The items consisted of various edible candy items and various toys all costing one dollar.

Data analysis revealed low scores for participant 4 (typ 2) during the test for mutually and combinatorial entailed relations under section AC. The low level of performance of AC, given the high performance on AB, was assumed to be a lack of understanding the testing and training condition of no prompts or reinforcement. This was anticipated and as such we ran the formal pre-test as a probe condition to sensitize the children to this situation. Although, the contingency in place for the duration of the
study was powerful enough to evoke correct responses however, during test probes under conditions of no prompts or reinforcement, behavior was less likely to produce correct responses. It is likely; adding a performance-based schedule of reinforcement following the tests for derived relations would assist in higher scores of all participants.

Baseline sessions were run for all participants, however participants Mike, Sara, and Ryan underwent multiple baseline sessions. Mark was implemented under the original protocol with the rational for one baseline point being in educational studies, one data point is sufficient to show the child does not have the skill in his or her repertoire. Further, it was established that the participants did not have previous exposure to the arbitrary relations by the careful selection of such arbitrary symbols. Multiple baseline exposures could have influenced responses during subsequent training and testing phases due to the repeated exposures of each trial. It was later decided the multiple baseline was not necessary as a means to properly assess if the child had the skill prior to training and the acquisition of that skill during training.

Other limitations included environmental distractions in the home such as phones ringing, televisions on nearby, and siblings and/or parents in close proximity during time of training or testing. We attempted to remedy all environmental distractions by requesting the participant and trainer work in a quieter location, which often resulted in parent recognition and the reduction of distractions.

Future Directions

The purpose of the study was to assess if typically developing children were able to relate stimuli in larger relational networks as compared to the ability of children diagnosed with AS. The results indicated the typically developing children and children
with AS performed comparable. All participants were able to form mutually and combinatorial entailed relations, however there was no consistency in responses on derived relations. In addition, there was no clear differentiation between participants ability to form derived relations. The rational being, typically developing participants were able to derive relations that participants with AS did not, and participants with AS were able to derive relations that the typically developing participants did not.

This study largely serves as a preliminary step in further investigation of the inability to form relationships in larger networks of stimuli between children with developmental and social deficits and those who are typically developing. Future investigation on the topic of children with developmental disabilities and deriving responses should consider a larger number of participants. Additional participants may assist in data analysis and may be beneficial in helping to better understand the great differences that were observed in performances. Additional efforts may consist of outlining a preset schedule of four to five sessions per week that requires parental consent and commitment prior to the onset of the study. Parental commitment to the required number of sessions would facilitate acquiring relationships of each section and expedite the entire training and testing process.

It may be beneficial to alter the schedules of reinforcement and include a performance-based reinforcement schedule to assist in poor performance during test probes under conditions of no prompts or reinforcement. In addition, future research in the area of training and testing derived relations should address the number of trials for each relation. Increasing the number of presentations of each relation within each trial block offers a larger margin for error with the potential to meet criteria; however, close
observation must be given to the population of interest and assess the ability of participants to sit and respond to a larger number of stimulus sets in one sitting. The amount of time per session and attending limit of each participant are issues of concern when working with sensitive populations. It is important to minimize the participant’s response effort and time spent attending to tasks when conducting research that depends on the children’s’ ability to accurately respond to given stimuli.

The results of the study suggest typically developing children were able to form mutual and combinatorial relationships between arbitrary stimuli in a shorter number of training sessions and trials as compared to the children diagnosed with AS. It is the study’s aim to offer a preliminary data analysis of derived relational responding in order to use the information in adapting future methodologies and teaching strategies when working with individuals with developmental and social deficits, as well as general language deficits. The ability to form relationships at greater distances and within larger networks is what typically developing individuals are able to complete each and every day given their ability to engage in functional, complex communication in the absence of direct training to do so. Understanding how stimuli are related provides individuals the capacity to expand on their environments and in turn verbalize the relationships into communication with others. Teaching individuals the ability to form relationships between abstract concepts offers the ability to increase functional, meaningful communication with others, by simply providing individuals with more concepts and language to communicate with, and as social deficits are the primary deficit of those diagnosed with AS, the adaptation and modification of methodologies in the direction of
deriving responses may assist in increasing the success of teaching abstract concepts like social skills in the field of behavior analysis.
References


