A STUDY OF TEACHING STRATEGIES THAT FACILITATE STIMULUS GENERALISATION IN CHILDREN WITH AUTISM

A thesis submitted in fulfilment of the requirements for the degree

of Doctor of Philosophy in Education

at the University of Canterbury

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July 2011

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ACKNOWLEDGEMENTS

I owe my deepest gratitude to my primary supervisor Dr John Church. Many times John exceeded his role as primary supervisor. Without his extensive knowledge, his willingness to provide assistance, and his unwavering support, this thesis would not have been possible. I would also like to thank my associate supervisor Dr Dean Sutherland for his advice, guidance and encouragement.

I am indebted to each of the 20 families who allowed their children to take part in my experiments and equally indebted to each of the 20 children who took part and who continued to work on their number learning tasks often for many sessions. Without your willing participation the research described in this thesis could not have been undertaken.

I would like to thank my family for instilling in me the determination and commitment to commence and complete this thesis. I would particularly like to thank my parents for their love and support. I dedicate this thesis to my mother Glenys. Sadly, she has passed away. However, she continues to be an inspiration to me.

This thesis would not have been possible without the support and kindness of my husband Greg. You encouraged me to pursue this degree and have supported me in its completion and for that I am extremely grateful. I also need to acknowledge the contribution made by the newest addition to our family Dougal the dachshund. You provided a pleasant distraction however, it needs to be noted that you may be responsible for any typing errors observed in this thesis.

Finally, I would like to thank the School of Educational Studies and Human Development at the University of Canterbury for providing me with the resources that I needed to enable me to complete this degree.

ABSTRACT

Language development involves the learning of multiple sets of equivalence relations. Research has shown that if certain conditional relations are directly taught for one member of a class of stimuli, then additional conditional relations often emerge for other members of that class, without direct training. There are currently very few studies which have demonstrated this research finding in individuals with autism spectrum disorder (ASD). The research design used for the present experiment was a single-subject AB cross-over design replicated across five plus five children with ASD and five plus five typically developing children. The children with ASD and the typically developing children were matched on their level of vocabulary development. Participants were randomly assigned to either a teaching order Treatment A+B or a teaching order Treatment B+A. The first experimental treatment (Treatment A+B) involved teaching responses to S1 and S2 in the order Condition A followed by Condition B. The second experimental treatment (Treatment B+A) involved teaching responses to S1 and S2 in the order Condition B followed by Condition A. Condition A involved the teaching of AB and AC *(hear-select)* relations, and Condition B involved the teaching of BA and CA *(see-say)* relations. The participants in this study were taught stimulus-response relations that involved six names and numerical representations of quantities in the range 1 to 18. Tests for the emergence of symmetry and transitivity were then conducted. The relationships between the emergence of the untaught equivalence relations and teaching condition, the entering characteristics of the children, and trials to criterion were examined. The results of this study showed that five out of ten participants with ASD demonstrated the emergence of all of the untaught equivalence relations regardless of the treatment condition. The remaining five participants with ASD showed substantial variability. Of the children in the Typically Developing Group nine of the ten demonstrated emergence of all of the untaught equivalence relations. The variables that were most strongly

correlated with the emergence of untaught equivalence relations were speed of acquisition of taught relations, functional academics scores, and the chronological age of the participants. The effect of communication ability, pre-academic numeracy skill level, and the experimental treatment (the teaching order conditions) were not strongly related to the emergence of untaught equivalence relations. These findings suggest that outcomes on tests for emergence may have been a function of children's rate of development and prior learning history. The findings of the current study are best explained by Relational Frame Theory. The implications of these findings for teaching children with ASD and other developmental disabilities, and also teaching in general are discussed.

CHAPTER 1

INTRODUCTION

Children with autism spectrum disorder (ASD) often have difficulty acquiring and generalizing new skills. Historically, much of the research literature has focused on developing strategies to facilitate learning and behaviour change. Increasingly, however, recent research has focused on ways to enhance the likelihood of generalization and maintenance of these skills. If we are to more adequately understand the nature of this disorder and how to teach this population then significantly more experimental research will need to be undertaken.

The main aim of the present research is to enhance our understanding of how to teach new skills to children with ASD and the conditions under which these children are most likely to generalize the skills which are being taught. The particular area of interest is in investigating whether children with ASD are capable of acquiring untaught equivalence relations following the teaching of specific stimulus-response relations.

Characteristic Features of Children with Autism Spectrum Disorder

Autism is a genetic, neurodevelopmental disorder that has a profound effect on several areas of an individual's development. The disorder was first described by Leo Kanner in 1943. Children with ASD are generally characterised by impairment across three areas. These are social interaction, communication, and behaviour. Included amongst each of these symptoms is impairment in the use of non-verbal behaviours and motor development, delayed cognitive development, a lack of desire to interact or share interests with others, difficulty forming or maintaining peer relationships, delayed language development including minimal receptive and expressive language, difficulty initiating or sustaining conversation with others, ritualistic and stereotyped patterns of behaviour, unusual and repetitive motor movements, and a pre-occupation with specific features of items or elements of activities (American Psychiatric Association, 2000). Impairment is observed in at least one of these areas prior to the age of three. As well as autistic disorder, there are four additional diagnoses within the category of Pervasive Developmental Disorders. These are Rett syndrome, childhood disintegrative disorder, Aspergers disorder and pervasive developmental disorder – not otherwise specified or PDD-NOS (American Psychiatric Association, 2000)

Making a diagnosis of autism spectrum disorder is a highly complex process as there is significant variation in the degree to which people are affected by the characteristic features of ASD. There are a range of behaviours that can fall within the realm of symptoms for each of the specified domains and there is also substantial variation in the way in which these symptoms manifest themselves. As a consequence there is considerable diversity within the group of children who are diagnosed with autistic spectrum disorder both with respect to behavioural characteristics and rates of learning.

Prevalence of Autism Spectrum Disorder

Recent estimates internationally suggest that the prevalence of children with autism spectrum disorders is 1 in 100. (Autism New Zealand Inc., 2008). While the rates in New Zealand are not known for certain it is estimated that 40,000 people in this country could qualify for diagnosis (New Zealand Ministry of Health, 2008). It is apparent that rates of ASD are higher among males than females with an average ratio of 4:1 male to female (Fombonne, 2005).

It is a generally held belief that the prevalence of ASD has increased significantly over the past 30 years. A report by Fombonne (2003) suggested that prevalence rates of ASD have increased from 4 to 5 per 10,000 to over 10 per 10,000. In another more recent study it is suggested that prevalence rates have increased from an estimated 5 per 10,000 in the 1960's to as high as 72 per 10,000 in the 1990's. (Kadesjo, Gillberg, & Hagberg, 1999; Sponheim & Skjeldal, 1998). While rates may have increased significantly, there are several possible explanations for this increase. These include the broadening of the definition of ASD, a change in diagnostic criteria to include pervasive developmental disorders and Asperger's syndrome, an increase in clinicians and diagnosticians who are aware of and able to identify children with the disorder, an increase in the availability of services for children with ASD, and diagnostic substitution. That is, the diagnosis of ASD for children previously classified as having an intellectual disability.

Etiology of Autism Spectrum Disorder

The Influence of Genetics

While it appears that the prevalence of ASD is increasing, researchers have yet to determine the specific etiology or causal mechanisms of this disorder. There is increasing evidence within the research literature to suggest that there is a genetic component to ASD. While further research is needed, twin studies have demonstrated much higher concordance rates among monozygotic (MZ) twins than dizygotic (DZ) twins (Bailey, Le Couteur, Gottesman, Bolton, 1995; Steffenburg et al. 1989). Bailey et al. (1995) found a 60% concordance rate across MZ twins compared to 0% concordance across DZ twins. This suggests a strong genetic influence. Support for a genetic link has also been provided through sibling studies. One research study by Bailey, Phillips, and Rutter (1996) found recurrence rates amongst siblings of 3 to 7%. In addition to this, there is evidence, based on research including high risk siblings, that 20-25% of the younger siblings of children with a diagnosis of ASD exhibited developmental delays within the first or second year of life.

(Zwaigenbaum et al., 2005). When all of the evidence is considered, there is strong indication that a genetic susceptibility to ASD may exist.

While there is the suggestion of a genetic link, researchers have yet to isolate the specific genes that are affected in individuals with ASD. There are several genes that have been implicated in the research. However, the most conclusive and rigorous of this research suggests that it may be a gene or combination of genes on Chromosome 7q which leaves individuals at risk of ASD (Bacchelli & Maestrini, 2006; Klauck, 2006). There is also a suggestion that the genes for gamma-aminobutyric acid (GABA) may be effected (Bauman & Kemper, 2005). Further replication of this and other studies suggesting genetic influences on ASD are necessary at this point if we are to draw more robust conclusions.

The Influence of the Environment

A number of research studies have attempted to determine the role of environmental factors in the manifestation of ASD. A review of the literature by Newschaffer et al. (2007) outlines several possible environmental causes. These include immunological issues and abnormalities such as "atypical levels of antibodies to neural antigens, immunoglobulins, inflammatory cytokines, and other markers that may signal disregulation and/or dismaturation of both adaptive and innate immune systems" (Newschaffer et al., 2007, p. 242). Additional environmental factors that may be linked to ASD include prenatal exposure to viruses such as rubella or cytomegalovirus, abnormal levels of neuropeptides, neurotrophins and neurotransmitters such as brain-derived neutrophic factor (BDNF) and GABA (gamma-aminobutyric acid) (Bauman & Kemper, 2005), higher concentrations of serotonin in peripheral blood, as well as possible deficits in the processing of oxytocin.

Additional factors that have been suggested in this review include maternal hormone abnormalities, specific medication effects, and heavy metal exposure. This research remains inconclusive in determining specific environmental influences and further investigation and replication of existing research is essential.

Abnormal Brain Development

Another area of research investigating causal mechanisms in ASD involves the use of functional magnetic resonance imaging (fMRI). Functional magnetic resonance imaging research has begun to examine specific areas of the brain for unusual patterns of development in those with ASD. A review of this literature by Amaral, Mills-Schumann, and Wu-Nordahl (2008), which includes post-mortem studies, suggests that pathology in areas of the cerebellum, amygdala and frontal lobes is often present in children with ASD.

Recently, several studies have focused on abnormalities in brain size and head circumference rather than abnormalities in specific areas of the brain. As a result, there are several research studies that indicate that during early childhood years the brain circumference, weight and volume may show an abnormal increase in children with ASD when compared with typically developing children (Bauman & Kemper, 2005). This includes increased whole brain volume (Courchesne et al., 2001) and increased cerebellar volume (Amaral et al., 2008). Amaral et al. (2008) have also shown that in 19 of the 24 post-mortem studies reviewed in which the cerebellum was studied, there was a decreased number and density of Purkinje cells in those with ASD.

In addition to overall brain size, there appears to be an abnormal growth trajectory in the amygdala for those with ASD. The review by Amaral et al. (2008) cites several studies which demonstrate that children with ASD have abnormally large growth in the amygdala in early childhood. One study in particular, by Sparks et al (2002), showed that in children aged between 36-56 months of age, there was a 13-16% abnormal enlargement of the amygdala. Anderson (2005) further suggests “a particularly strong rationale for involvement of the amygdala and associated areas of the limbic cortex" (p. 305). Unusual development in the region of the amygdala may have important implications for children with ASD as this is an area of the brain that is associated with socialisation and communication.

It is important to note that no consistently and clearly identified pathology has been found to be present in the brains of children with ASD. Overall, the brains of those with ASD are not remarkably different from those of typically developing individuals (Bauman & Kemper, 2005) and, given the large degree of variation that exists across the autism spectrum, it is quite possible that different kinds of neuropathology could be giving rise to the developmental delays exhibited by children with ASD. According to Bauman and Kemper (2005), the general view is that the manifestation of autism may be the result of the "expression of multiple abnormal genes acting in concert, perhaps in relation to some additional, as yet unspecified environmental factor" (p. 387).

Skill Acquisition in Children with Autism Spectrum Disorder

Relatively little is currently known about the most effective way to teach new concepts to children with ASD. The general view is that interventions should begin at an early age, be sufficiently intensive, and address the core symptoms of ASD (National Research Council, 2001).

There have been several reviews of the research on general teaching strategies for children with ASD. Vismara and Rogers (2010) examined the effectiveness of two different types of ABA intervention. Those that provide a comprehensive behavioural approach which aims to address all developmental domains (for example, Discrete Trial Training, Pivotal Response Training, and Developmental Intervention), and those which target specific skill sets (for example, Picture Exchange Communication System and Reciprocal Imitation Training). Within this review Vismara and Rogers (2010) identified several research studies which have demonstrated the effectiveness of behavioural interventions for increasing language and communication (Cohen, Amerine-Dickens, & Smith, 2006; Sallows & Graupner, 2005), social skills (McConnell, 2002), and academic skills (Lovaas, 1987), and for modifying problem behaviour (Horner, Carr, Strain, Todd, & Reid, 2002). Vismara and Rogers (2010) concluded that approaches to intervention that are based on behavioural principles, whether designed as comprehensive programmes or focused on more specific skills, are both effective in improving communication, social skills and managing behavioural concerns in children with ASD. They suggest that outcomes are most favourable when intervention begins prior to age five, and is provided for a minimum of 20 hours per week over a period of at least two years. Finally they state that while there are several short-term benefits for both types of intervention approaches, more long-term outcome studies are needed.

A second review was conducted by Virues-Ortega (2010). This review involved a meta-analysis of the literature that included sensitivity analysis, dose-response meta-analysis, quality assessments, and meta-regression. A total of 22 studies were included in the analysis and based on the findings, Virues-Ortega concluded that long-term and comprehensive intervention based on the principles of ABA have medium to large positive effects on areas of language, social functioning, daily living skills, and intellectual functioning. Outcomes related to language had the largest positive effect sizes when compared to other domains.

A third review was conducted by Mudford et al. (2009). This review evaluated the effectiveness of intervention based on Applied Behaviour Analysis for individuals with ASD. A total of 463 studies were included in the review. The articles included in the review were analysed according to the components of the intervention, the behaviours that were assessed, and the impact of the interventions. Outcomes for each area were classified as being beneficial, unknown, ineffective or harmful. Based on the review, Mudford et al. (2009)

concluded that there is strong evidence for the beneficial effects of ABA interventions for children with ASD up to 15 years of age. These benefits are apparent in communication, self-regulation, interpersonal skills, personal responsibility, and cognitive functioning domains. This review also assessed generalization and maintenance outcomes for 169 of the studies. Of the 169 studies, 45 assessed generalization of main effects. Twenty eight of these studies demonstrated strong evidence of generalized main effects across behaviour, academic skills, communication skills, interpersonal skills, and personal responsibility. In three studies, there was no evidence of a generalized main effect and in 14 of the studies the evidence for a generalized main effect was limited. It was also concluded that there was no single intervention strategy that enhanced the likelihood of generalization across a broad range of target behaviours.

Autism Interventions

The Lovaas Study

For children with autism, one of the most commonly implemented interventions is the teaching strategy which has come to be known as discrete trial training. This kind of teaching was developed by applied behaviour analysts and is presently the only kind of teaching which enables at least some autistic children to function effectively in a mainstream classroom (Rogers, 1998). The use of discrete trial training (also known as ABA training) with this population of children was originally studied by Ivar Lovaas as part of the UCLA Young Autism Project (Lovaas, 1987; McEachin, Smith, & Lovaas, 1993). This study is the most frequently cited study demonstrating the effectiveness of Discrete Trial Teaching for children with ASD. In this study participants were divided into a treatment group which received more than 40 hours of one-to-one therapy per week and a control group that received 10 hours of one-to-one therapy per week or less. Both groups received treatment for a period of two years or more. Lovaas (1987) reported that 47% of the children in the treatment group but only 2% of the control group achieved intellectual and educational functioning within the normal range and also demonstrated IQ scores within the normal range. While this evaluation has been criticised for the choice of outcome measures used, for the methods for assigning participants to each group, and for the subject selection methods (e.g. Schopler, Short, & Mesibov, 1989) it is one of the pioneering studies in the field of early intensive intervention for children with ASD and has stimulated significant further research. It is now widely recognised that ABA type interventions are the most effective interventions for individuals with ASD (Rogers, 1998; National Research Council, 2001; Vismara & Rogers, 2010).

Discrete Trial Teaching

Discrete Trial Teaching is a teaching method that has significant research support (Lovaas, 1987; Rogers, 1998; Vismara & Rogers, 2010). One of the essential elements of a discrete trial teaching method is that teaching aims are broken down into component skills and then systematically and individually taught. Each practice trial involves the teacher presenting a stimulus. The child responds to this stimulus and is then provided with feedback. When the child responds correctly, the feedback comes in a variety of forms. For example, praise, tangible items, access to activities, or a token. When the child responds incorrectly, they are given corrective feedback and, generally, are then provided with a prompt for the correct response. It is believed that children with ASD respond well to the discrete trial teaching method because it strongly emphasises individual learning goals, is based on empirically validated principles of learning, incorporates the analysis and systematic teaching of tasks, and utilises reinforcement to maintain attention and motivation (Dunlap, Kern, & Worcester, 2001). DTT also incorporates explicit teaching procedures which include multiple practice opportunities, prompting, shaping and systematic reinforcement for appropriate responses when teaching target skills.

Recently, the range of intervention strategies within the realm of ABA have been expanded to include more naturalistic approaches to teaching. These include pivotal response training (Koegel, Koegel, Harrower, & Carter, 1999), incidental teaching (Hart & Risley, 1980), and milieu teaching (Alpert & Kaiser, 1992). These behavioural approaches are thought to enhance generalization outcomes for children with ASD.

Research into Generalization

The use of behavioural principles and specifically, the use of DTT has been criticised by some who suggest that the structured nature of the teaching strategies and the use of extrinsic reinforcement inhibits generalization (Daniel, 2004; Vismara & Rogers, 2010) and there are several studies which have attempted to outline some of the methodological considerations which are involved when interpreting findings in the ABA literature (Gresham, Beebe-Frankenberger, & MacMillan, 1999).

Stokes and Baer (1977) defined generalization as “the occurrence of relevant behaviour under different, non-training conditions (i.e., across subjects, settings, people, behaviours, and/or time) without the scheduling of the same events in those conditions as had been scheduled in the training conditions” (p. 350). According to Cooper, Heron and Heward (2007), there exist three basic types of generalized behaviour change. These are response generalization, stimulus generalization, and response maintenance. Response generalization is the case where the learner demonstrates an untrained response or behaviour that serves an equivalent function to that which was taught. Setting/stimulus generalization is the case where a behaviour or response begins to occur in the presence of a stimulus or setting other than those used during training. Response maintenance is said to have been demonstrated when a behaviour or response continues to occur, even after the intervention or teaching has ceased. Cooper et al. (2007) go on to list five approaches which facilitate the likelihood of generalized behaviour change. These are (1) teach the full range of relevant stimulus conditions; (2) make the instructional setting similar to the generalization setting; (3) maximise the target behaviours contact with reinforcement in the generalization setting; (4) mediate generalization; and (5) train to generalize.

One unique type of generalization that does not fit well within any of the types specified by Cooper et al. (2007) is the emergence of untaught equivalence responses during the teaching of equivalence relations. This type of generalized behaviour change will be discussed in further detail in subsequent sections.

Stimulus and Response Generalization in Children with Autism Spectrum Disorder

Generalized stimulus control tends not to occur during the teaching of children with ASD (Betz, Higbee & Pollard, 2010). Several causal theories have been suggested regarding this lack of generalization and these are reviewed individually here.

One theory is that children with ASD tend to be taught using very specific training stimuli and that this limits the degree of generalization which can occur (because generalization is dependent on the number and variety of training stimuli used). A review of the research on concept formation indicates that the most effective procedure for facilitating generalization of newly acquired concepts is a general case teaching procedure (Englemann & Carnine, 1991; Westling & Floyd, 1990). The teaching sequence outlined in a general case design involves specific principles. The first principle is to use consistent wording when presenting examples. The second principle is that the positive examples used during teaching should exhibit the range of possible features which are exhibited by members of that stimulus class. Third, the variation between positive and negative examples should be minimised during teaching and practice to emphasise the relevant features of the concept being taught. Fourth when moving from one example to another only one attribute or feature of the stimuli should change. Fifth, minimally different examples and non-examples should be targeted simultaneously to sharpen the distinction between examples and non-examples. If the range of examples and non-examples used during discrete trial teaching is limited this could limit the degree of generalization exhibited by the child with ASD.

A second possibility is that children with ASD may have difficulty generalizing because they may be bound by their individual reinforcement history or a history of being reinforced for a single response type (Egel, Shafer, & Neef, 1984; Young, Krantz, McLannahan, & Poulson, 1994). This may lead to a decrease in motivation to respond in novel settings, when novel stimuli are utilised or when the expectation is to use a unique response topography, especially if they have not previously been reinforced for doing so. In other words, a lack of generalization to variants of the stimulus class may be a function of the individual child's history of reinforcement.

Third, it has been suggested that children with ASD may become dependent on prompts or on eliciting stimuli in order to make a response. This hypothesis has received some support in the literature (Betz et al., 2010; Williams, Carnerero & Perez-Gonzalez, 2006) and is possibly a reflection of the structured nature of teaching that is often used with children with ASD. When teaching children with ASD, a potential discriminative stimulus is always presented. Very often this takes the form of a question or statement to which a specific response is expected and which, if not given, is then prompted. Using such a structured teaching method may inhibit the likelihood of spontaneous responding in the absence of the prompts used following a non-response. Highly prompted responding is one of the important differences between a discrete trial method and an incidental teaching procedure which involves more natural contingencies.

Fourth, it has been found that some children with ASD only attend and respond to selected aspects of the stimuli that they are presented with (Lovaas & Schreibman, 1971; Lovaas, Schreibman, Koegel, & Rehm, 1971; Rincover & Koegel, 1975). In the early literature, this was referred to as under-generalization. This means that when compared to typically developing children who are able to attend to multiple aspects of stimuli, children with ASD are more likely to respond to specific elements of complex stimuli - elements which may or may not be relevant to responding. By attending to irrelevant aspects of stimuli during teaching, children with ASD may not acquire the concepts that are being taught, and subsequently, teaching using a broader range of examples and non-examples becomes necessary to ensure that appropriate features or cues are being observed and can come to control the response which is to be acquired. In the current literature undergeneralization has come to be known as stimulus over-selectivity and it has been demonstrated in multiple research studies (e.g., Lovaas & Schreibman, 1971; Lovaas et al., 1971).

Finally, one of the features of children with ASD is that they exhibit restricted, repetitive and stereotypic patterns of behaviour, interests, and activities. Such rigidity and insistence that things remain the same may have a detrimental impact on the ability of children with ASD to generalize the skills that they have learned. Due to this insistence on sameness, children with ASD may have difficulty when presented with generalization conditions which are different from the teaching conditions.

Stimulus and Setting Generalization Research

A majority of the early research studies in the area of generalization with children with ASD focused on setting and stimulus generalization. A summary of this research is provided in Table 1. In the research which measured setting or stimulus generalization some of the studies examined whether the acquisition or performance of skills in a structured

Table 1. Summary of Research Investigating the Generalization of Skills across Stimuli and Settings in Children with ASD

Author/s	**Subjects**	**Target behaviour/skills**	**Generalization measure**	**Results**
Betz, Higbee & Pollard (2010).	Three children with ASD aged 3-5 years.	Taught to mand using 'where" questions.	Assessed generalization of mands to novel settings and stimuli. Generalization probes used (1) novel stimuli; (2) novel stimuli and setting; (3) verbal SDs faded.	For all three children additional teaching was required in the natural setting and without verbal SD in order for generalization to occur.
Craighead, O'Leary & Allen (1973).	One four-year old child with ASD.	Targeted the teaching of set individual instructions.	Assessed generalization to different people and novel instructions and also maintenance of instruction following over time.	Instruction following generalized across people and across novel instructions. Instruction following was maintained.
Handleman (1979)	Four children with ASD aged 6-7 years.	Taught responses to common questions in two different settings.	Measured generalization of behaviour to multiple different settings.	Three children demonstrated minimal generalization to home when trained in a cubicle. Generalization increased when trained in multiple settings. The fourth child generalized regardless of training.
Handleman (1981)	Six children with ASD aged 5-12 years.	Taught responses to common questions in a cubicle setting and when a tutor stood in different location on a pre-determined route.	Compared degree of generalization to different settings.	Two participants showed high rates of generalization regardless of the teaching condition. Four participants showed low rates of generalization across both training conditions.
Jones, Feeley & Takacs (2007).	Two three-year old children with a diagnosis of PDD-NOS.	Used discrete trial teaching to teach verbal responses to non-vocal stimulus (e.g., adult sneeze, followed by the child saying "bless you").	Assessed generalization to novel settings and novel persons.	Intervention was effective in teaching spontaneous vocal responses. Spontaneous responses generalized across novel settings and persons for both subjects.

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Table 1 continued

Author/s	**Subjects**	**Target behaviour/skills**	**Generalization measure**	**Results**
Koegel, Camarata, Valdez-Menchaca & Koegel (1998).	Three children with ASD. (3-5 years of age). Estimated language ages of 15-20 months old.	Taught question-asking skills. Varied reinforcement procedures during teaching.	Assessed generalization to novel settings, stimuli and people.	All children were able to learn to ask questions. All demonstrated generalization of question-asking to novel stimuli, settings and people (parents).
McGee, Krantz, Mason & McClannahan (1983).	Two individuals with ASD (12 and 15 years of age). Primary form of communication was sign.	Taught the receptive identification of items used in lunch preparation using incidental teaching procedures.	Assessed the rate of acquisition and generalization across novel settings and activities.	Both subjects acquired receptive identification of object names and the newly acquired skills generalized to a different setting and to traditional discrete-trial teaching session.
Pellecchia & Hineline (2007).	Three preschool-aged children with ASD.	Taught to mand for items.	Assessed the degree of generalization across parent, siblings and peers.	Direct teaching was required for generalization to occur for siblings and peers. Limited generalization to parents.
Rincover & Koegel (1975)	10 children with ASD aged 6.5-13.5 years.	Various target behaviours taught including, nonverbal imitation, identifying body parts, and discrimination of right and left.	Transfer to a novel room was tested. Analysed stimulus control in students who failed to generalize skills.	4/10 participants showed no transfer to a novel setting. When incidental stimulus was introduced in novel setting, generalization occurred. The children whose behaviour did not generalize were responding to an irrelevant stimulus.
Secan, Egel & Tilley (1989).	Four children with ASD. (5 to 9 years). IQs of 40-95.	Taught discrimination of Wh-questions using magazine pictures.	Assessed generalization to natural setting and story books.	Initially responses were not generalized to novel examples. Generalization training using interspersed trials which included pictures, was required when the relevant cue was not visible.

setting would then generalize to novel settings (Betz, et al., 2010; Handleman, 1979; Handleman, 1981; Jones, Feeley & Takacs, 2007; Koegel, Camarata, Valdez-Menchaca & Koegel, 1998; McGee, Krantz, Mason & McClannahan, 1983; Rincover & Koegel, 1975).

Other studies examined whether teaching using a specific set of examples would then generalize to novel examples or novel presentation methods (Betz et al., 2010; Craighead, O'Leary & Allen, 1973; Koegel et al., 1998; Pellecchia & Hineline, 2007; Secan, Egel & Tilley, 1989). Some studies focused on generalization from trainers to parents, peers, or siblings (Craighead et al., 1973; Jones et al., 2007; Koegel et al., 1998).

In general, the research summarized in Table 1 found that, in order for children with ASD to generalize newly acquired skills to novel settings, novel stimuli and/or novel people, additional teaching in the generalization setting was required. It should be noted, however, that the results were variable, and in four of ten studies high rates of generalization occurred for all participants (Craighead et al., 1973; Jones et al., 2007; Koegel et al., 1998; McGee et al., 1983). Many of these studies examined multiple aspects of generalization within the same study.

Generalization of Language Responses and Response Topographies

While our understanding of generalization has increased, very little research has focused on the generalization of language responses or generalization across response topographies. There are two types of generalized language responses. The first is stimulus generalization, that is, generalization of verbal responses across stimulus classes. In this example, generalization is demonstrated when the child applies the correct label to various representations of a concept (e.g., a child applies the verbal label "three" not only to various forms of the written numeral "3" but also to various representations of the quantity "three"). The second type of language generalization is generalization across response classes. This is a type of response generalization. For example, there are several different language responses which can be used interchangeably because they each have the same meaning (e.g., a child can greet somebody by saying “hi” or “hello” or “good morning” as each of these phrases has the same meaning). Research relating to the generalization of language responses, is summarised in Table 2.

Much of the research that has examined the generalization of language responses has focused on the effects of teaching method on the generalization of language responses across stimulus classes or response classes (Egel et al., 1984; Young et al., 1994). Three studies used spontaneous language use or spontaneous responding as their measure of response generalization. Two studies examined the degree of spontaneous language use which occurred during structured and unstructured teaching sessions (Kok, Kong, & Bernard-Opitz, 2002; Miranda-Linne & Melin, 1992) and one studied the effect of a verbal discriminative stimulus on the frequency of spontaneous responding (Williams et al., 2006).

The research summarised in Table 2 suggests that additional teaching is necessary before children with ASD will demonstrate generalization across and within verbal response classes (Egel et al., 1984; Williams et al., 2006; Young et al., 1994). It is not possible to determine whether generalization depends on the degree of structure used during teaching. In one study some children produced more appropriate generalized responding in the structured teaching condition (Kok et al., 2002) and in another study, children generalized more readily in an unstructured teaching condition (Miranda-Linne & Melin, 1992).

Strategies to Facilitate Generalization in Children with ASD

Based on the research in the area of generalization, it is apparent that while this is an area of difficulty for children with ASD there are a variety of strategies which will function to

Table 2. Summary of Research Investigating the Generalization of Language Responses in Children with Autism Spectrum Disorder

Author/s	Subjects	Target behaviour/skills	Generalization measure	Results
Egel, Shafer & Neef (1984).	Four children with ASD (6-8 years of age). One child was non-verbal.	Examined the receptive identification of prepositions using position self or position item.	Assessed generalization across untrained stimulus materials (using novel materials) and across response topographies.	Position object was acquired slightly more quickly than position self. For most students additional programming was required before generalization to novel materials and across response topographies occurred.
Kok, Kong & Bernard-Opitz (2002).	Eight, children with ASD (4-5 years of age). Some verbal and some non-verbal.	Examined the effects of a structured play (SP) condition and a facilitated play (FP) condition.	Spontaneous play and communication initiation was used as the measure of generalization.	Children with a higher level of verbal skills initiated play more in the FP condition. Responses occurred more frequently in SP condition. Three children initiated more inappropriate play in SP condition.
Miranda-Linne & Melin (1992).	Two children with ASD (10 and 12 years of age).	Compared incidental and discrete trial teaching procedures for teaching colour adjectives.	Examined rates of spontaneous use and generalization of colour labels. Generalization assessed at home.	Discrete trial resulted in faster acquisition and greater generalization. At follow-up incidental teaching resulted in greater generalization and equal or greater spontaneous language use.
Williams, Carnerero & Perez-Gonzalez (2006).	Six children with ASD (7-10 years of age).	Compared presence of question asking (e.g. "what is she doing?") paired with action, with just the presence of action and no verbal SD.	Looked at generalization to novel actions without presence of question.	To obtain generalization it was necessary for the child to learn to tact actions both with and without a verbal SD. No child performed a tact for an action without a verbal antecedent until they had been taught to do this with other actions during training.
Young, Krantz, McClanahan & Poulson (1994).	Four children with ASD (2-4 years of age).	Taught play skills using models from vocal play, toy play and pantomime.	Examined generalized imitation within and across response types.	Imitation generalized from reinforced training models to unreinforced probe trials within a response type but did not generalize across response types.

promote generalization. These include video modelling (Haring, Kennedy, Adams, & Pitts-Conway, 1987), the use of incidental teaching methods (McGee et al., 1983; Miranda-Linne & Melin, 1992), systematic reduction in the use of question asking as a means of eliciting a response (Betz et al., 2010; Williams et al., 2006), training in multiple settings (Handleman 1979), programming to eliminate irrelevant stimuli (Rincover & Koegel, 1975), reinforcing the use of skills in a generalization setting (Koegel et al., 1998) and the use of interspersed training conditions which employ a variety of response types and stimuli (Egel et al., 1984). It is important to note however that the majority of these studies have not been replicated and that further research in this area is essential if we are to further our understanding of strategies that may promote generalisation across stimuli and responses and also the maintenance of these skills for individuals with ASD.

What we can conclude from the research in this area is that many children with ASD have difficulty generalizing responses that have been learned and that transfer of stimulus control may not occur across the members of a stimulus class without direct teaching. It is also clear that the degree of generalization which occurs varies amongst children with ASD.

Equivalence Relations

One unique area of generalization which has received increasingly extensive study is the area of equivalence relations or stimulus equivalence. The emergence of untaught equivalence relations does not fit well within any of the above categories of generalization in that it is neither indicative of stimulus generalization nor of response generalization. While the emergence of untaught equivalence relations is a unique measure of generalization, it is still a measure of generalization as it fits within the definition provided by Stokes and Baer (1977). Measures of the emergence of untaught relations involve tests for the occurrence of a behaviour under non-training conditions and the testing that takes place involves different conditions to those that are used during teaching. It is for this reason that the emergence of untaught equivalence relations will be referred to as a measure of generalization.

Language development involves the learning of multiple sets of stimulus-response correspondences. The sets of correspondences which are learned can be referred to as equivalence relations. As an illustration, the equivalence relations for the concept of "one" are given in Table 3.

Table 3. Equivalence Relations for the Concept of "One"

Stimulus	**Taught response**	**Type of relation**
1. Child hears the word "one" A	Child selects the quantity one B	Aural comprehension A-B
2. Child sees the quantity one B	Child says "one" A	Quantity naming B-A
3. Child hears the word "one" A	Child selects the written numeral 1 C	Aural-written numeral matching A-C
4. Child sees the written numeral 1 C	Child says the word "one" A	Reading C-A
5. Child sees the written numeral 1 C	Child selects the quantity one B	Reading comprehension C-B
6. Child sees the quantity one B	Child selects the written numeral 1 C	Quantity-word matching C-B

For a stimulus-response relationship to be part of an equivalence class it must demonstrate what Sidman (1971, 1994) referred to as *reflexivity, symmetry* (or reversibility) and *transitivity*.

Reflexivity is demonstrated when the child can perform generalized identity matching, for example, when the child is required to find and point to two stimuli that are the same out of a field. Using the example provided Table 3, reflexivity is demonstrated when a learner sees the written numeral "1" and points to another example of the written numeral "1" when presented with several written numbers, or when the child hears the word "one" and says the word “one” or when the child sees the quantity “one” and selects another example of “one” from a set of several different quantities. This is often referred to as “matching to sample”.

Symmetry refers to the acquisition of a bi-directional relationship between two different stimuli such that if A is conditionally related to B, then B is conditionally related to A. In Table 3, discriminated responses 1 and 2, 3 and 4, and 5 and 6 constitute three symmetrical pairs of discriminated responses. A child who demonstrates that they have acquired both of the responses in a symmetrical pair (e.g., can demonstrate both comprehension of the oral word “one” and the ability to name quantities of “one” is said to be demonstrating symmetry. Symmetry is often referred to as “reversibility”. Symmetry is important because it has been found that once a child has acquired one of the responses in a symmetrical pair they will often be able to perform the other discriminated response in the pair without further instruction.

For transitivity to occur, a minimum of three pairs of symmetrical equivalence relations are required. Transitivity is demonstrated when, following acquisition of two of the three pairs of symmetrical responses, the learner is able to demonstrate that they have also acquired the third pair of symmetrical responses. Referring again to the example in Table 3, let us say that a child had acquired discriminated responses 1 to 4. If the child was then able to demonstrate that they had acquired responses 5 and 6 (reading comprehension and quantity-word matching) for the numeral “1” then this would be an example of a child demonstrating transitivity. Transitivity is important because transitive relations often occur without any direct teaching. Taken together symmetry and transitivity are important in the learning of sets of equivalence relations because the teaching of just two discriminated responses can result in the emergence of four additional discriminated responses without further teaching.

One of the ways in which researchers have tested for the occurrence of symmetry and transitivity is shown in Figure 1. In Figure 1 the solid lines represent the taught A-B (hear the name – select the quantity) and A-C (hear the name – select the numeral) relations. The dashed lines indicate the stimulus-response relations that can emerge without teaching and which indicate the phenomena of symmetry and transitivity. In this example, teaching of the A-B relation (hear the quantity-select the quantity) and the A-C relation (hear the numeral – select the numeral) may lead to the emergence of the B-A relation (see the quantity – say the quantity) and C-A relation (see the numeral – say the numeral) as a result of symmetry. The C-B relation (see the numeral – select the quantity) and the B-C relation (see the quantity – select the numeral) indicate the emergence of two further discriminated responses as a result of transitivity.

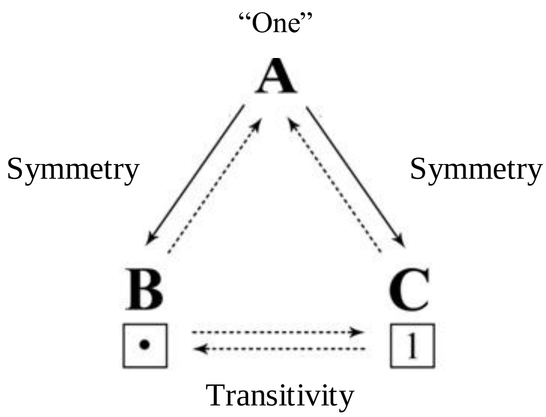


Figure 1. Diagram of each of the taught and tested stimulus-response relations that are commonly used in testing for the emergence of untaught equivalence relations in the set of the six pairs of equivalence relations which are involved in comprehending and using the word "one" and the numeral "1"

Closely related to the Sidman accounts of stimulus equivalence is the Relational Frame Theory of Hayes, Barnes-Holmes, and Roche (2001). Hayes et al., (2001) identify three properties of what they refer to as relational frames. These are *mutual entailment, combinatorial entailment,* and the *transfer/transformation of stimulus functions.*

Mutual entailment has features similar to what Sidman refers to as symmetry in that it incorporates the bi-directionality of two conditional discriminations. According to the principles of mutual entailment, if A is related to B, then B is also related to A (Hayes et al., 2001).

Combinatorial Entailment is similar to what Sidman refers to as transitivity. Combinatorial entailment is demonstrated when if, in a certain context, A is related to B, and B is related to C, and it is then subsequently observed that A and C are mutually entailed. In this way, at least two derived or trained stimulus relations mutually combine to produce two derived stimulus-response relationships.

The final component is termed *transformation of stimulus functions* or *transfer of stimulus functions*. Hayes et al. (2001) state that "When a given stimulus in a relational network has certain psychological functions, the functions of other events in that network may be modified in accordance with the underlying derived relation" (p. 31). This has been demonstrated with a variety of functions and various types of responding. For example, assume that somebody is taught that stimulus B is the opposite of stimulus A. If stimulus A is given a conditioned punishing function perhaps by pairing it with a loss of a reward then it is possible that stimulus B will acquire a reinforcing function (without direct teaching) by virtue of the fact that it is the opposite relation to stimulus A (Hayes et al., 2001). The transformation of stimulus functions must be under contextual control (e.g. the control of a specific stimulus such as the presence of a dictated word).

Theories of Derived Responding

There are three main theoretical attempts to explain the conditions which result in the emergence of derived responses. These are Sidman's theory of stimulus equivalence (Sidman, 2000), Relational Frame Theory (Hayes et al., 2001) and Naming theory (Horne, &

Lowe, 1996). Each of these theories has a different explanation for the nature of the relations that are formed and the role of naming in the formation of equivalence classes.

Relational Frame Theory (RFT)

Relational Frame theorists (Hayes et al., 2001) argue that for symmetry to be demonstrated, individuals require a history of being reinforced for bi-directional responding and it is an individual's prior learning history that accounts for the emergence of derived responding. RFT is not specifically focused on equivalence relations, but examines the principles behind relational responding in a more general sense. RFT suggests that it is an individual's history of multiple exemplar training which teaches individuals the relationships between the stimuli that are involved in the formation of equivalence responding. It is further suggested that derived responding is an example of generalization that has arisen from previously reinforced experience with arbitrary discriminated responses.

Naming Theory

Horne and Lowe (1996) argue that language is a crucial mediating factor in the emergence of equivalence classes. They state that as "naming is evoked by, and itself evokes classes of events, it brings about new or emergent behavior such as that reported in studies of stimulus equivalence" (p.185). The naming theory suggests further that the skill of naming incorporates two components that are symmetrically related. Firstly, specific stimuli control the verbal response that is produced and secondly, the alternative response (e.g., selection) is also controlled by that same stimulus. In this way, language involves both verbal responses and comprehension. Dugdale and Lowe (1990), Horne and Lowe (1996), and Clayton and Hayes (1999) argue that naming is a mediating factor in the emergence of untaught relations because assigning stimuli the same names and also assigning a common name to stimulus-response pairings develops an equivalence relation.

Support for this theory comes from the finding that some children with minimal verbal repertoires do not always demonstrate the emergence of untaught equivalence relations (Devany, Hayes, & Nelson, 1986). Further support for this notion is provided in studies which have included nonhuman subjects in which stimulus equivalence has not been demonstrated (D'Amato, Salmon, Loukas, & Tomie, 1985; Lipkens, Kop, & Matthijs, 1988).

Sidman's Theory of Derived Responding

Sidman's theory of derived responding described the emergence of equivalence relations as occurring as a direct outcome of reinforcement contingencies in which operant principles are applied (Jackson, Williams, and Biesbrouck, 2006). Sidman (2004) states that "a reinforcement contingency produces at least two types of outcome: analytic units and equivalence relations" (p. 128).

Sidman's theory of derived responding differs to that proposed by Naming Theorists in that he argues that the formation of equivalence classes has an important role in the acquisition of language and that language is not a mediating factor in this process. Essentially, this means that language in and of itself does not play a pivotal role in the likelihood of derived responding, as proposed by Naming Theorists.

Support for this view comes from research by Sidman, Willson-Morris, and Kirk, (1986) in which participants demonstrated the emergence of untaught equivalence relations following teaching using auditory-visual and visual-visual relations. A review of the literature on equivalence relations and individuals with intellectual disabilities (O'Donnell & Saunders, 2003) also concluded that naming is not essential for the emergence of derived relations.

Sidman's theory of derived responding differs from that of Relational Frame theorists in that he argues that the emergence of untaught equivalence relations is a primary behavioural function (Sidman, 1994) and a history of reinforcement for bi-directional responding is not essential for the emergence of derived responses.

While each of these theories differ in their account of derived responding all three theories view operant principles at work in the emergence of derived relations and one of the key theoretical underpinnings of both Relational Frame theory, and Sidman's theory of stimulus equivalence is that repertoires of derived responses consist of a number of complex human behaviours.

Terminology Used in this Thesis

For the purpose of the present experiments, the relationship between a stimulus and a response that is under the control of this stimulus will be referred to as a *stimulus-response relation*. A distinction will also be made between relations that are taught and relations that are not taught. The stimulus-response relations that are taught will be referred to as *taught relations*. Any stimulus-response relations that emerge without teaching will be referred to as *untaught relations*. When a stimulus-response relation that has not been directly taught is demonstrated during testing, that stimulus-response relation will be said to have *emerged*.

When the teaching of a stimulus-response relation such as A-B leads to the emergence of an untaught relation of the form B-A, the emergence of the B-A relationship will be referred to as a demonstration of *symmetry*.

The situation in which the teaching of two stimulus-response relations leads to the emergence of two further untaught stimulus-response relations, without direct teaching, will be referred to as a demonstration of *transitive* responding or *transitivity*.

This terminology has been selected because this is the language that was used in the original work conducted by Sidman as summarised in his 1994 book. The terms symmetry, transitivity, emergence and equivalence are also the terms that are commonly used to describe these processes in current research.

It is important to note that some writers have used the term *derived responding* to refer to the emergence of untaught stimulus-response relations. The term derived responding is not used to describe experimental outcomes in the present thesis because there are several different types of derived responding which can result from a variety of processes. The term derived responding is also most frequently associated with Relational Frame theory and Naming Theory rather than Sidman's theory of equivalence relations. The term emergence of untaught relations, by comparison, is not ambiguous and captures exactly the type of performances that are of interest in the present thesis.

The Research on Equivalence Relations

Extensive research has shown that if certain conditional relations are directly taught for one member of a class of stimuli, then additional conditional relations emerge for other members of that class, without direct training (Rehfeldt, 2011). This research shows that if the child is taught two conditional relations (e.g., A-B and A-C), they usually acquire four additional relations (B-A, C-A, B-C, C-B) without any further teaching. This is an example of the emergence of untaught equivalence relations and the class of stimuli in which this occurs is called an equivalence class.

Precisely how this type of learning is possible has yet to be determined but there is sufficient evidence to support the notion that the brains of typically developing individuals function in a way that results in this type of generalized responding. It is thought that we could greatly improve the efficiency with which we teach preacademic and academic skills, basic vocabulary, and advanced language concepts if we could develop a more comprehensive understanding of the conditions that lead to the emergence of untaught equivalence relations (Sidman et al., 1986).

Much of the original research focused on teaching children using conditional discrimination procedures. In this research the majority of individuals demonstrated the emergence of untaught equivalence relations. The pioneering research in this area was conducted by Sidman and his colleagues (Sidman, 1971; Sidman & Cresson, 1973; Sidman, Cresson, Wilson-Morris, 1974; Sidman & Tailby, 1982; Sidman et al., 1986; Spradlin, Cotter, & Baxley, 1973). Sidman was the first to employ a conditional discrimination methodology as the test for the emergence of untaught equivalence relations. This research provided considerable support for the view that untaught equivalence relations can emerge following the teaching of stimulus-response relations for a variety of populations. Sidman's early findings have since been replicated on many occasions (Brady & McLean, 2000; Carr et al., 2000; Cowley, Green & Braunling-McMorrow, 1992; Gast, Munson-Doyle, Wolery, Jones Ault & Kolenda, 1994; Kennedy, Itkonen & Lindquist, 1994; Lynch & Cuvo, 1995; Mackay, 1985; McDonagh, McIlvane & Stoddard, 1984; Rehfeldt & Root, 2004). Sidman concluded that an individual's acquisition of untaught equivalence relations is a basic learning process and is a crucial element of the language acquisition process.

Research into Equivalence Relations with Typically Developing Individuals

A number of studies have investigated stimulus equivalence in typically developing preschool-aged children (Brady & McLean, 2000; Devany et al., 1986; Mueller, Olmi, & Saunders, 2000), and school-aged children (De Rose & De Souza, 1996; Lynch & Cuvo, 1995; Sidman et al., 1986). In each of these investigations typically developing children were taught using a conditional discrimination procedure. A variety of teaching stimuli have been used in these studies. These include fractions/decimals, functionally related objects/lexigrams, sight words/spelling words, rhyme and non-rhyme classes, and Greek letter names. In the majority of the studies examined, the emergence of untaught relations was demonstrated given sufficient exposure to the training stimuli. In one study however, emergence of untaught equivalence relations was only demonstrated for some of the tested relations (Brady & McLean, 2000).

Research into Equivalence Relations in Individuals with Intellectual Disabilities

A number of studies have investigated the acquisition of equivalence relations in children with intellectual disabilities. The results of these studies are summarised in Table 4. These studies included pre-school aged children (Devany et al.,1986), school-aged children (Gast et al., 1994; Kennedy et al., 1994; Mackay, 1985) and adults with intellectual disabilities (Brady & McLean, 2000; Carr et al., 2000; Maydak, Stromer, Mackay, & Stoddard, 1995; McDonagh et al., 1984; Rehfeldt & Root, 2004; Saunders & McEntee; 2004; Stromer & Mackay, 1992). One experiment also involved adults with brain injuries (Cowley et al., 1992). Some of the equivalence relations that were taught in these studies included relationships between oral names and lexigrams, oral and written words, picture/colour/numeral relations, photographs of people and their names, constructed computer-based spelling in the presence of a picture, fraction and decimal fraction relations, and written monetary amounts and coins. The results of this research indicate that, in the majority of studies most of the participants with an intellectual disability and/or brain injury demonstrated emergence of untaught equivalence relations when provided with sufficient practice opportunities and appropriately sequenced training.

The emergence of untaught relations was not demonstrated in all studies however, (Brady & McLean, 2000; Devany et al., 1986; Hall et al., 2006; Saunders & McEntee, 2004).

Table 4. Summary of Research into the Emergence of Untaught Equivalence Relations in Children and Adolescents with Intellectual Disabilities.

Author/s	**Subjects**	**Relations taught**	**Relations tested**	**Results**
Brady & McLean (2000)	Eight adults with ID and four TD preschool children.	Taught to match objects to the corresponding lexigram. Each object was related by function to another object that was taught.	Tested the emergence of lexigram to lexigram, lexigram to object, spoken word to lexigram, lexigram to associated lexigram matching and lexigram naming.	2 of 4 TD children and 5 of 8 with an ID showed emergent relations between lexigrams and spoken words. Two TD children demonstrated emergence of functionally relating lexigrams.
Carr, Wilkinson, Blackman & McIlvane (2000)	Three people with severe ID (15-21 years).	Taught matching of picture to dictated word (BA), picture to letter (BC),and picture to random forms (BD).	Tested the emergence of AC, AD, BC, BD, CD, and DC relations.	All subjects showed emergence of all of the tested equivalence relations.
Cowley, Green & Braunling-McMorrow (1992)	Three men with brain injuries	Subjects already able to match dictated names to written names (AB). Taught to match dictated names to photos of people (AC).	Tested for emergence of BC and CA relations.	Two subjects showed the emergence of untrained relations The third participant was unavailable for these post-tests.
De Rose, De Souza & Hanna (1996)	11 first grade students (7-10 years) with reading and spelling difficulties.	Participants taught to match dictated word to printed word (AB) and dictated word to picture (AC). Also taught to construct (copy) the written word out of letters (spelling).	Tested for emergence of BA, CA, BC and CB relations. Also tested reading of training words and target generalization words which were presented as recombinations of phonemes used in training.	All children learned to read training words. Five children read generalization words. In Experiment 2 only one subject learned to read generalization words.
Devany, Hayes & Nelson (1986)	Eight children with ID. Four of whom had no verbal language. Four TD children (2-4 years).	Taught matching responses using arbitrary symbol to symbol matching (AB, DE, AC, DF).	Tested for emergent matching responses (BC, EF). Examined the relationship between equivalence performance and verbal ability.	All of the language-able children (both with an ID and TD) showed emergence of untaught relations. None of the language-disabled children did so.

Table 4 continued

Author/s	**Subjects**	**Relations taught**	**Relations tested**	**Results**
Hall, DeBernardis & Reiss (2006)	Five adolescents with Fragile X syndrome (12-19 years).	In math condition, taught AB (fraction to pie chart) and BC (pie chart to decimal) relations. In geography condition, taught AB (state name to state shape) and BC (state shape to state capital) relations.	Tested for emergent CA, AC, CB and BA relations.	Only one of the four participants who acquired the taught math relations demonstrated emergence of math relations. Three of the five participants demonstrated emergence of geography relations.
Kennedy, Itkonen & Lindquist (1994)	Three teenage children with Moderate disabilities	Taught AB, BC and CD relations which all involved selecting and naming a written word when presented with another written word from that class.	Tested for emergence of symmetry (BA, CB, DC) , one-node transitivity (AC, CA, BD, DB) and two-node transitivity, (AD, DA).	Symmetric relations emerged before one-node transitive relations and one-node transitive relations emerged before two-node transitive relations.
Lynch & Cuvo (1995)	Seven 5^{th} and 6^{th} grade students (11-13 years).	Trained to match pictorial representations of fractions to fraction ratios (AB) and to match printed decimals to pictorial representations of quantities (BC).	Tested BA, CB, AC and CA relations. Tests involving written responses were also used to assess generalization to writing fractions as decimals and vice versa.	All students showed emergence of equivalence relations between fractions represented as ratios, as decimals or pictorially. Limited generalization of fraction-decimal relations during writing tests.
Mackay (1985)	Three teenagers with ID.	Taught to use anagram letters to construct colour words when shown coloured patches.	Tested matching dictated word to written word and oral naming of words.	Participants demonstrated auditory reading comprehension and naming of written words.
Maydak, Stromer, Mackay & Stoddard (1995)	Two people with ID (30 and 49 years).	Participants taught various matching and sequencing tasks using numerals, quantities, words and arbitrary symbols.	Tested the emergence of sequencing when novel matching tasks were taught and also the emergence of matching skills when sequencing was taught.	Sequence training did not readily lead to new matching performances. Training in matching to sample led to emergent sequence production.

Table 4 continued

Author/s	Subjects	Relations taught	Relations tested	Results
McDonagh, McIlvane & Stoddard (1984)	One woman with ID.	Taught to match two different coin stimuli to the corresponding written price using 5, 10 and 15 cents.	Tested emergence of additional coin matching (matching coin stimuli to each other to make amounts) and oral naming of coin amounts and written prices.	Following teaching she could match coin stimuli to each other and state their values without further training.
Rehfeldt & Root (2004)	Four people with mild to moderate ID. (30-45 years).	Taught to match pictures to colours and pictures to numbers (AB and AC).	Tested the emergence of BA and BC relations. Also used variations of target colours to assess generalization across dimensional variants.	All subjects showed the emergence and generalization of all of the relations.
Saunders & McEntee (2004)	Six adults with mild ID.	Taught to match arbitrary stimuli with one another (AB, BC and CD) with four stimuli per class.	Compared teaching in which discriminative stimulus were presented in fixed pairs versus teaching in which stimulus were presented simultaneously. Tested emergence of AC, BD, AD, CA, DB, DB, DA.	In part one no participant showed emergence of equivalence classes during the initial testing but one showed emergence following repeated testing. In part two, 4/6 participants showed establishment of equivalence classes.
Sidman (1971)	One child with ID.	Taught to match the spoken word to the printed word (AB).	Tested the emergence of reading (BA) and comprehension (BC and CB) relations.	Following teaching of spoken word to printed words, the participant demonstrated the emergence of reading and comprehension skills.
Sidman & Cresson (1973)	Two people with Down Syndrome (17 and 18 years).	Taught printed word to printed word matching, dictated word to picture matching (AC) and dictated word to printed word matching (AB).	Tested for emergence of BA, BC and CB relations.	Emergence of comprehension and reading skills was only demonstrated after participants were taught to match dictated word to printed word.

Table 4 continued

Author/s	**Subjects**	**Relations taught**	**Relations tested**	**Results**
Sidman, Cresson, & Willson-Morris (1974).	Two individuals with a diagnosis of Down Syndrome.	Taught BA (dictated word to picture or dictated word to upper case letter) and CB (word to picture or lower case to upper case letter) matching.	Tested for the emergence of reading (oral naming of words or lower case letters) and matching of dictated word to printed word (CA) or dictated word to lower case letter.	Both participants demonstrated the emergence of CA relations (matching dictated word to written word and dictated word to lower case letter). Oral naming emerged for some stimuli.
Sidman, Willson-Morris, & Kirk (1986).	Two TD children (5-years old) and four people with ID (19-25 years).	Two sets of stimuli. Taught auditory-visual (AB, AC) and visual-visual (DE, DF) matching using Greek symbols.	Tested for the emergence of BC, CB, FE, EF, ED and FD relations. Compared stimuli taught using auditory-visual versus visual-visual.	All demonstrated emergence of untaught equivalence relations. This was demonstrated for auditory-visual and visual only stimulus for most participants.
Stromer & Mackay (1992)	Three students with ID (14-20 years)	Taught to match picture to picture or construct a word (spelling) when presented with a word.	Tested the emergence of constructed spelling to picture using a novel set of pictures and printed word. Also tested oral and written spelling.	Improvement was demonstrated after exposure to delayed constructed-identity matching. One subjects oral and written spelling also emerged.

TD: Typically developing. ID:Intellectual disability.

In the Devany et al study the untaught equivalence relations only emerged in the children who had some language. In the study by Saunders & McEntee (2004) repeated testing was required before equivalence emerged for some of the participants, and in another study some of the participants demonstrated emergence for some of the relations, whilst some did not (Brady & McLean, 2000).

Equivalence Relations Research and Children with Autism Spectrum Disorder

There have been very few investigations into the development of equivalence relations in individuals with autism spectrum disorder. The research which does exist is summarised in Table 5.

In the first of the five experiments in Table 5 (Eikeseth and Smith, 1992) four high functioning pre-school aged children with ASD were taught correspondences involving Greek letters and a printed version of the Greek letter name. In Part 1 of the experiment, subjects were taught using standard matching to sample procedures and then tested for the emergence of untaught relations. If subjects failed to demonstrate emergence during testing, in Part 2 of the experiment, they were then taught to say a common name for each member of each stimulus class. As part of this process, subjects were taught to say the name of the stimulus during the A-B and A-C discrimination training (labelling the materials as they pointed to them). B-C and C-B relations were then reassessed when the subjects had demonstrated mastery of this task. The stimuli in the condition without naming were also then checked and tested. Further teaching and testing was undertaken in subsequent experiments using new training materials in which assigning a common name to stimuli was manipulated. Initially, the four subjects showed emergence of untaught relations only after they were taught to assign the same name to each of the members of a stimulus class. Subjects were then trained to match unnamed stimuli with members of the sets of named

Table 5. Summary of Research into the Emergence of Untaught Equivalence Relations in Children with ASD

Author/s	**Subjects**	**Relations taught**	**Relations tested**	**Results**
Eikeseth & Smith (1992)	Four preschool aged children with ASD (3.6-5.6 years).	Taught to select the letter name (AB) and symbol (AC) when presented with the Greek Symbol. Subsequently, taught to assign a name to the stimuli.	Tested for emergence of BA, CA, BC and CB relations after each phase of teaching.	Initially, all subjects failed to demonstrate emergence of equivalence relations. When taught to assign the same name to all members of each stimulus class, relations emerged for two subjects.
Le Blanc, Miguel, Cummings, Goldsmith & Carr (2003)	Two children with ASD (6 and 13 years of age).	Participants were taught to match state name to state shape (AB) and state shape to capital city (BC) using three testing conditions.	Tested emergence of the CA, AC, CB and BC relations.	Both children were able to master trained geography relations and emergent CA, AC, CB and BC relations. All three testing procedures produced similar effects.
Noro (2005)	One child with ASD (5 years 9 months).	Taught to match faces to labels (AB) and emotion cartoons to faces (CA).	Tested for the emergence of emotion cartoons and label matching (CB). Assessed generalization to novel photos and scenarios.	Participants demonstrated the emergence of emotion cartoons to label matching and generalized labelling to novel scenarios. Direct training was required for transfer to photographs to occur.
O'Connor, Rafferty, Barnes-Holmes & Barnes-Holmes (2009)	Fifteen children with ASD. (5-8 years) and 3 TD children (7-10 years).	Word to object (AB) and object to picture matching (BC) was taught. Taught using actual items, photographs and words and also nonsense items, nonsense sketches and syllables.	Tested for the emergence of AC and CA relations. Examined the role of stimulus nameability, verbal competence and stimulus familiarity.	Those with more advanced verbal language produced more rapid equivalence performances and took fewer trials to reach mastery. Training and test performance was mediated at least partially by children's verbal development.
Wynn & Smith (2003)	Six children with ASD (3-6 years).	Participants were taught attribute word pairs. Half of the pairs were taught expressively then receptively. Half the pairs were taught in the reverse order.	Compared generalization from receptive identification to expressive labelling and vice versa.	For five participants, teaching expressive labelling first led to generalization across modes more readily than teaching the receptive discrimination first. For one child the opposite finding was apparent.

TD: Typically developing. ASD: Autism Spectrum Disorder.

stimuli. When subjects were then tested for emergent relations between the new unnamed stimuli and the named stimuli, untaught relations only emerged consistently for one out of the four children. This study highlights the need for further examination of the teaching conditions that may be necessary for the emergence of untaught equivalence relations, particularly, the teaching of stimulus-response relations that involve naming. The variation among participants in terms of the testing outcomes also highlights the need for more extensive documentation of participant characteristics.

In the second experiment by Le Blanc et al., (2003) two children with ASD participated. One of the children was 6 years old and one was 13 years old. Both children had some language and reading skills. The participants in this study were taught relations between printed U.S. state capital names, map outlines and printed state names. Emergence of untaught relations was then tested to evaluate the effect of three different procedures. The first condition incorporated extinction procedures during pre-test and post-test. This meant that no differential feedback was provided by the instructor and regardless of the individuals response, the instructor moved immediately onto the next trial. In the second condition no differential feedback was used during pretests and responses to one trial were immediately followed by the presentation of the next stimulus. In this condition, training trials were also interspersed during testing. The third condition incorporated reinforcement procedures during both pre-test and post-test. In this condition, the child was reinforced regardless of the accuracy of their response. In this study, the emergent relations were demonstrated for each of the participants regardless of the nature of the reinforcement that was used during testing procedures. Further replication of these findings would enable us to draw more robust conclusions about the role that reinforcement procedures may play in the emergence of untaught equivalence relations.

In the third study by Noro (2005) one 5-year-old child with ASD was taught to recognise the emotions happy, sad, angry and surprised and was taught to match cartoon faces showing the emotions to the printed labels. She was also taught to match cartoon pictures which demonstrated the emotion to the photos of the faces demonstrating the emotion. Following teaching, this child then demonstrated emergence of relations between the printed emotion labels and the cartoons which demonstrated the emotion. The child was also able to name the emotion when presented with an emotion eliciting scenario. Direct training was required for this child to be able to label the emotion when it was presented in photographs. The finding that the child in this study demonstrated emergence for only some of the untaught equivalence relations raises questions about the utility of this procedure across curriculum domains. It also highlights the need for further investigation into the teaching variables that may facilitate the emergence of untaught equivalence relations.

The fourth study by O'Connor et al. (2009) investigated the role of stimulus nameability, stimulus familiarity and verbal ability in the performance of 15 school-aged children with ASD and three typically developing school-aged children. Within this study subjects were provided with conditional discrimination training for word-object-picture relations. Participants were taught word to object (A-B) and object to picture matching (B-C) relations. They were then tested for the emergence of word to picture (A-C) and picture to word (C-A) relations . The materials used in this study included written words which were actual words or nonsense words, objects which were either real objects or abstract objects, and photographs or printed sketches. This was done in order to control for stimulus nameability/familiarity. The performance of typically developing children and children with ASD were compared. The findings of this study indicated that those children with ASD who had a higher verbal ability required relatively fewer teaching trials to reach mastery criterion and responded more accurately during testing for the emergence of untaught relations with fewer testing trials. It was also evident that the typically developing children required relatively few training trials to acquire the discriminated responses and also demonstrated accurate performance when tested for emergence of untaught equivalence relations. In addition, the children with ASD who had higher levels of verbal ability performed in a similar way to the typically developing children. The results suggest that for typically developing children and children with ASD the acquisition of equivalence relations may be mediated to some degree by language development and also familiarity with the stimuli. Further research is needed that assesses learner characteristics, records training variables and manipulates teaching conditions. The comparison between the typically developing children and children with ASD that was included in this study is also in need of replication if we are to draw more robust conclusions about the differences in the way in which children with ASD learn.

The final study by Wynn and Smith (2003) investigated generalization from receptive to expressive vocabulary and also the generalization from expressive to receptive vocabulary in six children with ASD aged between 47-76 months of age. This study taught word pairs such as hot/cold and tall/short. For each participant, half of the attribute pairs were first taught using expressive labelling (e.g. children were asked "what height is this?") and for the other half the word pairs were first taught receptively ("touch tall" versus "touch short"). Generalization from expressive labelling to receptive and receptive to expressive was assessed following mastery under each condition. Within this study, this type of generalization is referred to as cross-modal generalization. It has been included in this review because the properties of cross-modal generalization are similar to those of symmetry. Results of this study indicated that teaching the child to say the word first, led to a greater likelihood of generalization to a receptive response than the receptive first condition. For one of the participants in the study however, there was greater likelihood of generalization in the receptive to expressive condition and for three of the participants, the likelihood of cross-modal generalization varied across stimulus materials. It is worthy of note, that in this study, children who did not demonstrate generalization from receptive identification to expressive labelling were responding based on the physical similarities that were present between pre-training stimuli and stimuli used within the study. It was also apparent that the children who did generalize from receptive to expressive labelling had the highest scores during language testing. While the aforementioned study examined cross-modal generalization, the similarities with symmetrical responding means that these findings have implications for equivalence relations research. The finding that there was variation in the likelihood of generalization across response modes suggests that the teaching conditions may have a profound impact on whether untaught equivalence relations emerge for some children. Whether or not this is the case requires more extensive investigation.

In summary, it is apparent that there is significant variation amongst children with ASD with regard to whether untaught equivalence relations will emerge following the teaching of certain stimulus-response relations. It seems that several variables may affect the likelihood of generalization with this population of children, including language ability, training and testing conditions, familiarity with stimuli, reinforcement history, and for some children, the tendency to respond to irrelevant features of stimulus materials.

Unanswered Questions

A review of previous research has identified a number of unanswered questions which require further investigation.

From a theoretical perspective, we still do not understand whether emergence is a function of an individual's history of reinforcement for bi-directional responding, as proposed by Relational Frame theorists, whether it is mediated more explicitly by naming as argued by naming theorists, or whether it is a basic learning process in human language acquisition as argued by Sidman. While there is some suggestion in recent research that stimulus familiarity and verbal ability may affect equivalence performance, there is also evidence that contradicts the role of verbal ability (Brady & McLean, 2000) and demonstrates inconsistency across subjects in relation to the role of naming (Eikeseth & Smith, 1992). In addition, the characteristics of the learners (i.e. their cognitive functioning level, verbal ability and so on) have not always been adequately documented in the research, making it difficult to draw firm conclusions about the role of individual differences in the emergence of untaught relations in children with ASD.

We also do not yet have a clear understanding of the teaching conditions that affect the emergence of untaught relations in children with ASD. Further research is needed into the affects of such variables as the teaching sequence, the number of practice opportunities provided, the stimuli used, the rate of reinforcement, and so on.

Finally, we still do not have a clear understanding of the way in which variations in severity across the autism spectrum affect the emergence of untaught equivalence relations. Research to date indicates that there is some variation in the extent to which the emergence of untaught relations occurs. However, we still do not know which features of the autism syndrome account for this variation. Further investigation into the role of language level, cognitive ability, speed of skill acquisition and other variables is still necessary if we are to develop our understanding of which children are likely to demonstrate symmetry and transitivity during the learning of sets of equivalence relations.

Aim of the Present Research

Previous research into the emergence of untaught stimulus response relations in children with ASD raises several unanswered questions. The first of these is the question of whether children with ASD are capable of demonstrating the emergence of untaught equivalence relations following the teaching of specific stimulus-response relations. The second is the question of whether there are any differences in the likelihood of emergence of untaught equivalence relations in children with ASD when compared with typically developing children matched on levels of language development. The third is the question of which particular teaching conditions affect the likelihood that untaught equivalence relations will emerge. Finally, there is the question of whether there is variation in the degree of generalization amongst the children with ASD and, if so, whether there are identifiable variables which account for this variability.

In order to study these questions, an appropriate teaching topic is required. It was decided that these questions should be studied using six unknown number concepts (e.g., “four”, “five”, “six”, “seven”, “eight” and “nine”). Number concepts were chosen for several reasons. First, quantity and number concepts are highly functional and socially valid skills for all children, including those with ASD. They are part of the National Curriculum and are a prerequisite for further numeracy development. Second, the three pairs of stimulus-response relations which have to be acquired during the learning of each number concept (as shown in Table 3), make them ideal concepts for stimulus equivalence research. Third, there are a large number of math concepts and they tend to be acquired sequentially. This greatly facilitates the task of finding half a dozen concepts which participating children have not yet acquired.

Research Questions

The investigation described in this thesis explored the following questions.

1) Will children with an Autism Spectrum Disorder demonstrate the emergence of untaught equivalence relations?
2) Are there any differences with respect to the emergence of untaught equivalence relations in children with ASD and that which occurs in typically developing children with closely similar levels of language development?
3) Does instruction in naming facilitate the emergence of untaught equivalence relations?
4) Is there variability within the ASD population in terms of those who do and do not acquire untaught relations? If so, are there developmental factors which account for this variability?

CHAPTER 2

METHOD

Participants

Two groups of 10 children took part in the present investigations. This included a group of 10 children who had been diagnosed with ASD (Autism Group) and a group of 10 typically developing children (Typically Developing Group) with levels of language development similar to that of the children in the Autism Group. The children in the Autism Group were between 4.5 and 11.5 years of age at the start of the study. The children in the Typically Developing Group were between 3 and 4 years of age at the start of the study.

Recruitment Procedures

The children in the Autism Group were recruited in various ways. These included professional contact with families, through contact with schools, via the Autism Canterbury newsletter, and through contacts at the Ministry of Education. Information was provided to relevant individuals and groups using information brochures and, in one instance, an oral presentation. In every case, contact to discuss possible involvement was initiated by the parents/guardians of the children following receipt of news about the project. The typically developing children in this study were not recruited until each of the assessments, teaching, and testing sessions had concluded for the ten children with autism. This ensured that the typically developing children were able to be appropriately matched with the children in the autism group.

A majority of the children in the Typically Developing Group were recruited through contact with families known to the researcher. Several of the children in the Typically Developing Group were also recruited after their parent made contact with the researcher as the result of discussions with staff of kindergartens and other children's families.

Selection into the experiment involved a three step screening procedure: 1) initial screening, 2) developmental assessment, and 3) number knowledge screening.

Initial Screening

The children in the Autism Group were included in the research if they had a formal diagnosis of Autism Spectrum Disorder as defined by DSM-IV (American Psychiatric Association, 2000*)*, were using spontaneous mands or labels of at least one word, were able to identify pictures by pointing to or retrieving the item, demonstrated an ability and willingness to comply with simple requests, and had parents who were willing to give informed consent for their child to participate.

The majority of the children in the Autism Group were diagnosed by a developmental paediatrician or registered clinical psychologist who was employed privately by the parent/caregiver or appointed at the Ministry of Education or local hospital/medical centre. A variety of assessments were undertaken for each child depending on the age of the child and the clinician conducting the assessment. These specific measures included the Bayley Scales of Infant Development –II (BSID-II) (Bayley, 1993), the Vineland Adaptive Behavior Scales (VABS) (Sparrow, Cicchetti, & Balla, 2005), the Wechsler Nonverbal Scale of Ability (WNV) (Wechsler & Naglieri, 2006) and the Griffiths Mental Development Scales-Extended Revised (GMDS-ER) (Griffiths & Huntly, 1996).

The presence of spontaneous mands was determined during the investigator's discussions with the parents of the child, as well as informal observation. It was deemed that the child was using one-word mands if they were using one-word verbal labels to make a spontaneous request for something and/or they were using an oral label to make a comment.

The ability to identify and label pictures was determined by observation or by discussion with parents of the child or by informal observation. This was further assessed as part of the screening process, when children were tested for their ability to respond to the question "What is it?" when presented with a series of pictures of objects (oral naming) and also when asked to identify specific pictures out of a field of three (receptive identification).

The ability to comply with simple requests was determined through discussion with the child's parent and also during tasks in which the experimenter asked the child to come and sit down on the floor or at the table. Informed consent was obtained from each child's parent or primary caregiver. This process involved an initial meeting with the parents to go through the information sheet, discuss the purpose of the study and outline the procedures and teaching that would be involved with their child. The child was also read an information sheet outlining in simple words what would be involved in the teaching. This included telling them that if they wanted to discontinue with a teaching session or no longer wanted to be involved in the teaching then they could tell me or their parents without any repercussions. If the child was able to print part or all of their name they then signed the consent form. If they were not able to do this then the child's parent signed the child's consent form. The parent was also informed that they were able to terminate their child's involvement in the study without any penalty.

As part of the consent process, the parents were informed of the processes that would be involved to ensure that their child and family details would remain anonymous. This involved giving each child a code. This code was known only to the experimenter and was used throughout the project. The parent was also informed that the results of the study would be kept in a locked cabinet at the University for a minimum of five years.

Children in the Typically Developing Group were included if they did not have any identified diagnosis or learning difficulties, if they were using spontaneous mands of at least one word, if they demonstrated an ability to identify pictures by pointing or retrieving the item, if they showed an ability and willingness to comply with simple requests, if their Peabody Picture Vocabulary Test score was in the same range as those of the Autism Group and if their parents gave consent for their child to participate. The process for determining whether or not the above criteria were met was the same for the Typically Developing Group as it was for the Autism Group.

Prior to commencing the study, the approval of the University of Canterbury Human Ethics Committee was obtained. This approval is reproduced in Appendix 1.

Developmental Assessment

Prior to teaching, developmental assessments were administered for participants in both the Autism Group and the Typically Developing Group. Assessments included the Peabody Picture Vocabulary Test-IV (PPVT-IV) (Dunn & Dunn, 2007), the Adaptive Behavior Assessment System-II (ABAS-II) (Harrison & Oakland, 2003) and tests for instruction following.

The PPVT-IV is a standardized assessment tool that is used to measure receptive vocabulary development. Vocabulary is measured by asking children to point to a picture which has been orally named by the examiner. Correct pictures are presented as one of a field of four. The PPVT-IV is an individually administered instrument with reliabilities (coefficients of internal consistency) averaging .97 and .96 for Form A and Form B respectively and with test-retest correlations averaging .93. Validity data have also been reported. The average correlation between PPVT-IV scores and scores on the Expressive Vocabulary Test, 2nd Edition (EVT-2) (Williams, 2007) across age groups is .82.

The Adaptive Behavior Assessment System-II (ABAS-II) (Harrison & Oakland, 2003) is a standardised tool that is used to assess adaptive functioning on the ten adaptive domains outlined in the DSM-IV-TR (American Psychiatric Association, 2000). The ABAS-II uses a five point rating scale and can be completed by the participant's parent/guardian or their teacher. Reliability coefficients (internal consistency) for each of the skill areas range from .80-.97 and the average reliability coefficient in the adaptive domains range from .91-.98. Clinical validity studies, which include children diagnosed with ASD, indicate high levels of sensitivity when distinguishing between these children and a non-clinical sample group and also show moderate levels of correlation between ABAS-II scores and scores on various cognitive and IQ assessments (Harrison & Oakland, 2003). For the present study, the ABAS-II was used to compare children on adaptive behaviour scores. Of particular interest were scores on the functional academics and communication domains as these skills constituted part of the conceptual domain which seemed to be of most relevance to the acquisition of numeracy skills. For those children who did not attend a kindergarten, school or other educational institution (Child 14, Child 15, Child 19 and Child 20), only parent (not teacher) ratings were collected. For children who were rated using the 5-21 year old scale (Child 1, Child 4, Child 5, Child 6, Child 9 and Child 10), the Work section was ignored as none of these children were in full or part-time employment. For children on the 2-5 year old scale (Child 2, Child 3, Child 7, Child 8 and all of the children in the Typically Developing Group), this section was rated according to motor skills rather than work. As a result, Motor skills ratings are provided for children in the 2-5 year age range only. In addition, the community use scores are not measured for this age range and therefore are not recorded.

As part of the assessment process, each child in the Autism Group and the Typically Developing Group were also tested using unrelated pictures of objects to ensure that they were able to respond to the instructions which were going to be used. This was done to ensure that the ability of children to respond correctly during tests for untaught relations was unhindered by a lack of understanding of the instructions to be used. The responses that were tested were identical to those that would be used during teaching and testing for stimulus equivalence. These included, “Point to the___”, in which the child was required to identify the picture out of a field of three by pointing; “What is it?”, in which the child was required to orally name the item in the picture; and “Match this”, in which the child was required to point to a matching item.

The children in the Autism Group were included in the study regardless of their scores on the PPVT-IV and ABAS-II. Children in the Typically Developing Group were included in the study if they scored within the 3-4 year old range on the PPVT-IV, that is, within the range of PPVT-IV scores obtained by the children in the Autism Group. Children in the Typically Developing Group were included regardless of their ABAS-II scores.

If children in either group were unable to follow the instructions to be used during teaching and testing, then they were taught to do so. All of the children in the Typically Developing Group were able to respond correctly to each of these instructions without requiring additional teaching. Most of the children in the Autism Group were also capable of responding correctly with the exception of two children who required teaching for a pointing response. These were Child 8 and Child 10. A summary of each participant’s chronological age, PPVT-IV age equivalent score, and ABAS-II scores are presented in Tables 6 and 7.

Table 6. Chronological Ages, PPVT-IV Scores and ABAS-II Scores for Each of the Ten Children in the Autism Group

Participant	C.A.	PPVT-IV	COM	CU	FA	SL/HL	HS	LS	SC	SD	SOC	MO/WK
Child 1	5.7	4:11	5 **	4 **	5 **	6 ***	7 ***	6 ***	4 **	6 ***	4 **	-
			5 **	5 **	5 **	5 ***	6 ***	5 ***	3 *	7 ***	7 ***	
Child 2	4.5	3:6	1 *	4 **	4 **	7 ***	2 *	3 *	3 *	6 ***	4 **	4 **
			2 *	-	1*	1*	1*	1*	2*	2*	1*	5**
Child 3	5.0	4:8	2 *	1 *	12 ****	7 ***	1 *	5 **	3 *	6 ***	2 *	11 ****
			5 **	-	11****	12****	7***	7 ***	10****	9****	8****	11 ****
Child 4	11.5	2:9	1 *	1 *	1 *	1 *	1 *	1 *	1 *	1 *	1 *	-
			1 *	1 *	1 *	1 *	1 *	1 *	1 *	1 *	1 *	
Child 5	8.5	8:5	1 *	2 *	2 *	2 *	3 *	1 *	7 ***	1 *	1 *	-
			1 *	2 *	3 *	2 *	2 *	2 *	7 ***	4 **	1 *	
Child 6	6.6	3:8	1 *	1 *	2 *	2 *	2 *	4 **	2 *	2 *	1 *	-
			1*	1*	5 **	1*	1*	2*	2*	1*	1 *	
Child 7	4.11	2:6	1 *	1 *	6***	1*	1 *	1 *	1*	2 *	1*	4 **
			1 *	-	3*	1 *	1*	1*	1*	1*	1*	2*
Child 8	4.6	3:4	3 *	6 ***	8 ****	5 **	4 **	7 ***	3 *	8 ****	3 *	4 **
			6***	-	4 **	6***	3 **	3**	1 *	5 **	1 *	4 **
Child 9	6.1	5:5	1 *	3 *	5 **	7 ***	7 ***	8 ****	9 ****	8 ****	8 ****	-
			1 *	6 ***	6 ***	3 *	5 **	2 *	1 *	1 *	1 *	
Child 10	9.1	5:3	1*	1*	1*	1*	1*	1*	1*	1*	1*	-
			1*	1*	1*	1*	1*	2*	1*	1*	1*	
	Mean	54 months										
	SD	18 months										

C.A.: Chronological age. PPVT-IV: Age-equivalent score in years and months
ABAS-II COM :communication.CU: community use, FA: functional academics, SL: school living. HS: health and safety/, LS: leisure skill, SC: self-care, SD: self-determination, SOC: social skills MO: motor skills, WK: work skills.
*Line 1: parent ratings, Line 2: teacher ratings. *Extremely low ** Borderline *** Below Average **** Average ***** Above Average ****** Superior*

Table 7. Chronological Ages, PPVT-IV Scores and ABAS-II Scores for Each of the Ten Children in the Typically Developing Group

Participant	C.A	PPVT-IV	COM	CU	FA	SL/HL	HS	LS	SC	SD	SOC	MO/WK
Child 11	3:3	2:11	13 ***** 10 ****	13 ***** -	9 **** 10 ****	16****** 11 ****	13 ***** 8 ****	12 ***** 8 ****	6 *** 12 *****	12 ***** 11 ****	11 **** 7 ***	11 **** 10 ****
Child 12	3:4	3:8	9 **** 10 ****	10 **** -	11 **** 12 *****	8 **** 12 *****	9 **** 11 ****	9 **** 11 ****	6 *** 11 ****	10 **** 15 ******	8 **** 15 ******	8 **** 9 ****
Child 13	3:6	3:11	14 ***** 11 ****	12 **** -	16****** 12 *****	9 **** 14 *****	9 **** 12 *****	13 ***** 8 ****	7 *** 15 ******	12 ***** 13 *****	11 **** 13 *****	14 ***** 16 ******
Child 14	3:5	4:1	14 ***** -	11 **** -	14 ***** -	12 ***** -	10 **** -	13 ***** -	11 **** -	12 ***** -	13 ***** -	13 ***** -
Child 15	3:6	3:10	11 **** -	10 **** -	9 **** -	6 *** -	8 **** -	11 **** -	4 ** -	8 **** -	8 **** -	10 **** -
Child 16	3:1	4:2	11 **** 14 *****	11 **** -	9 **** 7 ***	7 *** 11****	8 **** 10 ****	12 ***** 14 *****	7 *** 11****	7 *** 12*****	12 ***** 12*****	8 **** 7 ***
Child 17	3:5	3:5	9 **** 10 ****	9 **** -	8 **** 10 ****	7 *** 8 ****	8 **** 10 ****	9 **** 12 *****	5 ** 13 *****	11 **** 11 ****	9 **** 12 *****	8 **** 13 *****
Child 18	3:7	3:7	11 **** 9 ****	6 *** -	9 **** 12 *****	8 **** 11 ****	5 ** 8 ****	6 *** 7 ***	4 ** 8 ****	7 *** 10 ****	7 *** 7 ***	5 ** 11 ****
Chid 19	3:3	4:3	14 ***** -	16****** -	14 ***** -	9 **** -	9 **** -	14 ***** -	7 *** -	13 ***** -	12 ***** -	14 ***** -
Child 20	3:2	3:8	14 ***** -	12 ***** -	13 ***** -	14 ***** -	10 **** -	14 ***** -	7 *** -	11 **** -	12 ***** -	14 ***** -
	Mean	45 months										
	SD	5 months										

C.A.: Chronological age. PPVT-IV: Age-equivalent score in years and months
ABAS-II COM :communication. CU: community use, FA: functional academics, SL: school living. HS: health and safety/, LS: leisure skill, SC: self-care, SD: self-determination, SOC: social skills MO: motor skills, WK: work skills.
*Line 1: parent ratings, Line 2: teacher ratings. *Extremely low ** Borderline *** Below Average **** Average ***** Above Average ****** Superior*

Number Knowledge Screening

Prior to teaching, each child's number knowledge was assessed to ensure that, first, the child was not already familiar with number concepts beyond 14 and, secondly, to identify any pre-teaching that would be required. This assessment was also used to determine the point in the number sequence 1 to 14 where teaching was to commence. Number knowledge screening involved the following tests: (1) numeral reading – hold up a written numeral and ask the child to name the numeral, (2) aural-written number matching – display three numerals in front of the child and ask them to identify a particular numeral by pointing to it or handing it to the tester, (3) rote counting – the child was asked count as far as they can without any objects present, (4) counting with one-to-one correspondence – objects were put in front of the child and they were asked to count how many items there were, (5) number comprehension – the child was shown a numeral and then asked to give the tester that many cubes, (6) quantity naming – children were shown a card with an array of dots and asked how many dots there were without counting them and, (7) quantity comprehension – the child was presented with three cards and asked to point to or hand over the card with a given number of dots on it. The screening test sequence is outlined in Table 8.

Table 8. The Screening Test Sequence for Each Participant using the Example of "Three"

Stimulus	**Response**	**Relation**
1. Child sees the numeral 3	Child says the word "three"	Numeral reading
2. Child hears the word "three"	Child selects the numeral 3	Aural written number matching
3. Child asked to count	Child rote counts (no cubes present)	Rote counting
4. Child presented with cubes	Child counts cubes	Counting (one-to-one correspondence)
5. Child sees numeral 3	Child gives 3 cubes	Number comprehension
6. Child sees the quantity card representing 3	Child says the word "three"	Quantity naming
7. Child hears the word "three"	Child selects the quantity card representing 3	Quantity comprehension

During the screening test, for all children, the numeral and quantity first presented was 3. If the child demonstrated the appropriate responses for 3, then the tester moved to 5. If the child continued to perform correctly then the tester moved to 7, and so on. If the child responded incorrectly, they were re-tested on that number task. If they responded incorrectly again, the tester moved to the immediately preceding number (e.g., from 7 to 6). If they responded correctly, this was deemed to be their current level of number knowledge. This procedure was followed for all of the skills outlined in the screening assessment. Children were not prompted in any way or given feedback on their performance during screening tests.

If a child was not able to identify or name and/or comprehend written numerals and quantities beyond 14 then they met the criteria for inclusion in the study. Children who did not demonstrate any numerical understanding were taught to count with correspondence up to 6, to ensure that they had the pre-requisite skills necessary for inclusion in the study. Child 2 was the only child that required this pre-teaching. The results from the number knowledge screening tests for each child in the Autism and Typically Developing Groups are shown in Tables 9 and 10.

Characteristics of the Participants

While all children met all screening criteria, there was nevertheless some variability across the participating children in each group. This variability is described below for each of the ten children in (a) the Autism Group and (b) the Typically Developing Group.

Child 1. Child 1 was 5 years 7 months when teaching commenced. He was diagnosed by a developmental paediatrician at the Ministry of Education. As part of this diagnosis he was formally assessed using the Wechsler Nonverbal Scale of Ability (WNV). Results indicated that he performed within the average range for 5 year olds on subtests of the WNV. Child 1 received an age equivalent score of 4 years 11 on the PPVT-IV. He scored in the

Table 9. Highest Number Knowledge Screening Scores for Children in the Autism Group

Child	Rote counting	Counting with correspondence	Oral naming of numerals	Numeral recognition	Numeral comprehension	Quantity naming	Quantity comprehension
Child 1	20	20	12	12	12	6	6
Child 2	0	0	0	0	0	0	0
Child 3	20	20	12	12	0	3	3
Child 4	10	5	4	4	0	3	3
Child 5	10	10	10	10	9	4	5
Child 6	20	15	11	11	11	4	5
Child 7	3	3	4	4	0	3	3
Child 8	14	12	12	12	9	4	4
Child 9	19	12	10	10	5	4	4
Child 10	6	6	3	5	0	2	2

Table 10. Highest Number Knowledge Screening Scores for Children in the Typically Developing Group

Child	Rote counting	Counting with correspondence	Oral naming of numerals	Numeral recognition	Numeral comprehension	Quantity naming	Quantity comprehension
Child 11	12	6	0	0	0	0	0
Child 12	12	3	3	3	0	2	2
Child 13	18	14	11	11	11	5	5
Child 14	13	13	3	3	3	3	3
Child 15	5	5	3	3	3	3	3
Child 16	14	13	8	8	4	4	4
Child 17	10	2	0	0	0	2	2
Child 18	10	10	5	5	4	2	5
Child 19	10	6	0	3	3	3	3
Child 20	12	5	0	10	0	0	0

borderline or below average range for each of the developmental areas assessed in the ABAS-II on both the parent and the teacher forms. He was able to count up to 20 and to recognise, name, and demonstrate comprehension of quantities to 12.

Child 2. Child 2 was 4 years 5 months old at the time that teaching commenced. He was diagnosed at the age of 3 years 2 months by a developmental paediatrician at the Ministry of Education. Child 2 received an age-equivalent score of 3 years 6 months on the PPVT-IV. Parent ratings were in the extremely low range for all ABAS-II teacher ratings except motor skills. He scored in the extremely low range for communication, leisure skills, self-care, and health and safety, and in the borderline to below average range in community use, functional academics, home living, self-determination and social domains. When teaching commenced, Child 2 did not demonstrate any knowledge or understanding of number concepts.

Child 3. Child 3 was diagnosed at 2 years and 10 months of age by a developmental paediatrician. Selected items of the BSID and the Merrill-Palmer Revised Scales of Development (Roid & Sampers, 2004) were administered at 3 years 2 months of age. He scored above age expectations in the area of visuo-spatial skills and fine motor skills, and at an age-appropriate level in tests for cognitive skills (though specific age equivalent scores were not reported for this domain). On assessments of language development, it was reported that receptive language skills were difficult to assess though it appeared he had acquired a few object names and was able to follow simple directions. At this point some sounds were developing though no coherent words were reported.

Child 3 was 4 years 8 months old at the time when teaching commenced. He achieved an age equivalent score of 3 years 1 month on the PPVT-IV. Based on the parent rating scale of the ABAS-II, he was in the extremely low range for communication skills and in the average range for functional academics. Based on the day care provider ratings, he was in the average range for functional academics and in the borderline range for communication skills. In all other areas he rated in the below average to average range by his day care provider and in the extremely low to average range by his parent. Prior to teaching, Child 3 was able to rote count up to 20. He was also able to recognise and label numerals to 12 and quantities to 3**.** He did not demonstrate any number comprehension skills.

Child 4. Child 4 was diagnosed by a private clinical psychologist. Assessments that were conducted included the Child Autism Rating Scale (CARS) (Schopler, Reichler, & Rochen-Renner, 1993) and the ABAS-II. The CARS indicated that Child 4 had Moderate Autism and overall indications based on ABAS-II scores and CARS indicate that she was functioning at a level of 1 to 2.5 years of age. Child 4 was 11 years 5 months when teaching commenced. Her age equivalent score on the PPVT-IV was 2 years 9 months. Child 4 scored in the extremely low range in all domains on both the parent and teacher rating forms of the ABAS-II. These ratings were consistent with those previously obtained by the clinical psychologist. ABAS-II ratings indicate that Child 4 scored significantly higher in the conceptual skills domains than in the practical skills domains. Prior to teaching she was able to rote count up to 10 and count with one-to-one correspondence up to 5. She was able to name and recognise numerals up to 4, and quantities up to 3. However she did not demonstrate any comprehension skills.

Child 5. Child 5 received a diagnosis of ASD from a developmental paediatrician appointed by the Ministry of Education. No further assessment information was provided for this child. Child 5 was 8 years 5 months old and received an age equivalent score of 4 years 2 months on the PPVT-IV. He received ratings in the extremely low range on the ABAS-II for communication and functional academics from both his parents and his teacher. In most other developmental domains Child 5 received extremely low to below average ratings. Parent and teacher ratings of self-care were in the below average range while for self-determination, he scored in the borderline range for teacher ratings and extremely low range for parent ratings. Prior to teaching, Child 5 was able to count up to 10 by rote and with one-to-one correspondence. He was able to recognise and name numbers up to 10, recognise quantities up to 5, label quantities to 4 and demonstrate comprehension up to 9.

Child 6. Child 6 was referred to a developmental paediatrician following an initial appointment with a GP initiated by the child's parents. He was diagnosed as having ASD based on DSM-IV criteria. Child 6 was assessed using the Vineland Adaptive Behavior Scales (VABS) by a clinical psychologist. This assessment indicated that Child 6 was functioning in the preschool age range on all developmental domains. Child 6 was aged 6 years 6 months at the time that teaching commenced. He obtained an age equivalent score of 3 years 8 months on the PPVT-IV. He scored in the extremely low range in almost all developmental domains on both the teacher scale and the parent scale on the ABAS-II. Exceptions were leisure skills where his parents and teacher rated him as being in the borderline range. Child 6 was able to rote count to 20 and count with one-to-one correspondence up to 15. He was able to name and recognise numerals to 12 and he demonstrated comprehension up to 12. He was able to label quantities to 5 and recognise quantities to 4.

Child 7. This child received their diagnosis through a developmental paediatrician at the age of 2 years and 8 months. An assessment was conducted by a private clinical psychologist when he was 4.5 years old. This child was assessed using the Mullen Scales of Early Learning (Mullen, 1995). He scored in the very low range on all measures, including visual reception, fine motor, receptive language and expressive language. The Vineland Adaptive Behaviour Scales were also used as part of this assessment and findings indicated that he had adaptive skills in the 1 to 2 year age range. Child 7 was 4 years and 11 months old when teaching commenced. He received an age equivalent score of 2 years and 6 months on the PPVT-IV. ABAS-II results indicated that Child 7 scored in the extremely low range for all developmental domains based on both teacher ratings and parent ratings, with the exception of functional academics where he scored in the below average range based on the parent rating. Prior to teaching he was able to rote count and count with one-to-one correspondence up to three. He was able to recognise and name numerals to 4. Child 7 did not demonstrate any comprehension of numerals but was able to recognise and label quantities up to 3.

Child 8. Child 8 was 4 years and 6 months old when teaching commenced. He had been assessed and diagnosed by a paediatrician. The assessment (which was conducted when he was 4 years 3 months of age) used the Griffiths Mental Development Scales-Extended Revised (Griffiths & Huntly, 1996). This indicated that he was below the 1st percentile in all developmental domains and functioning developmentally at approximately a 3-year old level. Results on the PPVT-IV showed that Child 8 had an age equivalent score of 3 years 4 months on the PPVT-IV. Parent rated ABAS-II scores demonstrated that he was in the extremely low range for communication, self-care and social skills. He scored in the average range for functional academics and self-determination, and in the borderline or below average range for all other developmental areas that were assessed. Teacher rated ABAS-II scores indicated that Child 8 was in the borderline to below average range for all developmental areas with the exception of self-care and social domains in which he scored in the extremely low range. Prior to teaching he was able to rote count up to 14 and count with correspondence up to 12. He was able to recognise and name numerals to 12, comprehend numerals to 9, and recognise and label quantities to 4. Child 8 also required teaching to respond correctly to specific instructions such as “Show me”.

Child 9. Child 9 was 6 years 1 month old at the time that teaching commenced and she was in a new entrant class. Child 9 was diagnosed by a developmental paediatrician and also a private clinical psychologist at the age of 6 years 3 months. As part of the diagnostic process the Autism Diagnostic Interview-Revised (Rutter, Le Couteur, & Lord, 2003) was administered. This assessment resulted in an Autism Spectrum Disorder diagnosis. Child 9 received an age equivalent score of 5 years 5 months on the PPVT-IV and her ABAS-II ratings were in the extremely low range for communication and in the borderline to below average range for functional academics. She scored in the below average to average range in all other domains based on teacher ratings but in the extremely low to below average range for the remaining domains based on parental rating. Prior to teaching Child 9 was able to rote count to 19 and count with one-to-one correspondence up to 12. The participant was able to name and recognise numerals to 10, recognise and label quantities to 4 and comprehend numerals to 5.

Child 10. Child 10 was aged 9 years 1 month when teaching commenced. He was diagnosed by a paediatrician. As part of the diagnosis a BSID-II was conducted by a psychologist at the Ministry of Education. Child 10 was 4 years 4 months old at the time that this was administered. Results on the BSID-II indicate that he was functioning cognitively at the 16-month level. On the PPVT-IV he obtained an age equivalent score of 5 years 3 months. It is also worth noting that he had significant difficulty with expressive language relative to his receptive language ability. ABAS-II ratings showed that he was functioning in the extremely low range for all developmental domains on both parent and teacher ratings. Prior to teaching he was able to rote count and also count with one-to-one correspondence up to 6. Child 10 could name numerals up to 3 and recognise numerals to 5. He did not demonstrate comprehension of any numerals but could recognise and name quantities of 1 and 2. Teaching of equivalence relations was delayed as he had difficulty with a number of learning readiness skills (e.g. responding to feedback and prompts, changing responses when stimuli changed). Each of these skills were taught to mastery prior to the introduction of experimental teaching.

Child 11. Child 11 was 3 years 3 months old when teaching commenced. He obtained an age-equivalent score of 2 years 11 months on the PPVT-IV. On the ABAS-II he was rated as within the average to above average range in all developmental domains with the exception of the social domain where his teacher rated him as below average. Parent ratings were in the average to superior range in all developmental domains except self-care where he was rated below average. Prior to teaching he was able to rote count up to 12 and count with one-to-one correspondence up to 6. He was unable to recognise or name any numerals or quantities and did not demonstrate comprehension of any numerals.

Child 12. Child 12 was 3 years 4 months at the time that teaching commenced. She received an age-equivalent score of 3 years 8 months on the PPVT-IV. Child 12 was rated in the average to above average range for most developmental domains by both her parent and her teacher. Exceptions were self-care where she was rated below average, self-determination where she was rated superior and social skills where she was rated superior by her parent. When teaching began, she was able to rote count up to 12 and count with one-to-one correspondence up to 3. She could recognise and name numerals up to 3, and could recognise and label quantities of 1 and 2. Child 12 did not demonstrate any numeral comprehension.

Child 13. Child 13 was 3 years and 6 months of age at the time of teaching. An age-equivalent score of 3 years and 11 months was obtained on the PPVT-IV. Child 13 was rated in the average to superior range for most developmental domains by both her parent and teacher. The exception was self care where her parent rated her in the below average range. Prior to beginning teaching she was able to rote count to 18, and count with one-to-one correspondence to 14. She recognised and named numerals and also demonstrated comprehension up to 11. Quantity recognition and naming was demonstrated up to 5.

Child 14. Child 14 was 3 years and 5 months old at the time that teaching commenced. She had an age-equivalent score of 4 years 1 month on the PPVT-IV. According to parent ratings on the ABAS-II, Child 14 was in the above average range for all developmental domains with the exception of self-care and home living where she was rated in the average range. Teacher ratings were not available for Child 14 as her early childhood educators declined to conduct this assessment. Prior to teaching, Child 14 was able to rote count and also count with one-to-one correspondence up to 13. She was able to identify and name numerals and quantities to 3, and to demonstrate comprehension to 3.

Child 15. Child 15 was 3 years 6 months old at the time that teaching commenced. He obtained an age-equivalent score of 3 years 10 months on the PPVT-IV. Child 15 scored in the below average to average range for all developmental areas assessed on the ABAS-II. He did not attend any early childhood institution and so results are based on parent ratings alone. Prior to teaching, he was able to rote count and count with one-to-one correspondence to 5. He could recognise and name numerals and quantities to 3, and he could comprehend numerals to 3 also.

Child 16. Child 16 was aged 3 years 11 months when teaching began. He received an age-equivalent score of 4 years 2 months on the PPVT-IV. Child 16 scored in the below average to above average range for all developmental domains across both parent and teacher ratings. Number screening assessments indicated that he was able to rote count to 14 and count with one-to-one correspondence to 13 prior to teaching. He was able to recognise and name numerals to 8 and he was able to comprehend, recognise and name quantities up to 4.

Child 17. Child 17 was 3 years and 5 months when teaching began and obtained an age-equivalent score on the PPVT-IV which matched her chronological age. She was placed in the average to above average range for all developmental domains based on parent and teacher ratings with the exception of home living and self-care domains where she was placed in the below average and borderline range respectively by her parent ratings. Prior to beginning to teach, she was able to rote count to 10 and count with one-to-one correspondence to 2. She was not able to recognise or name any numerals or to demonstrate comprehension. She was however, able to recognise and name quantities of 1 and 2.

Child 18. Child 18 was 3 years and 7 months of age when teaching commenced. Her age-equivalent score on the PPVT-IV was 3 years 7 months. Based on her parent and teacher ABAS-II ratings she was in the borderline to average range for all developmental domains and in the above average range for functional academics according to her teacher rating. When the screening test was conducted, she was able to rote count and count with one-to-one correspondence up to 10. She was able to recognise and label numerals up to 5, recognise quantities up to 5, comprehend numbers up to 4 and label quantities to 2.

Child 19. Child 19 was 3 years 3 months of age when teaching began. He received an age-equivalent score of 4 years 3 months on the PPVT-IV. ABAS-II parent ratings were in the average to superior range for all developmental domains except for self-care which was rated below average. Teacher ratings were not available as the child had only been attending preschool for three weeks when teaching commenced. Prior to teaching he was able to rote count to 10 and count with one-to-one correspondence to 6. Child 19 was not able to name any numerals. However he was able to comprehend quantities, recognise numerals, and recognise and label quantities up to 3.

Child 20. Child 20 was 3 years 2 months old when teaching commenced and received an age-equivalent score of 3 years 8 months on the PPVT-IV. Child 20 did not attend an early childhood institution and so teacher ABAS-II ratings are not available. Parent ratings placed him within the above average range on all developmental domains except health and safety and self-determination where he was rated in the average range and self-care where he was rated below average. He was able to rote count to 5 prior to teaching. However he did not demonstrate any other numeracy skills.

Stimulus Materials

The teaching materials developed for the present experiments included one set of flashcards on which the numerals 1-20 were printed and a second set of flashcards that displayed the quantities from 1 to 20. The colour (black), the font and the size of the numerals and quantities was consistent across all teaching materials during each phase. Quantities were represented by black dots presented as random arrays. The quantity cards differed only by array and the number of dots and did not differ in any other way. Only one example was used to represent each numeral and quantity. Two sets of identical materials were used interchangeably to reduce the likelihood that any individuals were responding to irrelevant features of the stimuli, such as damage or blemish marks on the cards. The numeral cards and quantity cards used during the screening assessment were identical to those used during teaching and testing. In addition, the screening materials included 1cm white cubes for the counting and numeral comprehension tests. Examples of the two smallest taught quantities and numerals and the two largest quantities and numerals is provided in Figure 2.

Six consecutive quantities and six consecutive numerals comprised the teaching materials for each child. The materials used during tests for the emergence of untaught equivalence relations were the same as those used during teaching.

During pre-teaching of discriminated responses (i.e., responses to instructions to "show me___" and "what is it?") with Child 8 and Child 10 flashcards with pictures of animals and household objects were used.

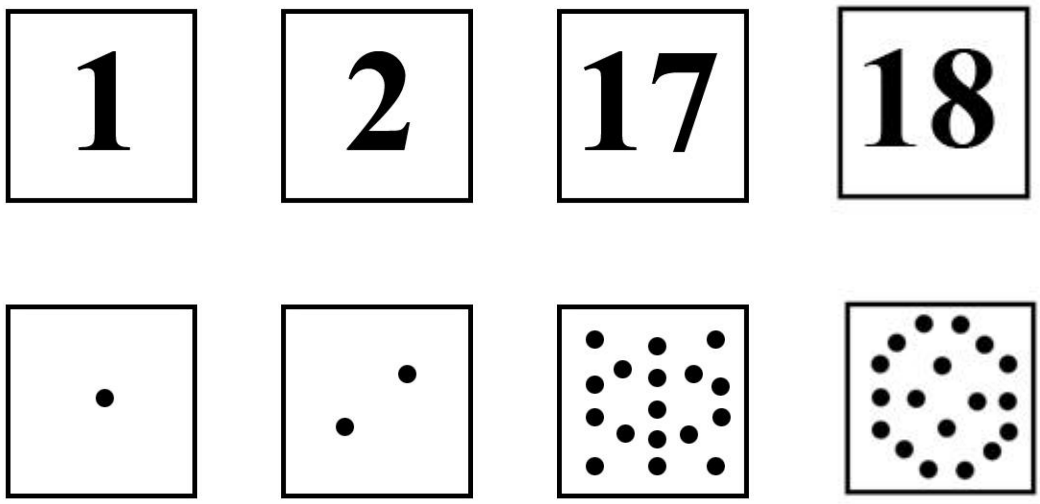


Figure 2. Examples of the two smallest quantities and numerals and the two largest quantities and numerals used during teaching and testing

Teaching Setting

Teaching and testing was undertaken in the individual child's home, school or preschool setting depending on the setting deemed by the child's parent as being the most appropriate and convenient location. Teaching was usually conducted in a private room or quiet area that was free from distraction and was typically conducted at a small table or on the floor with the experimenter sitting across from or next to the child. The parents, education support workers/teacher aides and classroom teacher were invited to observe teaching and testing sessions and did so on occasion. Teachers and parents of each of the 20 children in the study were specifically asked to refrain from teaching any of the number concepts being taught by the experimenter for the duration of the experiment. They were also regularly reminded of this. The parents and teachers of all of the participating children appear to have complied with this request.

Testing Procedures

Tests for Taught Relations

Three test trials were conducted per taught relation for each of the two taught relations (e.g., numeral comprehension and aural-written number matching). If the participant responded with 3 out of 3 correct responses for one of the taught relations then that test was repeated at the beginning of the next session. A taught relation was considered to be mastered if the child responded with 100% accuracy across the three test trials for that relation across two consecutive days. If a child responded incorrectly during a test then teaching for that taught relation continued. Three numerals and the three corresponding quantities were taught in each treatment condition (e.g., 8, 9 and 10). Teaching and testing for the taught stimulus-response relations only stopped when both of the two taught relations for all three quantities were mastered.

In order to ensure the reliability of the decision that taught stimulus-response relations had met mastery criterion, every discriminated response was tested three times over two days. This means that six tests were administered per taught stimulus-response relation.

Tests for Untaught Relations

At the point at which the learner demonstrated mastery of both of the taught stimulus-response relations for all three of the numerals and quantities in the teaching set, testing for the emergence of the untaught relations commenced. This involved tests for symmetry and tests for transitivity. For the case where the child was taught hear-select relations (e.g., child hears the word “one” and selects the numeral 1, and child hears the word “one”, and selects the quantity one) they were tested for the emergence of see-say relations (child sees the numeral 1 and says the name “one” and child sees the quantity 1, and says the name “one”). This was the test for symmetry. The child was also tested for numeral comprehension (child sees the numeral 1 and selects the card with a quantity of 1) and quantity to numeral matching (child sees the card with a quantity of 1 and selects the numeral 1). This was the test for transitivity.

For the case where the child was taught see-say relations the child was tested for the emergence of hear-select relations (child hears the word “one” and selects the card with the quantity 1, and child hears the word “one”, and selects the numeral 1). This was the test for symmetry. Secondly the child was tested for numeral comprehension (child sees the numeral 1 and selects the card with the quantity 1) and quantity to numeral matching (child sees the card with the quantity 1 and selects the numeral 1). This was the test for transitivity.

Generalization testing was always undertaken over two days. The first test was conducted on the day in which the child demonstrated mastery of the three pairs of taught relations. The second test was conducted either one or two days later depending on availability. The four untaught sets of relations were tested individually. Three testing trials were conducted per relation for each of the four sets of untaught stimulus-response relations. If the child responded incorrectly on one of the trials and then proceeded to respond correctly on another trial then on that occasion, four successive testing trials were conducted. Responses were recorded as incorrect if the child made an error or if they did not respond at all. During testing the child was not given assistance, corrective feedback or reinforcement for their responses.

In order to ensure the reliability of the conclusion that children had demonstrated the emergence of untaught equivalence relations, every test for symmetry and every test for transitivity was administered six times (three times on each of two days).

A child was deemed to have demonstrated emergence of an untaught relation if they responded with 100% accuracy across the three trials for that relation or if four testing trials were conducted, and three out of the four responses were correct. If untaught relations did not emerge for some or all of the relations then the testing procedure was repeated the next day or as soon as possible thereafter, as the emergence of untaught relations can be delayed. If untaught relations did not emerge following the two tests then this was the point at which testing ceased for the four untaught relations. The four recording forms which were used are reproduced in Appendix 2, 3, 4, and 5

Experimental Design

The research design utilised for the present experiment was a single-subject AB cross-over design replicated across five plus five children with ASD and five plus five typically developing children.

Experimental Conditions

The effects of two experimental conditions were examined. Experimental Condition A involved teaching the two hear-select stimulus-response relations highlighted in Table 11. This condition will be referred to as the Hear-Select Condition. During Condition A, two equivalence relations were taught for each of three consecutive number concepts.

Experimental Condition B involved teaching the two see-say stimulus-response relations highlighted in Table 12. This condition will be referred to as the See-Say Condition.

During Condition B, two equivalence relations were taught for three consecutive number concepts.

Table 11. The Stimulus-response Relations that were Taught and Tested during the Hear-Select Condition

Stimulus	Taught response	Type of relation
1. Child hears the word "one" A	**Child selects the quantity 1 B**	**Comprehension A-B**
2. Child sees the quantity 1 B	Child says "one" A	Oral naming B-A
3. Child hears the word "one" A	**Child selects the numeral 1 C**	**Aural-written numeral matching A-C**
4. Child sees the numeral 1 C	Child says the word "one" A	Reading C-A
5. Child sees the numeral 1 C	Child selects the quantity 1 B	Reading comprehension C-B
6. Child sees the quantity 1 B	Child selects the numeral 1 C	Quantity-numeral matching B-C

The two taught relations are in bold.

Table 12. The Stimulus-response Relations that were Taught and Tested during the See-Say Condition.

Stimulus	Taught response	Type of relation
1. Child hears the word "one" A	Child selects the quantity 1 B	Comprehension A-B
2. Child sees the quantity 1 B	**Child says "one" A**	**Oral naming B-A**
3. Child hears the word "one" A	Child selects the numeral 1 C	Aural-written numeral matching A-C
4. Child sees the numeral 1 C	**Child says the word "one" A**	**Reading C-A**
5. Child sees the numeral 1 C	Child selects the quantity 1 B	Reading comprehension C-B
6. Child sees the quantity 1 B	Child selects the numeral 1 C	Quantity-numeral matching B-C

The two taught relations are in bold.

Six number quantities were taught. These were divided into two sets: Set 1 which consisted of the first three consecutive unknown number concepts and Set 2 which consisted of the next three consecutive unknown number concepts for each child. The particular number quantities taught to each child are shown in Table 13.

The two experimental conditions were crossed with the two sets of teaching content. The first experimental treatment (Treatment A+B) involved teaching Set 1 and Set 2 in the order Condition A followed by Condition B. The second experimental treatment (Treatment B+A) involved teaching Set 1 and Set 2 in the order Condition B followed by Condition A. The children in the ASD Group were randomly assigned to the A+B and B+A Treatments and the children in the Typically Developing Group were also randomly assigned to the two treatments. The experimental design is shown in Table 13. Also shown in Table 13 is the experimental treatment experienced by each child, that is, the order in which the two experimental treatments were experienced by each child in each of the two groups of children.

General Teaching Procedure

The general teaching procedure consisted of the following sequence of events: (a) reinforcer assessment, (b) the teaching of prerequisite performance skills, (c) the teaching of prerequisite number skills, (d) the first phase of teaching using discrete trial teaching procedures, (e) testing for the emergence of first phase untaught equivalence relations, (f) teaching for the second phase using discrete trial teaching procedures and (g) testing for the emergence of second phase untaught equivalence relations. The general teaching procedure is shown in the flowchart reproduced in Figure 3.

Table 13. Experimental Design and Teaching Content for each Participant in each Experimental Condition

Autism Group

	Treatment	*A+B*		*Treatment*	*B+A*
	Condition A	*Condition B*		*Condition B*	*Condition A*
Participant	*Number concepts taught (Set 1)*	*Number concepts taught (Set 2)*	*Participant*	*Number concepts taught (Set1)*	*Number concepts taught (Set 2)*
Child 2	1, 2, 3	4 , 5, 6	Child 1	13, 14, 15	16, 17, 18
Child 3	13, 14, 15	16, 17, 18	Child 5	11, 12, 13	14, 15, 16
Child 4	5, 6, 7	8, 9, 10	Child 6	12, 13, 14	15, 16, 17
Child 9	11, 12, 13	14, 15, 16	Child 7	5, 6, 7	8, 9, 10
Child 10	6, 7, 8	9, 10, 11	Child 8	13, 14, 15	16, 17, 18

Typically Developing Group

	Treatment	*A+B*		*Treatment*	*B+A*
	Condition A	*Condition B*		*Condition B*	*Condition A*
Participant	*Number concepts (Set 1)*	*Number concepts (Set 2)*	*Participant*	*Number concepts (Set 1)*	*Number concepts (Set 2)*
Child 12	4, 5, 6	7, 8, 9	Child 11	1, 2, 3	4, 5, 6
Child 13	12, 13, 14	15, 16, 17	Child 14	4, 5, 6	7, 8, 9
Child 18	6, 7, 8	9, 10, 11	Child 15	4, 5, 6	7, 8, 9
Child 19	4, 5, 6	7, 8, 9	Child 16	5, 6, 7	8, 9, 10
Child 20	2, 3, 4	5, 6, 7	Child 17	3, 4, 5	6, 7, 8

Reinforcer Preference Assessment and Reinforcement Procedures

Prior to teaching, the parents of each of the children were asked about their child's preferences in toys. In addition, the researcher sat down with each child and informally established which of the available items were most highly preferred. This was done to establish items that might function as reinforcers for each individual child. The items that were used as reinforcers differed for each child but were most commonly items such as trains, bubbles, balloons, cars, Barbie dolls, littlest pet shop and a tea set.

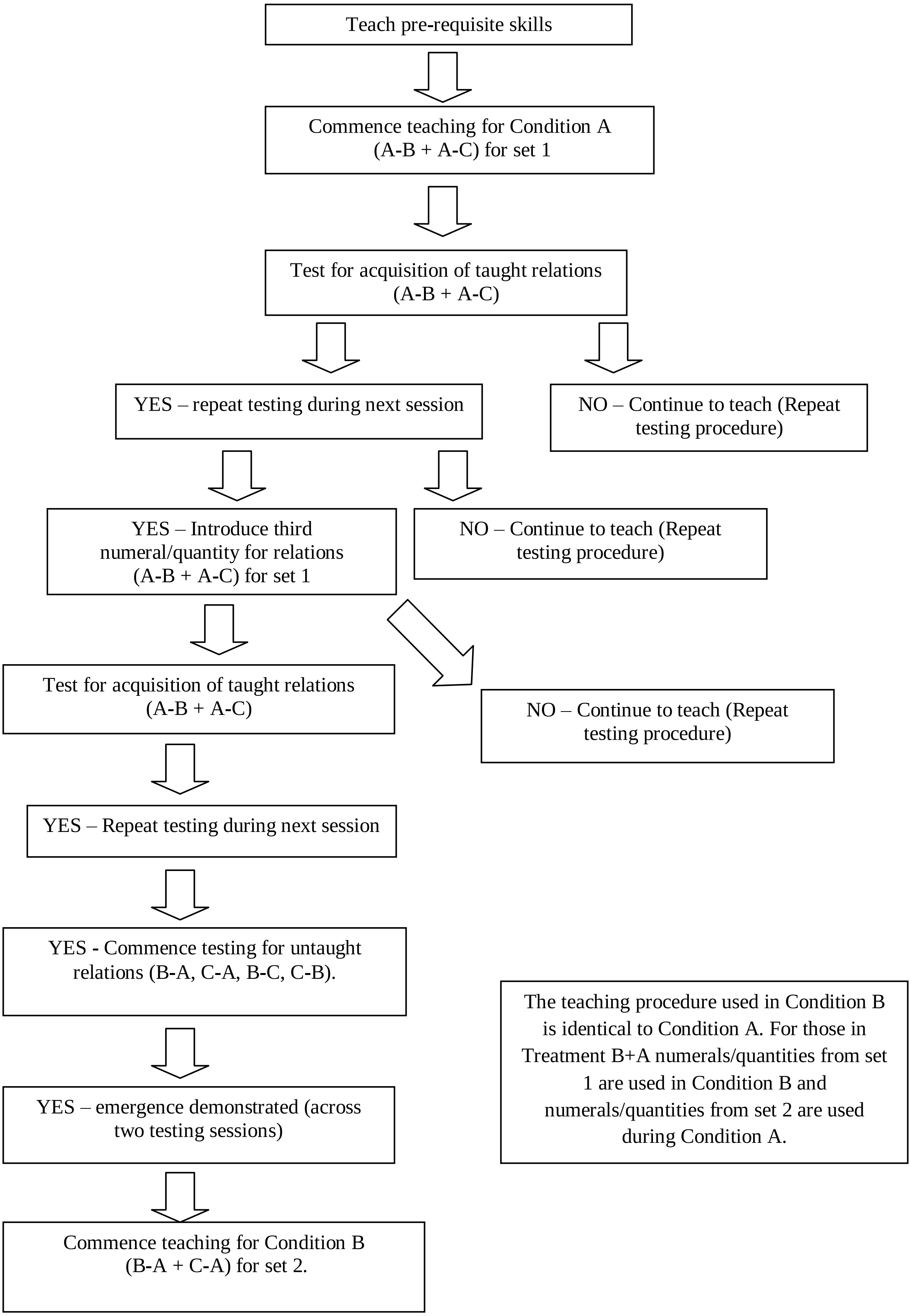


Figure 3. The pre-teaching, teaching, and testing sequence for Treatment A+B.

Teaching Method

The teaching method used in the present experiment was discrete trial teaching. Discrete trial teaching consists of three parts. A is the discriminative stimulus such as a question or a card plus a question. B is the behaviour or response which follows (e.g., the child correctly identifies the item, fails to identify the item or does not respond at all). If the child made an error, he or she was provided with a prompt where the teacher repeated the question and then modelled the correct response. During teaching Condition A, a hand-over-hand prompting procedure was used. During teaching Condition B, a verbal model of the correct response was provided as a prompt. Following unprompted correct responses, the child was given a token and praise (e.g. “well done, that was it”).

A token system of reinforcement was implemented with the children in the Autism Group and the children in the Typically Developing Group unless they specified that they did not want to use the tokens. This occurred on occasion. Tokens took the form of stickers and children were required to earn up to 6-12 stickers before being given a break and access to a reinforcer of their choice.

All 20 children required prior teaching in order to familiarize them with the token system that was used. This was done using identical picture matching tasks and the stimuli used were materials that were unrelated to numeracy (e.g., pictures of animals and pictures of clothing). During this pre-teaching, the children were provided with a token and verbal praise for each independently correct response. When the child had received all of their tokens they were given the choice of a preferred activity.

Teaching of Prerequisite Performance Skills

Before commencing teaching two children were taught certain pre-requisite skills. Child 8 and Child 10 required teaching in order to help them to understand how to respond to the instruction "point to___". Teaching of this skill was achieved using unrelated pictures of objects and animals. This teaching required very few trials and mastery of the response was achieved after 3-4 sessions. None of the children in the Typically Developing Group required pre requisite skills teaching. Some children were also unfamiliar with a token economy system and so this was explained and demonstrated to each child using unrelated materials, until they became familiar with it.

Teaching of Prerequisite Numeracy Skills

The screening assessments described identified various pre-requisite numeracy skills which needed to be acquired. The discriminated responses that were taught during pre-teaching sessions varied for each child and were dependent on the child's ability to recognise and name numbers, to count, and to recognise and name quantities.

If a child was not able to count or could not count with one-to-one correspondence a minimum of six numbers beyond the point at which teaching was to commence then preteaching of these discriminated responses was undertaken. If a child was able to recognise or name numerals up to a certain point (e.g., up to number 5) but could not recognise or name quantities up to the same level (e.g., could only recognise quantities to 2) then they were taught quantity recognition or quantity naming as a pre-requisite skill so that quantity and numeral concepts were at an even skill level (e.g., quantity recognition was taught up to 5) before starting the experimental teaching. If a child was able to recognise or name quantities up to a certain point (e.g., up to number 10) but could not recognise or name numerals up to the same level (e.g., could only read numerals to 5) then they were taught numeral reading as a pre-requisite skill so that, once again, quantity and numeral concepts were at the same skill level

No comprehension skills were taught regardless of the child's level of skill in this area as this was tested for during tests for the emergence of untaught equivalence relations. Teaching of prerequisite number skills was done using a discrete trial teaching method and modelling with hand-over-hand prompts.

Whether children were taught pre-requisite skills as an identification task or naming task was dependent upon whether they were first taught according to Condition A (the Hear-Select Condition) or Condition B (the See-Say Condition). If children were first taught under Condition A, then they were taught pre-requisite skills as a receptive identification task, with the exception of counting which needed to be verbalised. If the child was taught under Condition B first, then they were taught the pre-requisite skills as an expressive naming task. This was done to ensure that the children hadn't had prior experience in responding in a particular mode to the stimuli which would be used during tests of untaught relations. When individual children indicated that they were able to identify or name numerals to an equal level and were also able to count as high as required, then teaching commenced.

Teaching the Targeted Equivalence Relations

In Condition A (the Hear-Select Condition), children were first taught the A-B (hear the number-select the quantity), and A-C (hear the number-select the numeral) conditional discriminations. When relations A-B and A-C were mastered for all three target numerals and quantities the tests for symmetry and transitivity were undertaken. The emergence of the untaught pairs B-A (see the quantity-say the name), C-A (see the numeral-say the name), B-C (see the quantity-select the numeral) and C-B (see the numeral-select the quantity) were tested.

In Condition B (the See-Say Condition), children were first taught the B-A (see the quantity-say the name), and C-A (see the numeral-say the name), conditional discriminations.

When relations B-A and C-A were mastered for all three target numerals and quantities the tests for the emergence of symmetrical and transitive relations commenced. The emergence of the untaught A-B (hear the number-select the quantity), A-C (hear the number-select the numeral), B-C (see the quantity-select the numeral) and C-B (see the numeral-select the quantity) relations were tested.

During teaching, taught numerals/quantities were presented within a field of three. Two of the numerals/quantities were the teaching targets and one of the numerals/quantities was a mastered numeral/quantity. A field of three was employed to reduce guessing responses.

Teaching and Testing Schedule

Teaching sessions generally lasted for approximately 40 minutes for each child. Each block of teaching and testing took approximately 3-4 minutes. The teaching and testing was scheduled so that each session except the first began with a test for acquisition of one set of taught stimulus-response relations. Following this test the child was provided with a short break. The child was then tested for acquisition of the second set of taught stimulus-response relations. This was followed by another short break. Following these tests, teaching commenced for stimulus-response relations not yet acquired. Teaching was usually conducted in four blocks. Each set of stimulus-response relations was taught twice in this block of four in an alternating order. In between each block of teaching, the child was provided with a short break. At the end of the four blocks of teaching, tests for acquisition of untaught relations were conducted. These two tests were separated by a break. During breaks the children were able to engage in a free play activity of their choice.

Tests for the emergence of untaught stimulus-response relations were conducted at the end of each session but only if the child demonstrated that they had mastered all taught stimulus-response relations. Four sets of tests were conducted. One set for each of the untaught stimulus-response relations. Each test lasted approximately 3-4 minutes and was separated by a short break.

The general teaching and testing procedure is illustrated in Appendix 6 by describing the sequence of teaching and testing operations for Child 2.

CHAPTER 3

RESULTS

The results of the present investigations will be presented in two parts: first, the results of each of the 20 individual experiments and, secondly, the grouped results.

Individual Results

In this section, results will be presented treatment group by treatment group. The order of presentation of the results of each of the individual experiments will be as follows: the results of the five children in the Treatment A+B Autism Group, the results of the five children in the Treatment A+B Typically Developing Group, the results of the five children in the Treatment B+A Autism Group, and the results of the five children in the Treatment B+A Typically Developing Group. An overview of the individual results is presented in Table 14.

Treatment A+B – Autism Group

There were five children in the Treatment A+B Autism Group: Child 2, Child 3, Child 4, Child 9 and Child 10. Children in the Treatment A+B Group were first taught the aural comprehension stimulus-response relation A-B (hear the word – select the quantity) and the aural-written numeral matching relation A-C (hear the word – select the written numeral) for three quantities and then taught the quantity naming relation B-A (see the quantity – say the quantity) and the numeral reading relation C-A (see the numeral – say the numeral) for a further three quantities.

Table 14. Chronological Ages, Treatment Group, Total Trials to Criterion and the Results of Testing for Derived Relations for each Child in the Autism Group and Typically Developing Group.

Child number	Treatment group	Group	Chronological age	Derived relations Condition A	Derived relations Condition B	Total derived relations
2	A+B	Autism	4.5	0	2	2
3	A+B	Autism	5.0	2	2	4
4	A+B	Autism	11.5	0	1	1
9	A+B	Autism	6.1	2	2	4
10	A+B	Autism	9.1	1	1	2
12	A+B	Typically developing	3.4	2	2	4
13	A+B	Typically developing	3.6	2	2	4
18	A+B	Typically developing	3.7	2	2	4
19	A+B	Typically developing	3.3	2	2	4
20	A+B	Typically developing	3.2	2	2	4
1	B+A	Autism	5.7	2	2	4
5	B+A	Autism	8.5	1	1	2
6	B+A	Autism	6.6	2	2	4
7	B+A	Autism	4.11	2	2	4
8	B+A	Autism	4.6	0.5	1	1.5
11	B+A	Typically developing	3.3	1	1	2
14	B+A	Typically developing	3.5	2	2	4
15	B+A	Typically developing	3.6	2	2	4
16	B+A	Typically developing	3.1	2	2	4
17	B+A	Typically developing	3.5	2	2	4

Child 2

Preteaching. Child 2 was not able to respond correctly on any of the screening tasks during the number screening assessment and so the experimental teaching for this child involved the quantities 1 to 6. Prior to experimental teaching, Child 2 was taught to count with one-to-one correspondence from 1 to 6. This required a total of four pre-teaching sessions.

Condition A teaching. The Condition A results for Child 2 are presented in Figure 4 and Table 15. Child 2 was first taught the aural comprehension relationship (A-B) and the aural-written numeral matching relationship (A-C) for the quantities 1, 2 and 3. As can be seen from Table 15, Child 2 required a total of 71 teaching trials to master the A-B relations and a total of 51 trials to achieve mastery of the A-C relations. To master all of the Treatment A+B relations required a total of 122 trials. Child 2 did not demonstrate the emergence of any of the four untaught stimulus-response relations following the Condition A teaching.

Condition B teaching. In Condition B, Child 2 was taught the quantity naming (B-A) and numeral reading (C-A) relations for the quantities 4, 5 and 6. He required a total of 184 trials to master the relations taught in Condition B, 117 teaching trials to master the quantity naming relations and 67 trials to reach mastery of the numeral reading relations. During testing for the emergence of untaught relations, Child 2 demonstrated 100% correct responding on tests for all four of the untaught relations, thus demonstrating both symmetry and transitivity.

Child 3

Preteaching. During the number screening test, Child 3 demonstrated that he was able to rote count and to count with one-to-one correspondence to 20 and that he was able to name and recognise numerals to 12. However, Child 3 was only able to name quantities to 3 and to comprehend quantities to 3. He did not demonstrate any numeral comprehension skills. Based on these results, Child 3 was taught to recognise quantities to 12 before beginning instruction

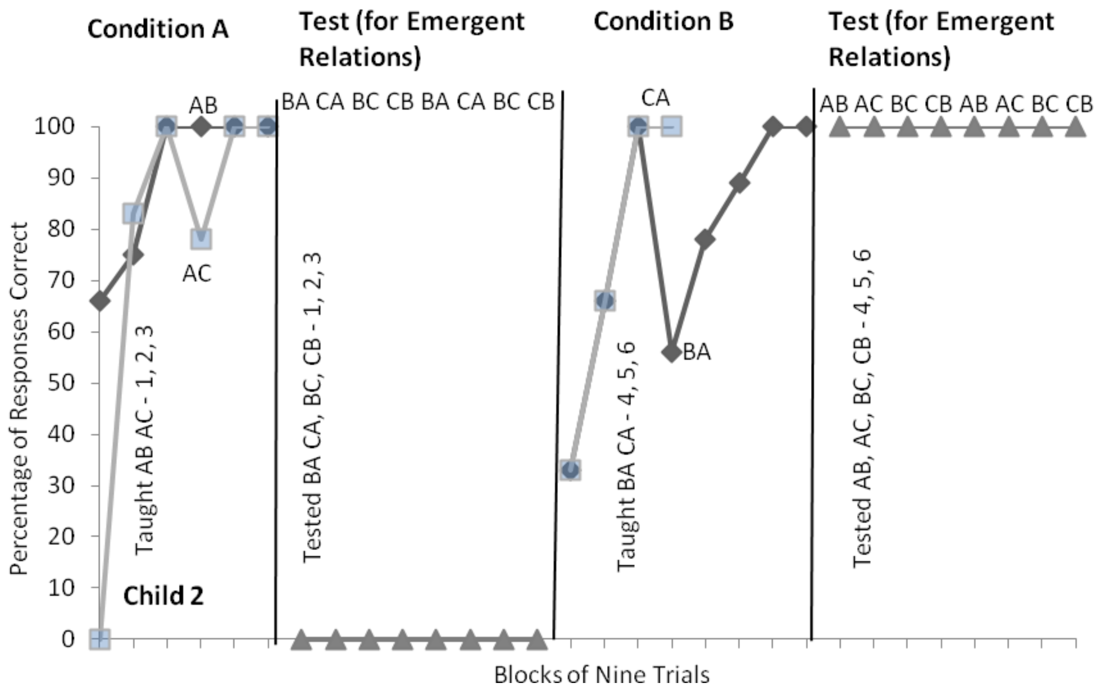


Figure 4. The percentage of correct responses obtained by Child 2 during teaching and testing in Treatment A+B

Table 15. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 2

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
1	35	18	0%	0%	0%	0%
2	25	18	0%	0%	0%	0%
3	11	15	0%	0%	0%	0%
Total:	71	51				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
4	43	17	100%	100%	100%	100%
5	47	24	100%	100%	100%	100%
6	27	26	100%	100%	100%	100%
Total :	117	67				

Relations taught are in bold.

with the numerals and quantities from 13 to 18. The number of pre-teaching sessions required was four.

Condition A teaching. The Condition A results for Child 3 are presented in Figure 5 and Table 16. Child 3 was first taught the A-B and A-C relations for the quantities 13, 14, and 15. As can be seen from Table 16, Child 3 required a total of 55 teaching trials to master the A-B relations and a total of 20 trials to achieve mastery of the A-C relations. To master all of the Treatment A+B relations required a total of 75 trials. During testing for emergence of the untaught relations, Child 3 demonstrated 100% correct responding on tests for all four of the untaught relations, that is, Child 3 demonstrated both symmetry and transitivity.

Condition B teaching. In Condition B, Child 3 was taught the B-A and C-A relations for the quantities 16, 17 and 18. As can be seen in Table 16, Child 3 required 58 teaching trials to acquire B-A relations and 42 trials to acquire C-A relations. A total of 100 trials were needed for Child 3 to master all of the Treatment B+A relations. During tests for derived responding, Child 3 demonstrated 100% correct responding for each of the stimulus-response relations that were tested, therefore demonstrating both symmetry and transitivity.

Child 4

Preteaching. During the number screening test, Child 4 demonstrated an ability to rote count to ten and to count with one-to-one correspondence to five. Child 4 was able to recognise and name numerals to 4 and comprehend and name quantities 1, 2 and 3. She did not demonstrate any numeral comprehension skills. Based on the screening test Child 4 was taught to count with one-to-one correspondence to 10 and to recognise quantities up to 4, prior to commencing teaching for numerals and quantities from 5 to 10. Six pre-teaching sessions were required for Child 4.

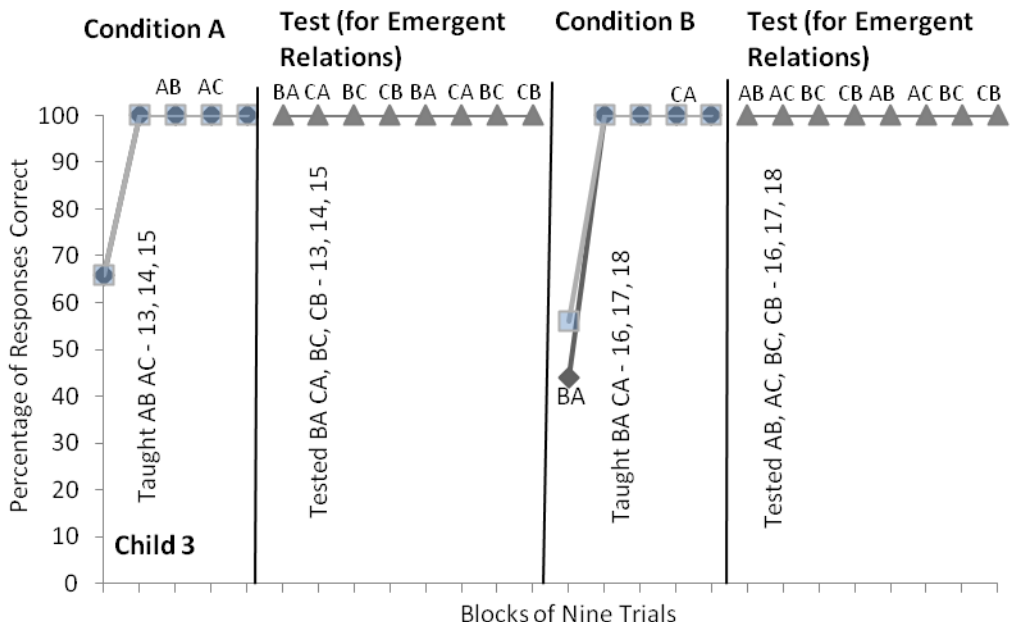


Figure 5. The percentage of correct responses obtained by Child 3 during teaching and testing in Treatment A+B

Table 16. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 3

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
13	**18**	**5**	100%	100%	100%	100%
14	**27**	**4**	100%	100%	100%	100%
15	**10**	**11**	100%	100%	100%	100%
Total:	**55**	**20**				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
16	**17**	**12**	100%	100%	100%	100%
17	**27**	**14**	100%	100%	100%	100%
18	**14**	**16**	100%	100%	100%	100%
Total :	**58**	**42**				

Relations taught are in bold.

Condition A teaching. The results of Condition A teaching for Child 4 can be seen in Figure 6 and Table 17. Child 4 was first taught the comprehension and aural-written numeral matching relations for quantities 5, 6 and 7. As can be seen in Table 16, Child 4 required 78 trials to reach mastery criterion for the A-B relations and 64 trials to reach mastery criterion for the A-C relations. In total 142 trials were required for Child 4 to master all of the Treatment A+B relations. As can be seen in Figure 6, Child 4 did not demonstrate the emergence of untaught relations for any of the stimulus-response relations that were tested. Child 4 therefore, did not demonstrate symmetry or transitivity following Condition A teaching.

Condition B teaching. The results for Condition B teaching are presented in Figure 6 and Table 17. Child 4 was taught the quantity naming and numeral reading relations for quantities 8, 9 and 10. Child 4 required a total of 190 teaching trials to master Treatment B+A relations. 73 trials were required to master C-A relations and 117 trials to master B-A relations. During testing for emergence, Child 4 demonstrated 100% correct responding for the A-B (comprehension) and A-C (aural-written numeral matching) relations, thus demonstrating symmetry. Child 4 did not demonstrate emergence of the untaught C-B (reading comprehension) or B-C (quantity-numeral matching) relations and therefore did not demonstrate transitivity.

Child 9

Preteaching. Child 9 demonstrated during the number screening test that she was able to rote count to 19 and count with one-to-one correspondence from 1 to 12. She was able to recognise and label numerals to 10 and comprehend and name quantities from 1 to 4. Child 9 demonstrated that she could comprehend numbers up to 5. Based on the information obtained in the number screening test, Child 9 was taught to count with one-to-one correspondence up

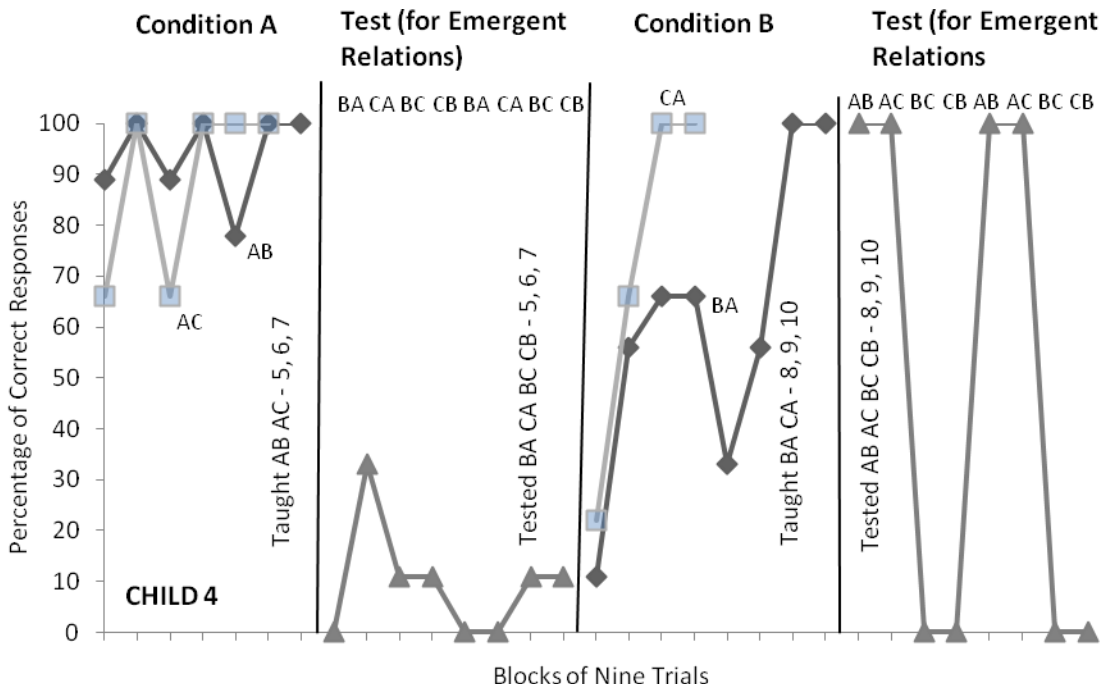


Figure 6. The percentage of correct responses obtained by Child 4 during teaching and testing in Treatment A+B

Table 17. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 4

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
5	15	18	0%	0%	0%	0%
6	39	21	0%	0%	0%	0%
7	24	25	0%	0%	0%	0%
Total:	78	64				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
8	23	22	100%	100%	0%	0%
9	49	25	100%	100%	0%	0%
10	45	26	100%	100%	0%	0%
Total :	117	73				

Relations taught are in bold.

to 16, and to recognise quantities up to ten as part of pre-teaching. Experimental teaching involved numbers and quantities 11 to 16. Child 9 required four pre-teaching sessions.

Condition A teaching. The results for Condition A teaching can be seen in Figure 7 and the first half of Table 18. Child 9 was first taught the A-B (hear the quantity – select the quantity) and A-C (hear the numeral – select the numeral) relations for 11, 12 and 13. As can be seen in Table 18 a total of 63 teaching trials were needed to reach mastery of A-B relations and 45 were required to master A-C relations. To master all of the taught A-B and A-C relations, a total of 108 trials were required. During testing for the emergence of untaught relations, Child 9 demonstrated 100% correct responding for each of the four untaught relations, therefore demonstrating both symmetry and transitivity.

Condition B teaching. Child 9 was taught quantities 14, 15 and 16 in Condition B. The Condition B results are presented in Table 18 and Figure 7. A total of 94 teaching trials were required for Child 9 to acquire each of the stimulus-response relations in Condition B. Sixty six trials were required to reach mastery of B-A relations and 28 were required to reach mastery of C-A relations. As can be seen in Table 18, Child 9 demonstrated both symmetry and transitivity when tested for the emergence of untaught relations. Child 9 responded with 100% accuracy for each of the four relations that were tested.

Child 10

Preteaching. Results of the number screening test indicated that Child 10 was able to rote count, and count with one-to-one correspondence up to six. He was able to name numerals up to 3, recognise numerals to 5, comprehend and recognise quantities 1 and 2. Child 10 did not demonstrate any numeral comprehension skills. During pre-teaching Child 10 was taught to count with one-to-one correspondence up to 11, and to recognise quantities up to 5.

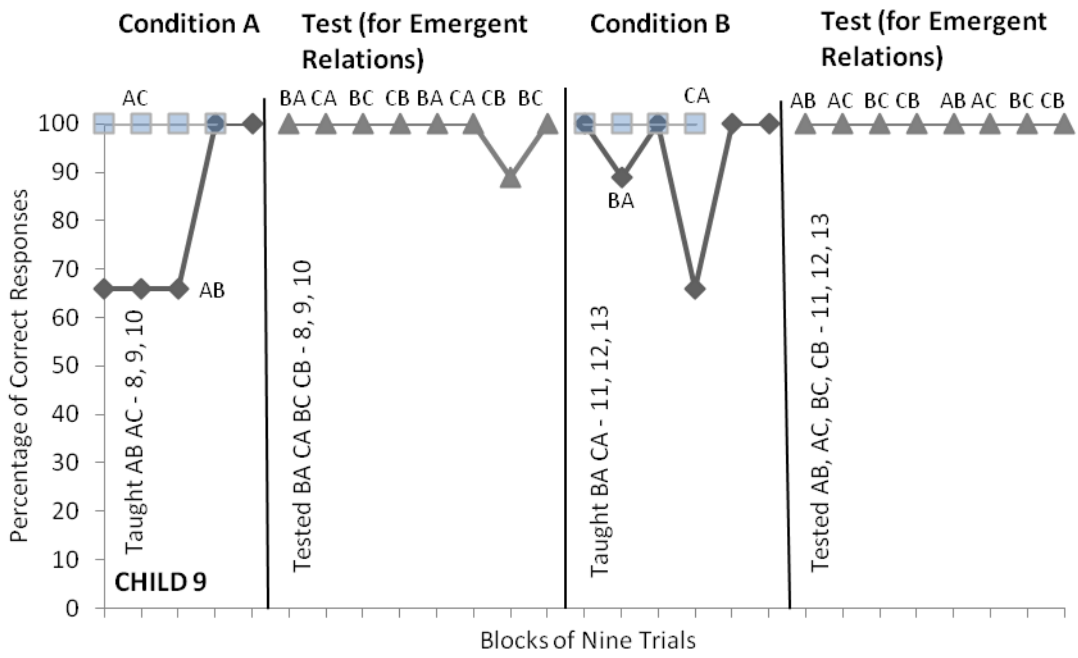


Figure 7. The percentage of correct responses obtained by Child 9 during teaching and testing in Treatment A+B

Table18. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 9

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
11	19	17	100%	100%	100%	100%
12	22	15	100%	100%	100%	100%
13	22	13	100%	100%	100%	100%
Total:	63	45				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
14	19	7	100%	100%	100%	100%
15	24	14	100%	100%	100%	100%
16	23	7	100%	100%	100%	100%
Total :	66	28				

Relations taught are in bold.

Based on the screening test results, Child 10 was taught numbers and quantities 6 to 11. Pre-teaching took a total of three sessions.

Condition A teaching. In Condition A, Child 10 was taught aural comprehension (A-B) and aural-written numeral matching (A-C) for quantities and numbers 6, 7 and 8. He required 119 teaching trials to acquire the A-B relations and 87 teaching trials for the A-C relations, a total of 206 teaching trials. As can be seen in Figure 8 and Table 19, during testing for the emergence of untaught relations, Child 10 demonstrated 100% correct responding for each of the stimulus response relations that were tested for the B-A and C-A relations, thus demonstrating symmetry. However, when tested on C-B and B-C relations he did not produce any correct responses and thus, did not demonstrate transitivity.

Condition B teaching. The Condition B results for Child 10 are presented in Figure 8 and the second half of Table 19. Child 10 was taught numerals and quantities 9, 10 and 11 for the B-A and C-A relations. As is presented in Table 19, a total of 159 teaching trials were required to reach mastery criteria for Condition B. For the B-A relations 105 teaching trials were required and for C-A relations 54 teaching trials were required. The results of the tests for A-B, A-C, B-C and C-B relations are presented in Table 19. The testing results demonstrate that Child 10 responded with 100% accuracy during testing for A-B and A-C relations. However, Child 10 responded with 0% accuracy when tested for C-B and B-C relations thus demonstrating symmetry but not transitivity.

Treatment A+B – Typically Developing Group

There were five children in the Treatment A+B, Typically Developing Group. These were: Child 12, Child 13, Child 18, Child 19 and Child 20. Children in the Treatment A+B Typically Developing Group were first taught the A-B aural comprehension relations (hear the word – select the quantity) and the A-C aural-written numeral matching relations (hear

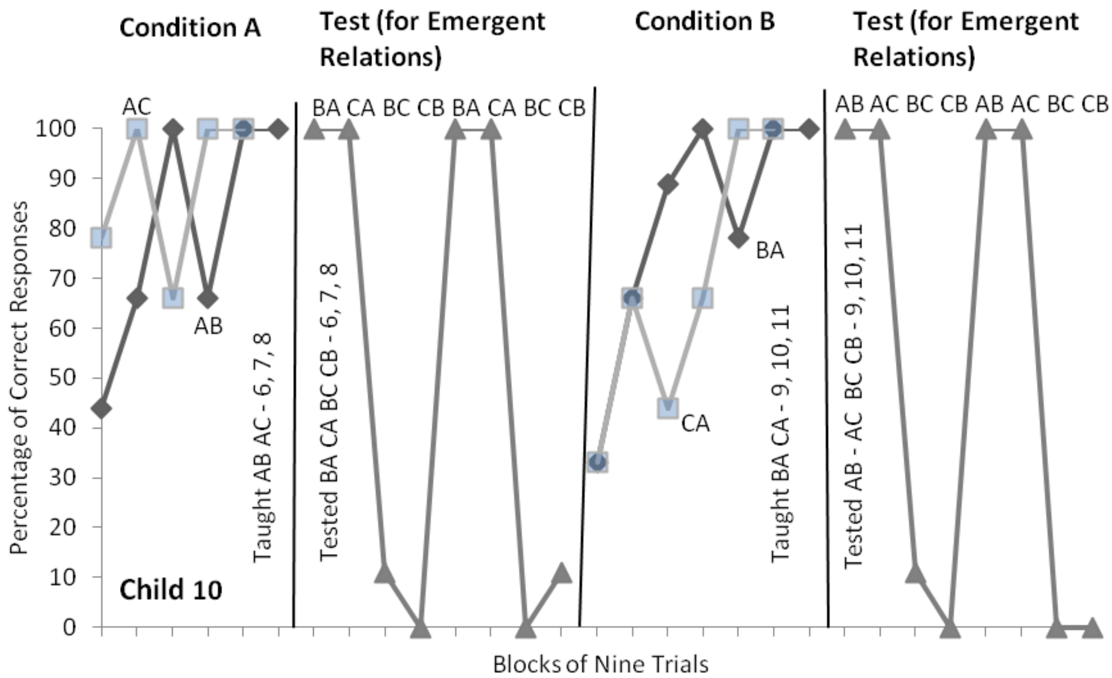


Figure 8. The percentage of correct responses obtained by Child 10 during teaching and testing in Treatment A+B

Table 19. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 10

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
6	43	26	100%	100%	0%	0%
7	49	41	100%	100%	0%	0%
8	27	20	100%	100%	0%	0%
Total:	119	87				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
9	27	22	100%	100%	0%	0%
10	35	24	100%	100%	0%	0%
11	42	19	100%	100%	0%	0%
Total :	104	55				

Relations taught are in bold.

the word – select the numeral) for three quantities and numerals. These children were then taught the B-A quantity naming relation (see the quantity – name the quantity) and the C-A numeral reading relation (see the numeral – name the numeral) for the next three quantities and numerals.

Child 12

Preteaching. During the number screening test Child 12 indicated that she was able to rote count to twelve, could count with one-to-one correspondence to 3, and could recognise and name numerals up to 3. Child 12 could comprehend and label quantities 1 and 2 but did not demonstrate any numeral comprehension skills. Prior to commencing teaching for the numerals and quantities 4 to 9, Child 12 was taught to recognise the quantity 3 and to count with one-to-one correspondence up to 9. Pre-teaching took a total of three sessions.

Condition A teaching. The Condition A results for Child 12 are presented in Figure 9 and the first half of Table 20. Child 12 was first taught the aural comprehension (A-B) and the aural-written numeral matching relations (A-C) for the quantities 4, 5 and 6. As shown in Table 20, Child 12 required a total of 39 trials to master A-B relations and 25 trials to master A-C relations. A total of 64 teaching trials were required to master all of the Treatment A+B relations in Condition A. Child 12 demonstrated 100% correct responding for all four of the untaught equivalence relations that were tested thus demonstrating both symmetry as well as transitivity.

Condition B teaching. The Condition B results for Child 12 are presented in Figure 9 and the second half of Table 20. In Condition B, Child 12 was taught numerals and quantities 7 to 9 for the quantity naming (B-A) and numeral reading (C-A) relations. A total of 195 trials were required to reach mastery of B-A and C-A relations for Condition B. A total of 114 trials were needed to acquire B-A relations, and 81 trials were required to master C-A

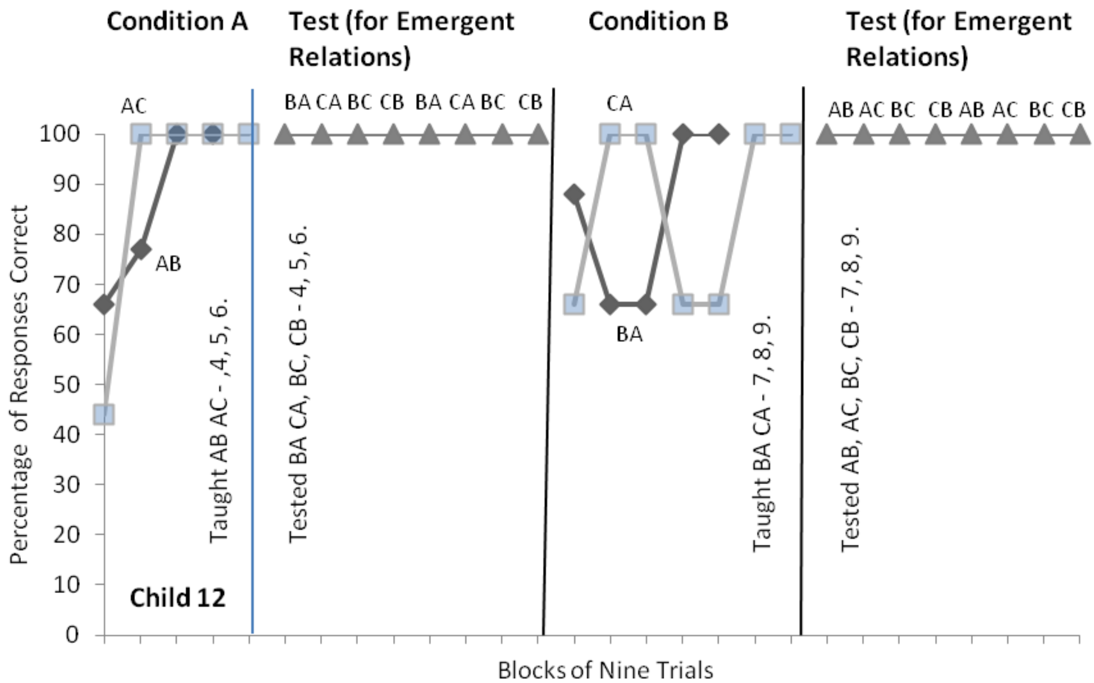


Figure 9. The percentage of correct responses obtained by Child 12 during teaching and testing in Treatment A+B

Table 20. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 12

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
4	11	8	100%	100%	100%	100%
5	16	11	100%	100%	100%	100%
6	12	6	100%	100%	100%	100%
Total:	39	25				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
7	41	21	100%	100%	100%	100%
8	33	22	100%	100%	100%	100%
9	40	38	100%	100%	100%	100%
Total :	114	81				

Relations taught are in bold.

relations. As can be seen in Table 20, Child 12 demonstrated emergence of all four of the untaught stimulus-response relations following Condition B teaching and therefore demonstrated both symmetry and transitivity.

Child 13

Preteaching. During the number screening assessment, Child 13 demonstrated she was able to rote count up to 18 and count with one-to-one correspondence up to 14. She was also able to name numerals, recognise numerals and demonstrate numeral comprehension up to 11. Child 13 could recognise and label quantities up to 5. Prior to experimental teaching, Child 13 was taught to count with one-to-one correspondence up to 17, and to recognise quantities up to 11. Mastery of pre-taught discriminated responses took three sessions. Following pre-teaching, teaching commenced for numerals and quantities 12 to 17.

Condition A teaching. The Condition A results for Child 13 are presented in Figure 10 and the first half of Table 21. In Condition A, Child 13 was taught A-B (hear the quantity – select the quantity) and A-C (hear the numeral – select the numeral) relations for numerals and quantities 12 to 14. She required a total of 67 trials to master the relations that were taught in Condition A, 38 trials to master aural comprehension relations and 29 trials to master aural-written numeral matching relations. During testing for emergence of the untaught relations, Child 13 demonstrated 100% correct responding on tests for all four of the untaught relations, thus demonstrating both symmetry and transitivity.

Condition B teaching. During Condition B, Child 13 was taught B-A and C-A relations for numerals and quantities 15, 16 and 17. The Condition B teaching results are presented in Figure 10 and the second half of Table 21. She took 42 teaching trials to master

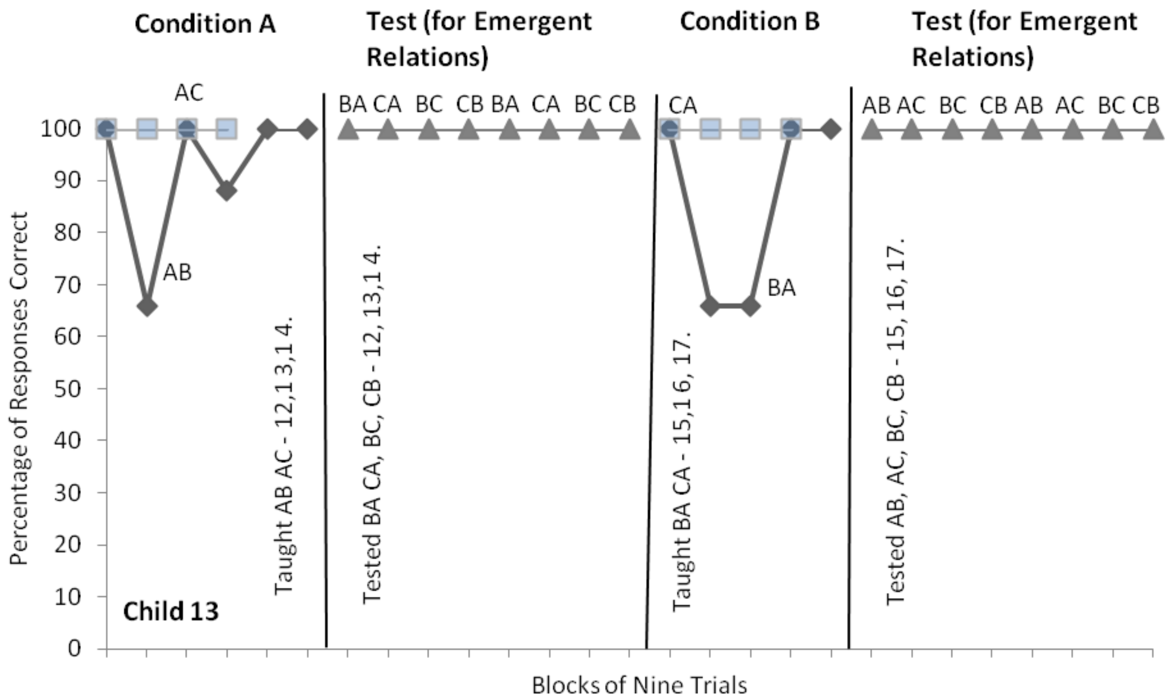


Figure 10. The percentage of correct responses obtained by Child 13 during teaching and testing in Treatment A+B

Table 21. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 13

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
12	15	11	100%	100%	100%	100%
13	16	7	100%	100%	100%	100%
14	7	11	100%	100%	100%	100%
Total:	38	29				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
15	15	9	100%	100%	100%	100%
16	12	7	100%	100%	100%	100%
17	15	7	100%	100%	100%	100%
Total :	42	23				

Relations taught are in bold.

B-A relations and 23 trials to master C-A relations, an overall total of 65 trials for all relations taught in Condition B. During testing for emergence of the untaught relations, Child 13 demonstrated symmetry and transitivity. That is, Child 13 demonstrated 100% correct responding on tests for all four of the untaught equivalence relations.

Child 18

Preteaching. Results of the number screening tests indicated that Child 18 was able to rote count and count with one-to-one correspondence to ten. She could recognise numerals and comprehend quantities to 5, and could name numerals to 5. She demonstrated numeral comprehension up to 4 and was able to name quantities 1 and 2. Before commencing experimental teaching for numerals and quantities 6 to 11, Child 18 was taught to count with one-to-one correspondence to 11. The number of pre-teaching sessions required was three.

Condition A teaching. During teaching for Condition A relations (A-B and A-C) Child 18 was taught numerals and quantities 6, 7 and 8. The results of this teaching are presented in Figure 11 and Table 22. As can be seen from the first part of Table 22, Child 18 required 68 teaching trials to master the A-B relations and 21 trials to master A-C relations (a total of 89 trials). Following teaching of A-B and A-C relations, she was tested for the emergence of the untaught quantity naming (B-A), numeral reading (C-A), reading comprehension (C-B) and quantity-numeral matching (B-C) relations. She responded with 100% accuracy during tests for all four untaught stimulus-response relations.

Condition B teaching. The Condition B results for Child 18 are presented in Figure 11 and Table 22. Numerals and quantities 9, 10 and 11 were taught for B-A and C-A relations in Condition B. A total of 125 trials were needed to reach mastery criteria for Condition B teaching, with 85 and 40 trials for B-A and C-A relations respectively. Child 18 demonstrated

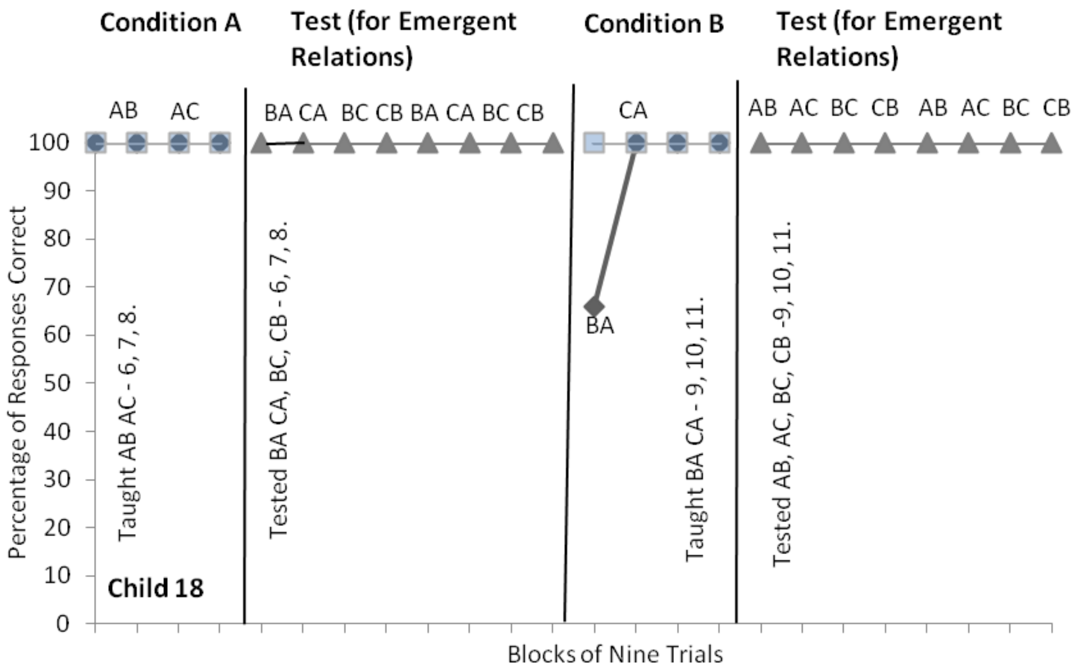


Figure 11. The percentage of correct responses obtained by Child 18 during teaching and testing in Treatment A+B

Table 22. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 18

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
6	20	7	100%	100%	100%	100%
7	29	7	100%	100%	100%	100%
8	19	7	100%	100%	100%	100%
Total:	68	21				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
9	30	15	100%	100%	100%	100%
10	32	18	100%	100%	100%	100%
11	23	7	100%	100%	100%	100%
Total :	85	40				

Relations taught are in bold.

100% correct responding for all of the untaught relations tested and thus demonstrated symmetry and transitivity during testing.

Child 19

Preteaching. During the number screening test, Child 19 demonstrated that he was able to rote count to 10 and count with one-to-one correspondence to 6. He was unable to name numerals. However, he could recognise numerals and comprehend quantities, name quantities, and demonstrate numeral comprehension up to 3. Child 19 was taught to count with one-to-one correspondence to nine before beginning experimental instruction. The number of pre-teaching sessions that was required was four.

Condition A teaching. In Condition A, Child 19 was taught numerals and quantities 4 to 6. As can be seen in Table 23 a total of 72 teaching trials were needed to reach mastery of the A-B and A-C relations, with 42 trials required to reach mastery of A-B relations and 30 teaching trials required to reach mastery of A-C relations. The Condition A testing results for Child 19 are presented in Figure 12 and Table 23. As can be seen in Figure 12, Child 19 demonstrated both symmetry and transitivity with 100% accuracy when tested for emergence of the untaught B-A, C-A, C-B and B-C relations.

Condition B teaching. During teaching Condition B, numerals and quantities 7 to 9 were taught for the quantity naming (B-A) and numeral reading (C-A) relations. As can be seen in the second part of Table 23, Child 19 required a total of 53 teaching trials to learn all of the B-A relations and 61 trials to master each of the C-A relations. An overall total of 114 teaching trials were needed to acquire all of the Condition B relations. As can be seen in Figure 12, Child 19 responded with 100% accuracy on all four tests for each of the untaught stimulus-response relations and therefore demonstrated both symmetry and transitivity.

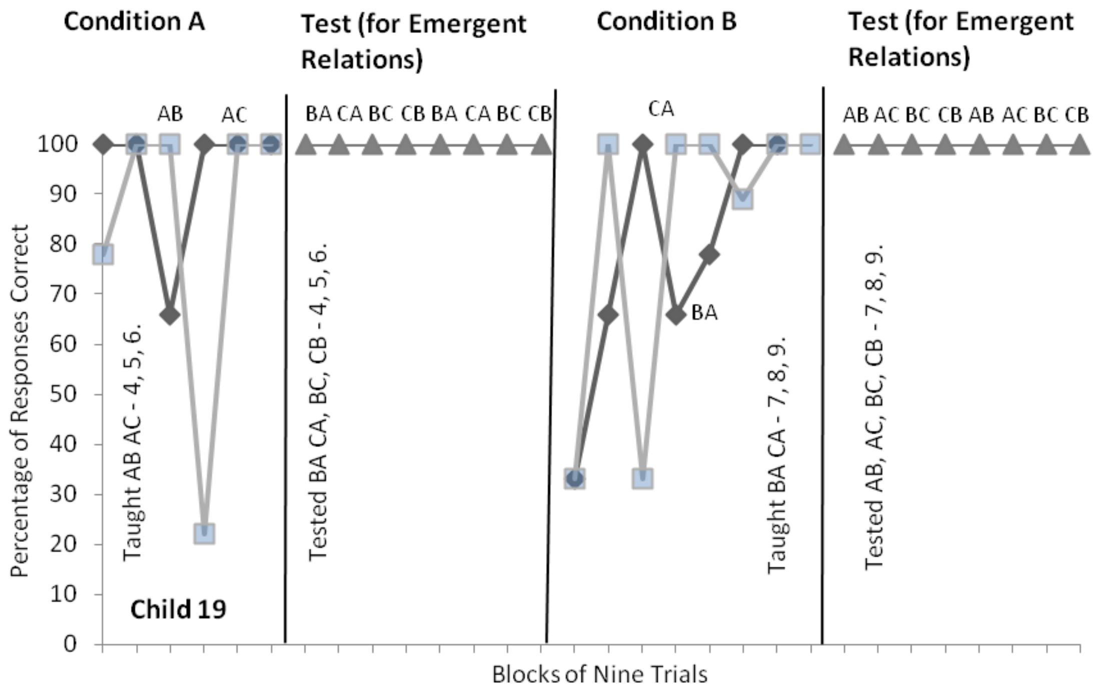


Figure 12. The percentage of correct responses obtained by Child 19 during teaching and testing in Treatment A+B

Table 23. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 19

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
4	11	7	100%	100%	100%	100%
5	20	7	100%	100%	100%	100%
6	11	16	100%	100%	100%	100%
Total:	42	30				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
7	15	21	100%	100%	100%	100%
8	17	17	100%	100%	100%	100%
9	21	23	100%	100%	100%	100%
Total :	53	61				

Relations taught are in bold

Child 20

Preteaching. During the number screening test, Child 20 demonstrated that he was able to rote count to 12 and count with one-to-one correspondence to 5. However, this child did not demonstrate any other number knowledge during the screening test. Child 20 was taught to count with one-to-one correspondence to 6 before beginning instruction with the numerals and quantities 1 to 6. The number of pre-teaching sessions required was three.

Condition A teaching. The Condition A results for Child 20 are presented in Figure 13 and Table 24. Child 20 was first taught the A-B (aural comprehension) and A-C (aural-written numeral matching) relations for numerals and quantities 1, 2 and 3. As can be seen in Table 24, Child 20 required a total of 51 teaching trials to reach mastery of both of the Condition A relations. He required 26 trials for mastery of the A-B relations to be achieved and 25 trials for mastery of the A-C relations. During testing for emergence of the untaught relations Child 20 demonstrated 100% accuracy on tests for all four of the untaught relations and thus demonstrated symmetrical and transitive responding.

Condition B teaching. In teaching Condition B, Child 20 was taught the quantity naming (B-A) and numeral reading (C-A) relations for the quantities 4, 5 and 6. He required a total of 109 trials to master the relations taught in Condition B, 52 trials to master the quantity naming relations and 57 trials to master numeral reading relations. Child 20 demonstrated symmetry and transitivity with 100% accuracy on all four tests of the untaught stimulus-response relations.

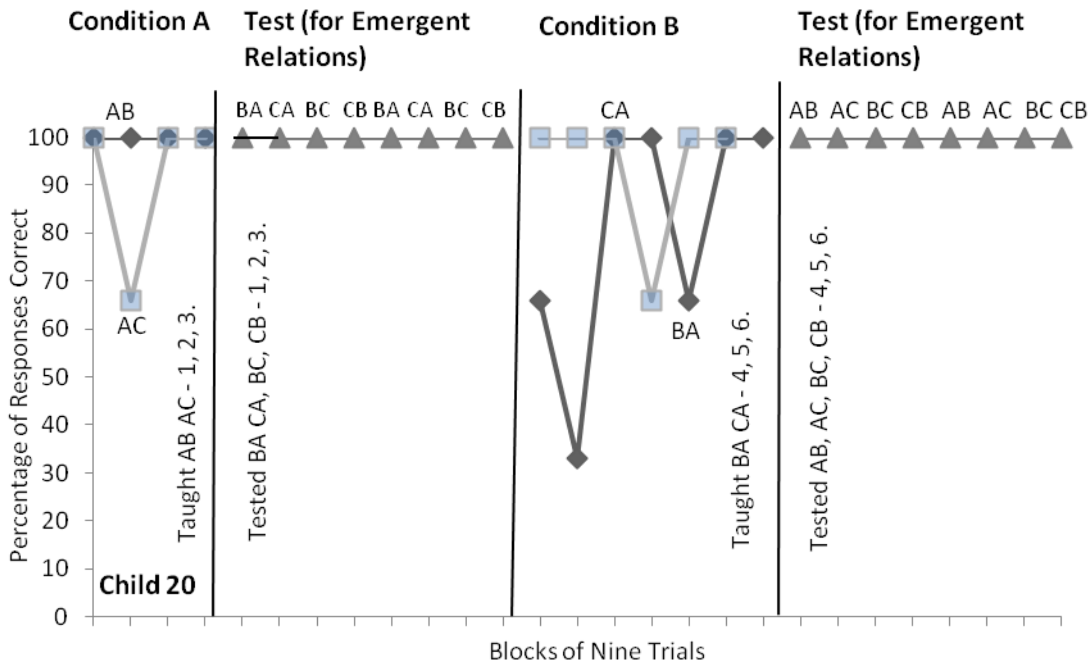


Figure 13. The percentage of correct responses obtained by Child 20 during teaching and testing in Treatment A+B

Table 24. Number of Teaching Trials Required during Treatment A+B and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 20

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
1	7	7	100%	100%	100%	100%
2	12	11	100%	100%	100%	100%
3	7	7	100%	100%	100%	100%
Total:	26	25				

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
4	11	15	100%	100%	100%	100%
5	18	10	100%	100%	100%	100%
6	23	32	100%	100%	100%	100%
Total :	52	57				

Relations taught are in bold.

Treatment B+A – Autism Group

Five children were in the Treatment B+A Autism Group. These children were: Child 1, Child 5, Child 6, Child 7 and Child 8. In the Treatment B+A Autism Group, children were first taught the quantity naming relations B-A (see the quantity – say the quantity) and the numeral reading relations C-A (see the numeral – say the numeral) for three consecutive quantities and numerals. Next, children in the Treatment B+A Autism group were taught the A-B aural comprehension (hear the quantity – select the quantity) and A-C aural-written numeral matching relations (hear the numeral – select the numeral) for the next set of three consecutive numerals and quantities.

Child 1

Preteaching. The results of the number screening assessment indicated that Child 1 was able to rote count and count with one-to-one correspondence to 20. He was able to recognise and name numerals to 12 and also demonstrated numeral comprehension to 12. Child 12 was only able to comprehend and name quantities to six. Prior to commencing teaching for numerals and quantities 13 to 18, pre-teaching was required. This pre-teaching involved teaching quantity recognition to 12 and took three sessions.

Condition B teaching. The Condition B teaching and testing results for Child 1 are presented in Figure 14 and Table 25. During Condition B teaching Child 1 was taught B-A (see the quantity – say the quantity) and C-A (see the numeral – say the numeral) relations for quantities and numerals 13, 14 and 15. He took a total of 45 trials to acquire quantities 13 to 15 for the quantity naming (see the quantity-say the quantity) relations and 39 trials in the numeral reading (see the numeral-say the numeral) relations. A total overall of 84 trials to acquire all of the Condition B stimulus-response relations. During tests for emergence of the

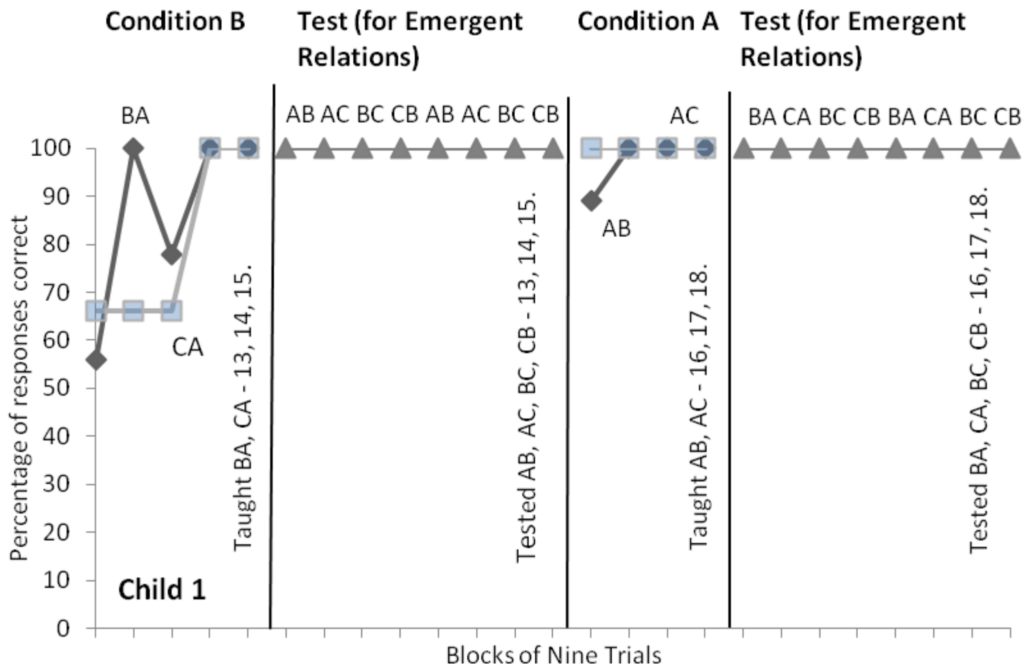


Figure 14. The percentage of correct responses obtained by Child 1 during teaching and testing in Treatment B+A

Table 25. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 1

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
13	**20**	**16**	100%	100%	100%	100%
14	**18**	**8**	100%	100%	100%	100%
15	**7**	**15**	100%	100%	100%	100%
Total :	**45**	**39**				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
16	**22**	**4**	100%	100%	100%	100%
17	**11**	**4**	100%	100%	100%	100%
18	**4**	**6**	100%	100%	100%	100%
Total:	**35**	**14**				

Relations taught are in bold.

untaught relations, Child 1 responded with 100% accuracy on each of the four tests. He therefore demonstrated symmetry and transitivity.

Condition A teaching. In teaching Condition A, Child 1 was taught aural comprehension (A-B) and aural-written numeral matching (A-C) for numerals and quantities 16 to 18. As can be seen from Table 25, Child 1 took a total of 35 trials to master the comprehension relations and 14 trials to master aural-written numeral matching relations, a total of 49 trials to achieve mastery of all taught Condition A relations. During the four tests for emergence of untaught relations Child 1 responded with 100% accuracy, thus demonstrating both symmetry and transitivity.

Child 5

Preteaching. Based on the number screening test results, Child 5 was able to count with one-to-one correspondence, rote count, and recognise and name numerals to 10 prior to commencing teaching. He demonstrated numeral comprehension to 9, quantity comprehension to 5 and quantity naming to 4. Prior to commencing experimental teaching, Child 5 was taught to count with one-to-one correspondence to 16 and to name quantities to 10. Pre-teaching took a total of five sessions. Numerals and quantities 11 to 16 were targeted during experimental teaching.

Condition B teaching. During teaching Condition B, the numerals and quantities 11, 12 and 13 were taught. As can be seen in Figure 15 and Table 26, a total of 144 teaching trials were required for mastery of each of the stimulus-response relations to be achieved. A total of 76 teaching trials were required for mastery of the B-A relations and 68 trials were required to reach mastery for C-A relations. During the tests for emergence, Child 5 demonstrated symmetry, in that he responded with 100% accuracy during tests for A-B and

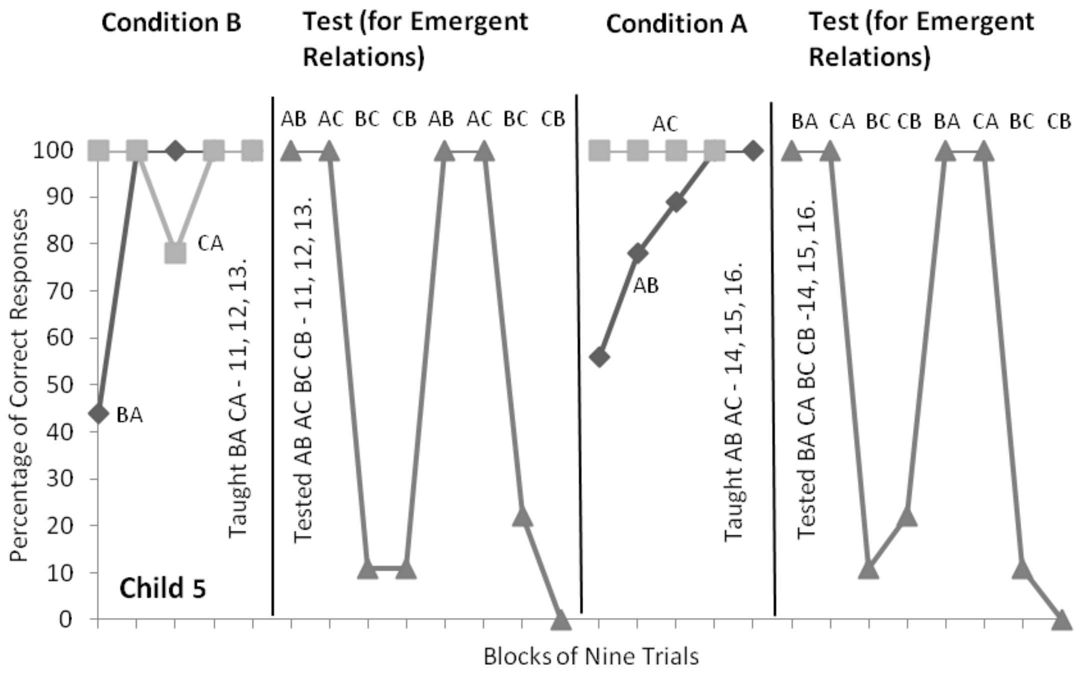


Figure 15. The percentage of correct responses obtained by Child 5 during teaching and testing in Treatment B+A

Table 26. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 5

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
11	29	14	100%	100%	0%	0%
12	35	24	100%	100%	0%	0%
13	12	30	100%	100%	0%	0%
Total :	76	68				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
14	34	11	100%	100%	0%	0%
15	22	10	100%	100%	0%	0%
16	12	3	100%	100%	0%	0%
Total:	68	24				

Relations taught are in bold.

A-C relations. However, Child 5 did not demonstrate transitivity, in that they responded with 0% accuracy during tests for the C-B and B-C relations for each of these tests.

Condition A teaching. During teaching for Condition A, Child 5 was taught numerals and quantities 14, 15 and 16 for the A-B (aural comprehension) and A-C (aural-written numeral matching) relations. As can be seen in Table 26, he required 68 teaching trials to reach mastery of each of the A-B stimulus-response relations and 24 trials to reach mastery of A-C stimulus-response relations. A total of 92 teaching trials were required for mastery of both of the Condition A relations. During testing for the emergence of untaught relations, Child 5 demonstrated emergence of B-A and C-A relations with 100% accuracy, thus demonstrating symmetry. However, as can be seen from Table 26, Child 5 responded with 0% accuracy when tested for emergence of C-B and B-C relations, and thus did not demonstrate transitivity.

Child 6

Preteaching. During the number screening test, Child 6 demonstrated that he was able to rote count up to 20 and count with one-to-one correspondence to 15. Child 6 could recognise numerals, name numerals, and demonstrate numeral comprehension up to 11. However, he could only comprehend quantities to 5 and name quantities to 4. Based on these results, Child 6 was taught to name quantities up to 11 and to count with one-to-one correspondence to 17 before beginning instruction with numerals and quantities from 12 to 17. The number of pre-teaching sessions required was four.

Condition B teaching. The Condition B results are presented in Figure 16 and Table 27. Child 6 was first taught the B-A and C-A relations for the quantities and numerals 12, 13 and 14. As can be seen in Table 27, Child 6 required a total of 118 trials to acquire all of the Condition B relations, 81 trials to master the B-A relations and 37 trials to master C-A

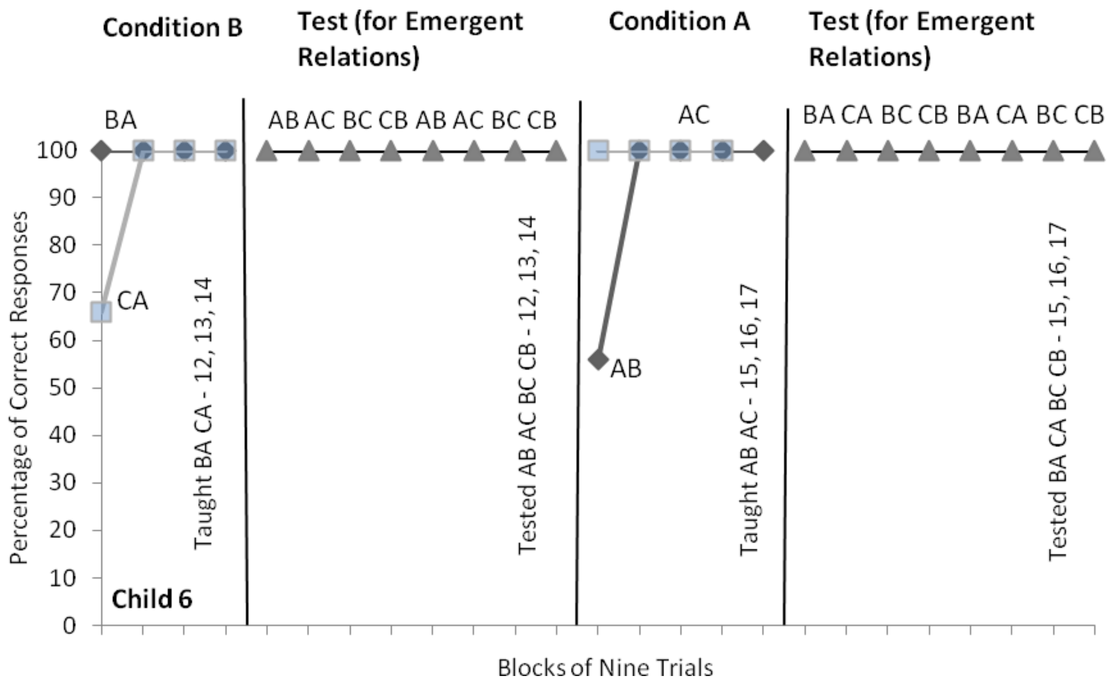


Figure 16. The percentage of correct responses obtained by Child 6 during teaching and testing in Treatment B+A

Table 27. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 6

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
12	20	13	100%	100%	100%	100%
13	31	11	100%	100%	100%	100%
14	30	13	100%	100%	100%	100%
Total :	81	37				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
15	23	9	100%	100%	100%	100%
16	21	8	100%	100%	100%	100%
17	11	3	100%	100%	100%	100%
Total:	55	20				

Relations taught are in bold.

relations. During testing for the emergence of untaught relations, Child 6 demonstrated 100% correct responding on tests for all four of the untaught relations, therefore demonstrating both symmetry and transitivity.

Condition A teaching. The Condition A results can be seen in Figure 16 and Table 27. In Condition A, Child 6 was taught numerals and quantities 15, 16 and 17. A total of 75 teaching trials were required to reach mastery criteria for all of the A-B and A-C relations. 55 trials were required for mastery of A-B relations and 20 trials for mastery of A-C relations. Child 6 demonstrated both symmetry and transitivity when tested for the emergence of untaught B-A, C-A, C-B and B-C relations.

Child 7

Preteaching. Results of the number screening test indicated that, prior to experimental teaching, Child 7 was able to rote count and count with one-to-one correspondence up to 3. He was able to recognise and name numerals to 4, and comprehend and name quantities 1, 2 and 3. He did not demonstrate any numeral comprehension skills. Prior to commencing the experimental teaching, Child 7 was taught to name quantities to 4 and to count with one-to-one correspondence to ten. This pre-teaching required three sessions.

Condition B teaching. The Condition B results for Child 7 are presented in Figure 17 and Table 28. Child 7 was first taught the quantity naming (B-A) and numeral reading (C-A) relations for the numerals and quantities 5, 6 and 7. As shown in Table 28, Child 7 required 67 trials to reach mastery criteria for B-A relations and a total of 45 trials to reach mastery of C-A relations. Child 7 demonstrated emergence of all four of the untaught relations for each of the stimulus-response relations with 100% accuracy, that is, he demonstrated both symmetrical and transitive responding.

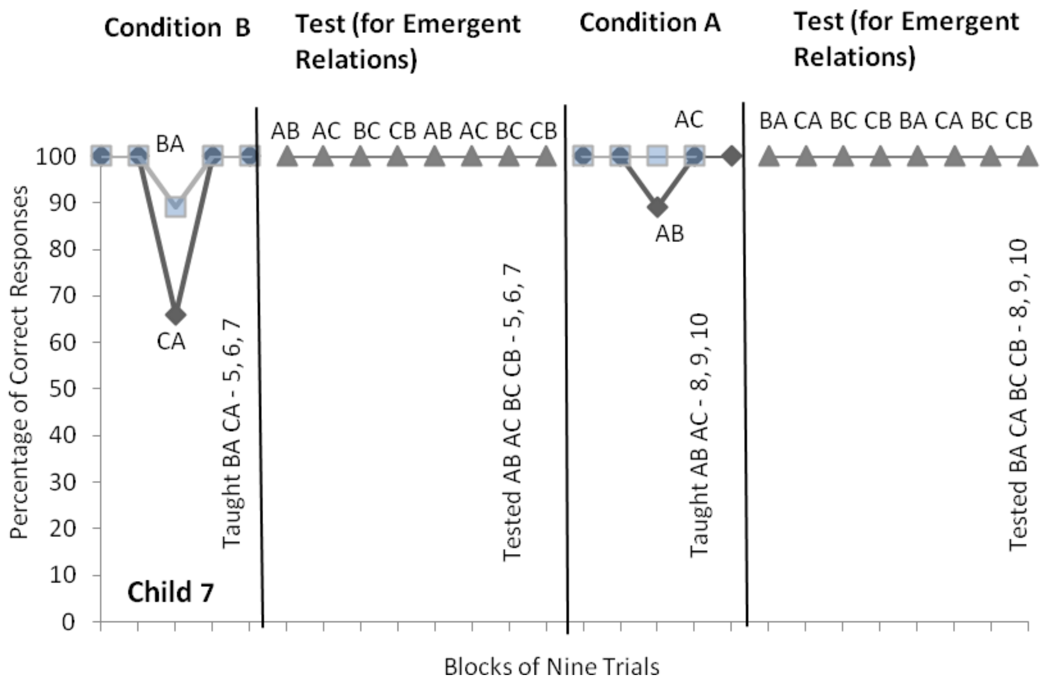


Figure 17. The percentage of correct responses obtained by Child 7 during teaching and testing in Treatment B+A

Table 28. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 7

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
5	18	16	100%	100%	100%	100%
6	27	21	100%	100%	100%	100%
7	22	8	100%	100%	100%	100%
Total :	67	45				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
8	12	13	100%	100%	100%	100%
9	22	15	100%	100%	100%	100%
10	25	13	100%	100%	100%	100%
Total:	59	41				

Relations taught are in bold.

Condition A teaching. In teaching Condition A, numerals and quantities 8, 9 and 10 were taught for the aural comprehension (A-B) and aural-written number matching (A-C) relations. Child 7 took a total of 100 teaching trials to acquire the relations taught in Condition A, 59 trials to reach mastery criteria for the A-B relations and 41 trials to reach mastery of the A-C relations. On the four tests for emergent relations, Child 7 demonstrated both symmetry and transitivity.

Child 8

Preteaching. During the number screening test Child 8 was able to rote count to 14 and count with one-to-one correspondence, recognise and name numerals to 12. He was able to comprehend and name quantities to 4 and demonstrated numeral comprehension up to 9. During pre-teaching, Child 8 needed to be taught to count with one-to-one correspondence to 18 and was taught to name quantities up to 12 before teaching commenced for quantities and numerals 13 to 18. Six pre-teaching sessions were needed for Child 8.

Condition B teaching. Child 8 was taught the numerals and quantities 13, 14 and 15 for the B-A and C-A relations in Condition B. The results of teaching are presented in Figure 18 and Table 29. A total of 169 trials were required to reach mastery for both of the Condition B relations, with 102 trials required to acquire B-A relations and 67 trials required to acquire C-A relations. As can be seen in Figure 18, Child 8 demonstrated the emergence of the untaught A-B and A-C relations with 100% accuracy, thus demonstrating symmetry. However, he did not demonstrate emergence of the untaught C-B and B-C relations, and so did not demonstrate transitivity.

Condition A teaching. During Condition A, numerals and quantities 16, 17 and 18 were taught for the A-B and A-C relations. A total of 118 trials were required to reach mastery criteria for both of the Condition A relations, with 100 trials needed for Child 8 to

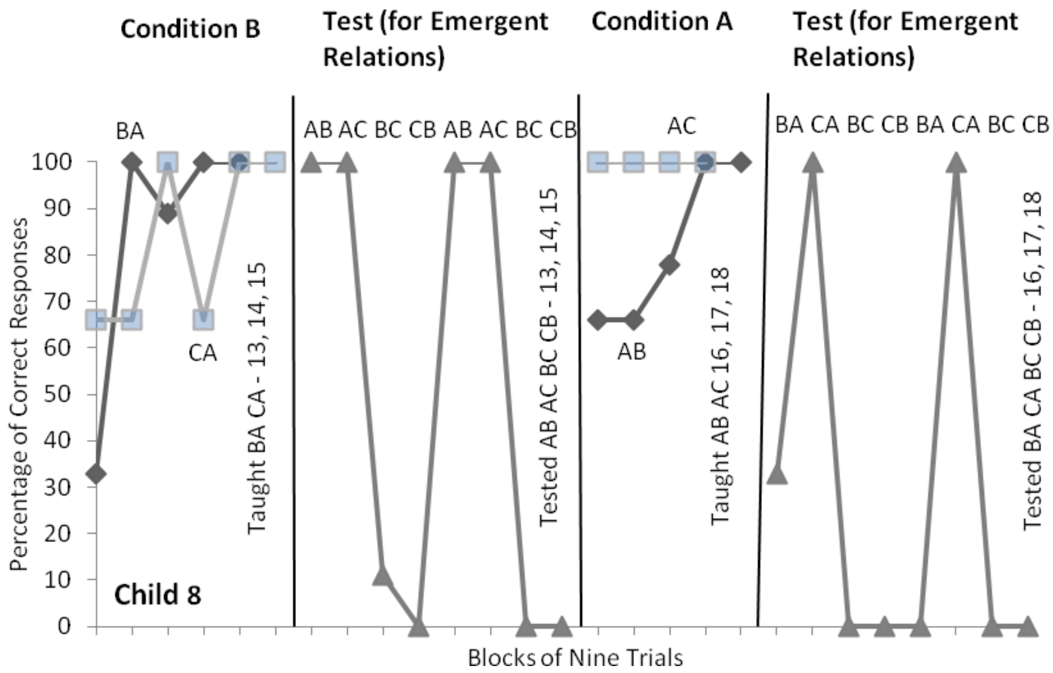


Figure 18. The percentage of correct responses obtained by Child 8 during teaching and testing in Treatment B+A

Table 29. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 8

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
13	43	39	100%	100%	0%	0%
14	30	19	100%	100%	0%	0%
15	29	9	100%	100%	0%	0%
Total :	102	67				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
16	39	7	0%	100%	0%	0%
17	24	7	0%	100%	0%	0%
18	27	4	0%	100%	0%	0%
Total:	100	18				

Relations taught are in bold.

master A-B relations and 18 trials required for him to master A-C relations. During testing for the emergence of untaught relations, symmetry was demonstrated for the C-A (numeral reading) relations. However, the B-A (quantity naming relations), C-B (reading comprehension) and B-C (quantity-numeral matching) relations did not emerge. Child 8 did not demonstrate any correct responses during these tests.

Treatment B+A – Typically Developing Group

Five children were in the Treatment B+A Typically Developing Group. These children were: Child 11, Child 14, Child 15, Child 16 and Child 17. In the Treatment B+A Typically Developing Group, children were first taught the B-A quantity naming relations (see the quantity – say the quantity) and the C-A numeral reading relations (see the numeral – say the numeral) for three consecutive quantities and numerals. Next, children in the Treatment B+A Typically Developing Group were taught the A-B aural comprehension (hear the quantity – select the quantity) and A-C aural-written numeral matching relations (hear the numeral – select the numeral) for the next set of three consecutive numerals and quantities.

Child 11

Preteaching. During the number screening test, Child 11 was able to rote count to 12 and was able to count with one-to-one correspondence to 6. He did not demonstrate any other number skills during screening. No pre-teaching was required for Child 11 prior to beginning the experimental teaching for numbers and quantities 1 to 6.

Condition B teaching. During teaching for Condition B the numerals and quantities that were taught were 1, 2 and 3. The results of Condition B teaching for Child 11 are presented in Figure 19 and Table 30. As can be seen in Table 30, to reach mastery of the B-A (quantity naming) and C-A (numeral reading) relations Child 11 required a total of 122

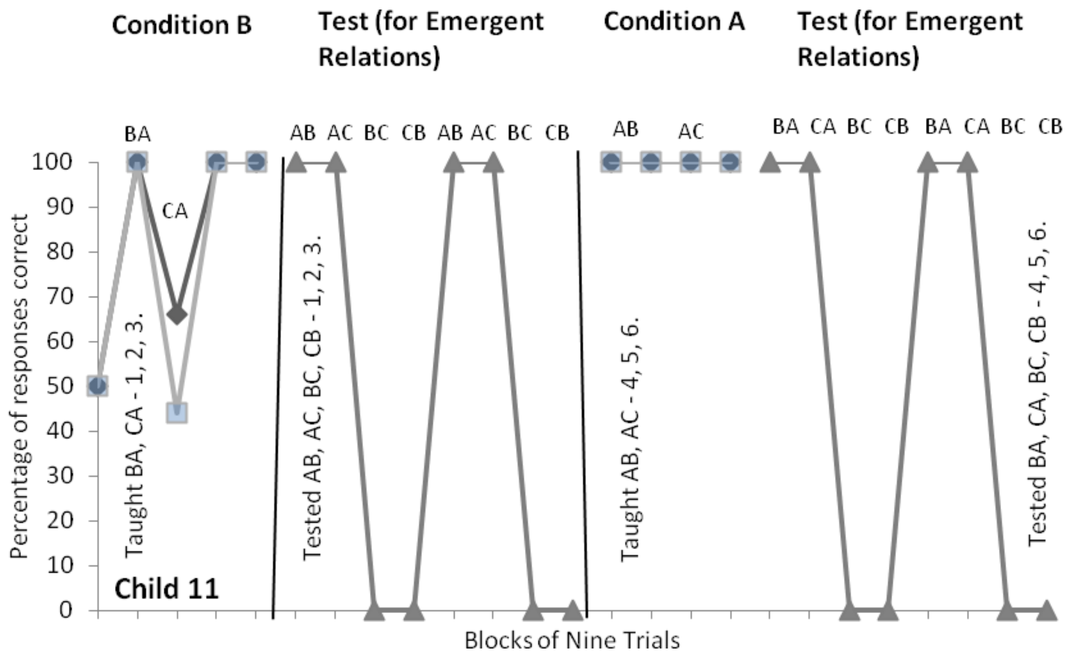


Figure 19. *The percentage correct responses obtained by Child 11 during teaching and testing in Treatment B+A*

Table 30. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 11

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
1	10	8	100%	100%	0%	0%
2	20	47	100%	100%	0%	0%
3	14	23	100%	100%	0%	0%
Total :	44	78				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
4	21	8	100%	100%	0%	0%
5	16	11	100%	100%	0%	0%
6	11	6	100%	100%	0%	0%
Total:	48	25				

Relations taught are in bold.

teaching trials. This included 44 trials to reach mastery of B-A (see the quantity – say the quantity) relations and 78 trials to reach mastery of C-A (see the numeral – say the numeral) relations. In tests for the emergence of untaught relations Child 11 demonstrated 100% correct responding for A-B (hear the quantity – select the quantity) and A-C (hear the numeral – select the numeral) for all numbers and quantities. He did not however, demonstrate transitivity, as he made no correct responses during testing for C-B (see the numeral – select the quantity) and B-C (see the quantity- select the numeral) relations.

Condition A teaching. During teaching Condition A, Child 11 was taught numerals and quantities 4 to 6. Results of Condition A teaching can be seen in the second half of Table 30 and in Figure 19. Child 11 required a total of 73 teaching trials to reach mastery of both of the sets of relations that were taught in Condition B. This included 48 teaching trials to acquire A-B relations and 25 teaching trials to acquire A-C relations. Child 11 demonstrated symmetry with 100% accuracy for all of the relations that were tested for both B-A and C-A relations. However, he failed to demonstrate transitivity, scoring 0% on the test for emergence of C-B and B-C relations.

Child 14

Preteaching. Child 14 was able to rote count and count with one-to-one correspondence up to 13 during the number screening test. She was also able to recognise and name numerals and quantities 1, 2 and 3 and demonstrated numeral and quantity comprehension up to 3. No pre-teaching was required for Child 14 prior to commencing the teaching for numerals and quantities 4 to 9.

Condition B teaching. The Condition B results for Child 14 are presented in Figure 20 and Table 31. Child 14 was first taught the quantity naming (B-A) and numeral reading (C-A) relations for the quantities and numerals 4, 5 and 6. As can be seen in Table 31, Child 14

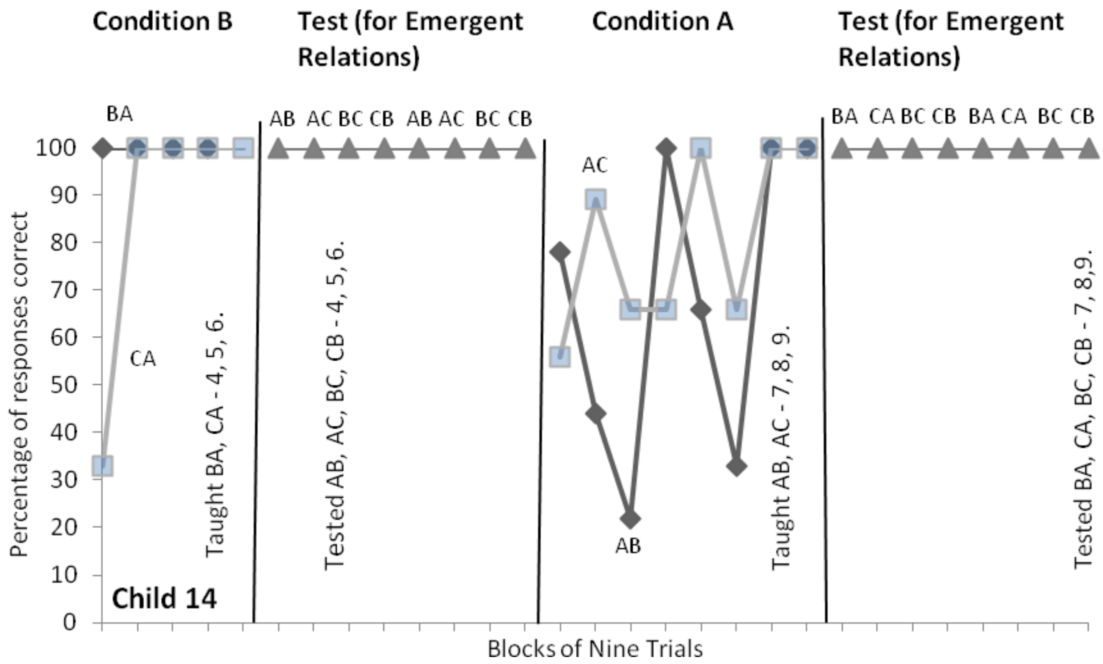


Figure 20. The percentage of correct responses obtained by Child 14 during teaching and testing in Treatment B+A

Table 31. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 14

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
4	12	7	100%	100%	100%	100%
5	7	15	100%	100%	100%	100%
6	7	9	100%	100%	100%	100%
Total :	26	31				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
7	13	21	100%	100%	100%	100%
8	25	7	100%	100%	100%	100%
9	25	19	100%	100%	100%	100%
Total:	63	47				

Relations taught are in bold.

needed 26 trials to achieve mastery of the B-A relations and 31 trials to achieve mastery of the C-A relations. To master both of the relations in Condition B took a total of 57 teaching trials. During testing for emergence of the untaught relations, Child 14 demonstrated 100% correct responding on tests for all four of the untaught relations, thus demonstrating both symmetry and transitivity.

Condition A teaching. The results of Condition A teaching can be seen in the second half of Table 31 and in Figure 20. During Condition A, numerals and quantities 7 to 9 were taught. Under this condition, a total of 110 teaching trials were needed to achieve mastery of the A-B and A-C relations. 63 trials were needed for acquisition of A-B relations and 47 trials for acquisition of A-C relations. As can be seen in Figure 20, Child 14 demonstrated emergence of all four untaught stimulus-response relations and thus demonstrated both symmetry and transitivity with 100% accuracy.

Child 15

Preteaching. Results of the number screening test indicated that Child 15 was able to rote count and count with one-to-one correspondence up to 5, and recognise, name and comprehend quantities and numerals 1, 2 and 3 prior to commencing pre-teaching and experimental teaching. Before commencing teaching in Treatment B+A Child 15 was taught to count with one-to-one correspondence up to 9. Three pre-teaching sessions were needed for this teaching. Treatment B+A teaching targeted numerals and quantities 4 to 9.

Condition B teaching. Child 15 was first taught the numerals and quantities 4 to 6 in Condition B. The results of teaching for B-A (see the quantity – say the quantity) and C-A (see the numeral – say the numeral) relations are presented in Figure 21 and the first part of Table 32. As can be seen in Table 32, Child 15 took 65 teaching trials to master B-A relations and 42 trials to master C-A relations, a total of 107 trials required for mastery of both sets of

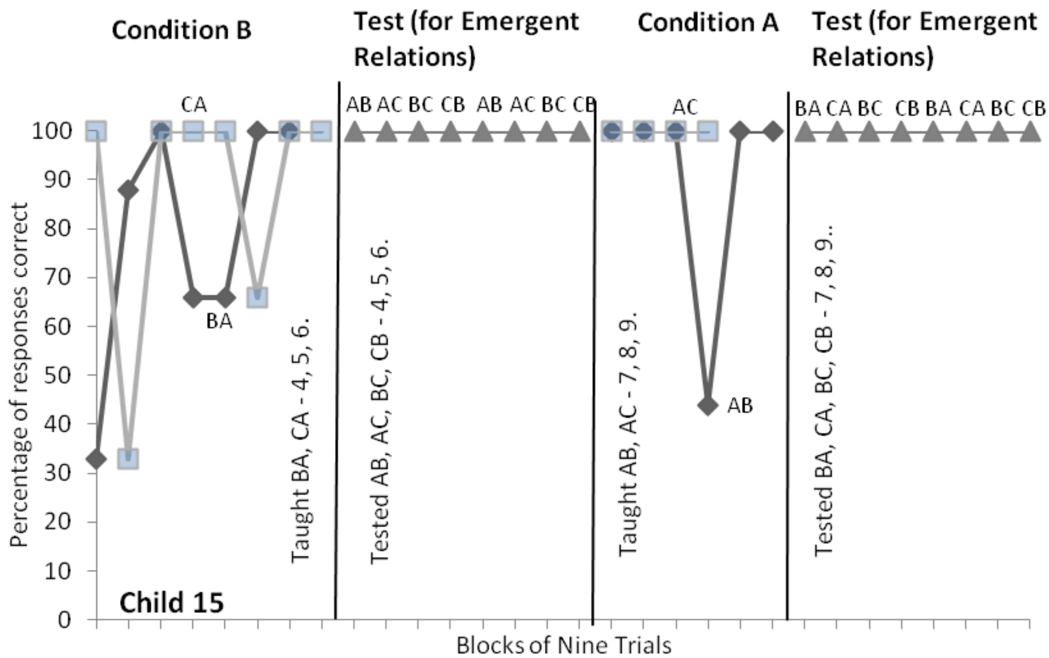


Figure 21. The percentage of correct responses obtained by Child 15 during teaching and testing in Treatment B+A

Table 32. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 15

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
4	30	18	100%	100%	100%	100%
5	20	10	100%	100%	100%	100%
6	15	14	100%	100%	100%	100%
Total :	65	42				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
7	18	12	100%	100%	100%	100%
8	16	10	100%	100%	100%	100%
9	20	7	100%	100%	100%	100%
Total:	54	29				

Relations taught are in bold.

stimulus-response relations taught in this condition. As can be seen in Figure 21, Child 15 demonstrated 100% correct responding for each of the emergent stimulus-response relations that were tested thus demonstrating both symmetry and transitivity.

Condition A teaching. In teaching Condition A, Child 15 was taught the numerals and quantities 7 to 9. As can be seen from Table 32, acquisition of the comprehension relations (A-B) took a total of 54 teaching trials and acquisition of aural-written numeral matching relations (A-C) took a total of 29 teaching trials. To learn both of the Condition A relations, therefore, took 83 teaching trials. During testing for the emergence of untaught relations (B-A, C-A, C-B and B-C) Child 15 demonstrated 100% correct responding thus demonstrating both symmetrical and transitive responding.

Child 16

Preteaching. Child 16 demonstrated an ability to rote count to 14 and count with one-to-one correspondence to 13 during the number screening test. He was also able to recognise and name numerals up to 8 and he demonstrated quantity comprehension, labelling and numeral comprehension to 4. Pre-teaching required that Child 16 was taught to name quantities to 8 and to count with one-to-one correspondence to 14 prior to beginning experimental teaching for the numerals and quantities 9 to 14. Pre-teaching required three sessions.

Condition B teaching. The results of teaching Child 16 are presented in Figure 22 and Table 33. Child 16 was first taught relations B-A and C-A for numerals and quantities 9 to 11. To acquire the taught relations in Condition B, Child 16 took a total of 69 teaching trials with 32 trials to learn the B-A relations and 37 trials to acquire the C-A relations. Child 16 scored 100% on tests for symmetry (A-B and A-C) and transitivity (C-B and B-C) for each of the stimulus-response relations in Condition B.

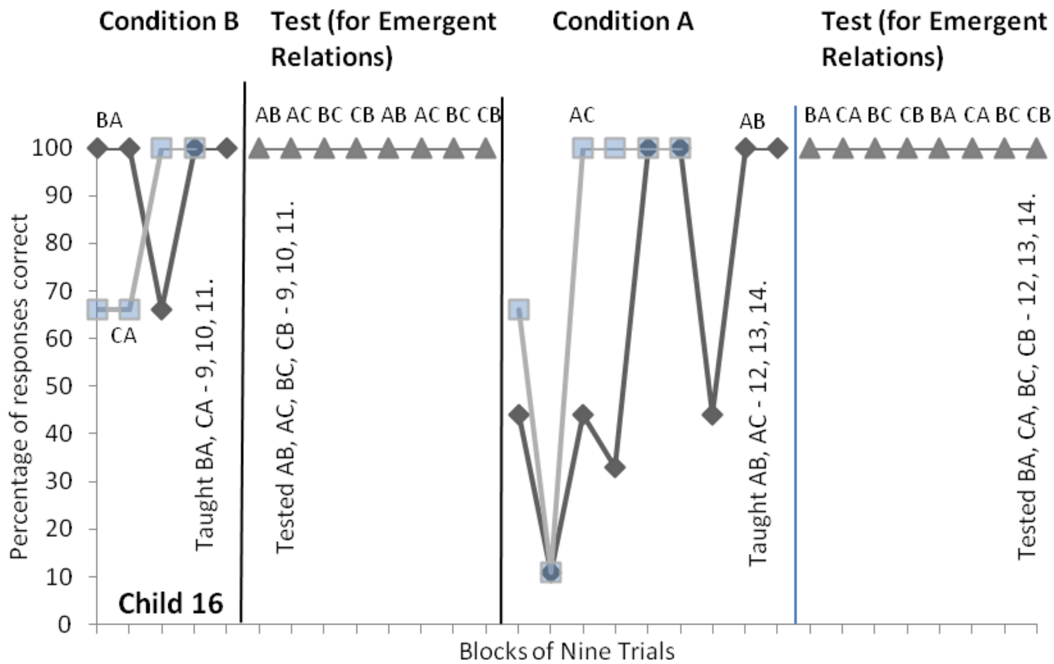


Figure 22. The percentage of correct responses obtained by Child 16 during teaching and testing in Treatment B+A

Table 33. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 16

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
9	7	23	100%	100%	100%	100%
10	10	7	100%	100%	100%	100%
11	15	7	100%	100%	100%	100%
Total :	32	37				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
12	22	18	100%	100%	100%	100%
13	24	20	100%	100%	100%	100%
14	13	7	100%	100%	100%	100%
Total:	59	45				

Relations taught are in bold.

Condition A teaching. During Condition A teaching, numerals and quantities 12, 13 and 14 were targeted for the A-B and A-C relations. As can be seen in the second half of Table 33, 104 trials were required to reach mastery of both of the taught relations in Condition A with 59 trials required to learn the A-B relations and 45 trials needed to learn the A-C relations. Testing results are presented in Figure 22 and Table 33. These findings show that Child 16 scored 100% correct during tests for emergence of untaught relations for each of the four sets of untaught relations. Child 16 thus demonstrated both symmetry and transitivity.

Child 17

Preteaching. During the number screening test, Child 17 demonstrated that she was able to rote count to 10, could count with one-to-one correspondence to 2, and was able to comprehend and name quantities to 2. She did not demonstrate any ability to recognise or name any numerals and did not demonstrate numeral comprehension. Based on these results, Child 17 was taught to count with one-to-one correspondence to 8 and to name numerals 1 and 2 before beginning instruction with numerals and quantities from 3 to 8. The number of pre-teaching sessions required was three.

Condition B teaching. The Condition B results for Child 17 are presented in Figure 23 and Table 34. Child 17 was first taught the B-A and C-A relations for quantities and numerals 3, 4 and 5. Child 17 required 68 trials to master B-A relations and 57 trials to master C-A relations. To master all of the Condition B relations took a total of 125 trials. During testing for the emergence of untaught relations, Child 17 demonstrated 100% correct responding on tests for all four of the untaught relations.

Condition A teaching. In Condition A, Child 17 was taught the comprehension (A-B) and aural-written numeral matching (A-C) relations for the quantities and numerals 6, 7 and

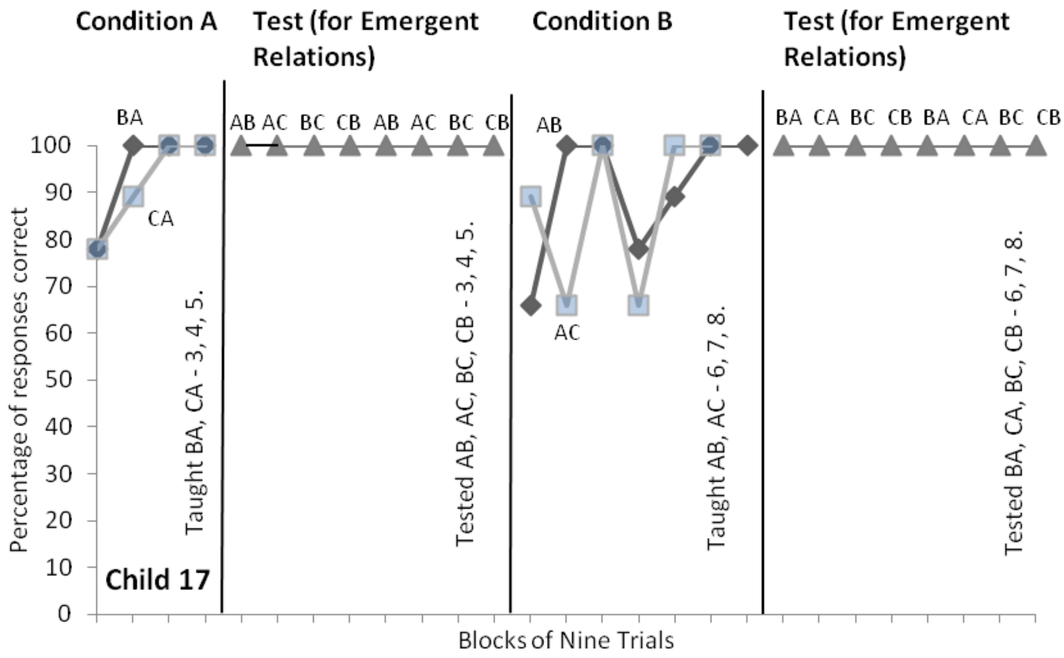


Figure 23. The percentage of correct responses obtained by Child 17 during teaching and testing in Treatment B+A

Table 34. Number of Teaching Trials Required during Treatment B+A and the Percentage of Correct Responses during Tests for the Emergence of Untaught Relations for Child 17

Condition B

Quantities taught	**Quantity naming B-A**	**Numeral Reading C-A**	Compre-hension A-B	Aural-written numeral match A-C	Reading comprehension C-B	Quantity-numeral match B-C
3	13	14	100%	100%	100%	100%
4	16	19	100%	100%	100%	100%
5	39	24	100%	100%	100%	100%
Total :	68	57				

Condition A

Quantities taught	**Compre-hension A-B**	**Aural-written numeral match A-C**	Quantity naming B-A	Numeral Reading C-A	Reading comprehension C-B	Quantity-numeral match B-C
6	17	7	100%	100%	100%	100%
7	7	24	100%	100%	100%	100%
8	7	7	100%	100%	100%	100%
Total:	31	38				

Relations taught are in bold.

8. This child required a total of 69 trials to master the relations taught in Condition B, 31 trials to master the A-B relations and 38 trials to master the A-C relations. During testing for the emergence of the untaught relations, Child 17 demonstrated 100% correct responding on tests for all four of the untaught relations, thus demonstrating both symmetry and transitivity.

Group Results

In an initial exploration of between group effects and the possibility that the emergence or non emergence of untaught relations might be related to one or more of the entry characteristics or training characteristics of the subjects in the present experiments, Pearson product moment correlations and intercorrelations were calculated for selected pretest, acquisition and posttest variables. This analysis was repeated for the Autism Group, the Typically Developing Group and the total group of learners.

The outcome variable in this initial group analysis was the number of untaught relations which emerged during the experiment. The score for derived relations was a score out of five. One point was awarded for symmetry and one point for transitivity following Condition A instruction plus one point for symmetry and one point for transitivity following Condition B instruction. It was also possible for children to score zero if symmetrical or transitive relations did not emerge.

The experimental treatment (whether Treatment A+B or Treatment B+A) was entered into the analysis as a binary variable. Also the total number of trials to criterion (across both Treatment A+B and Treatment B+A) was calculated and entered into the analysis for each child.

The training variables used in the analysis were (a) the trials to criterion across Condition A, (b) the trials to criterion across Condition B and (c) the total trials to criterion (across Condition A plus Condition B).

The following student characteristics were included in the analysis: group membership (whether ASD or Typically Developing Group), PPVT-IV age equivalent scores, ABAS-II functional academics scores, ABAS-II communication scores, highest number reached for rote counting during the number screening test and highest number reached for one-to-one counting during the number screening test. The results of the correlational analysis for the two groups combined are presented in Table 35. A table of correlations for the Autism Group and for the Typically Developing Group separately are presented in Appendixes 7 and 8.

Group Membership

The two groups in this study were the Autism Group and the Typically Developing Group. As shown in Table 35 there was a significant correlation between group membership and the total number of derived relations ($r=0.451$, $p<0.05$). A total of 28.5 untaught stimulus-response relations emerged for children in the Autism Group compared to the emergence of 38 untaught stimulus-response relations for children in the Typically Developing Group. This relationship indicates that the typically developing children were significantly more likely than the children with ASD to demonstrate the emergence of untaught equivalence relations.

Treatment Group

The two experimental treatments in this study were the Treatment A+B group and the Treatment B+A group. Children in the Treatment A+B group were first taught and tested in

Table 35. Results of the Correlation Analysis for the Pooled Autism Group Children and the Typically Developing Children (n=20)

	Total Derived Relations	Group	Treatment Group	Age in Months	PPVT-IV Age Equivalent Score	Functional Academics Score	Commun-ication Score	Rote Counting	One-to-one Counting	Trials to Criterion A	Trials to Criterion B
Group	.451*										
Treatment Group	.024	.000									
Age (in months)	-.607**	-.702**	-.114								
PPVT-IV Age Equivalent Score	.198	-.072	-.139	.134							
Functional Academics Score	.550*	.740**	-.157	-.800**	-.118						
Communication Score	.439	.953**	.009	-.716**	-.016	.819**					
Rote Counting	.340	-.054	.036	-.035	.269	.218	.058				
One-to-one Counting	.275	-.231	.160	.040	.308	.126	-.071	.842**			
Trials to Criterion A	-.602**	-.434	-.175	.619**	.202	-.538*	-.481*	-.415	-.217		
Trials to Criterion B	-.674**	-.335	-.288	.413	-.282	-.499*	-.465*	-.471*	-.575**	.379	
Total Trials to Criterion	-.770*	-.459*	-.282	.613**	-.065	-.622**	-.568**	-.535*	-.489*	.807**	.852**

*** p = <.01 *p = <.05*

Condition A (hear-select), followed by Condition B (see-say). Children in the Treatment B+A group were first taught the Condition B (see-say), followed by Condition A (hear-select) relations. As can be seen from Table 35, there was no relationship between Treatment group and the total number of derived relations (r=.024). As can be seen in Appendix 7 and 8 this correlation was not significant for either the Autism Group (r=0.211) or the Typically Developing Group (r=-.333).

Teaching Conditions

The number of occasions on which untaught equivalence relations emerged during Condition A and Condition B was also examined. These totals are shown in Table 36.

Table 36. The Number of Untaught Equivalence Relations that Emerged Following Condition A and Condition B Teaching for Children in the Autism Group and the Typically Developing Group

	Condition A	Condition B
Autism Group	12.5	16.0
Typically Developing Group	19.0	19.0
Total Emerged Relations	31.5	35.0
Total Possible Score	40	40

As can be seen from Table 36, there was no significant difference between the number of emerged relations following Condition A teaching compared to Condition B teaching in the present sample of 20 children ($\chi^2 = 1.19$, $p > 0.20$). Because there was no correlation between the experimental treatments (or the experimental conditions) and the emergence of untaught equivalence relations no further analysis of treatment effects was undertaken.

Entering Characteristics

The functional academics scores that were used for each participant in the correlation analysis were the norm-referenced scaled scores on the ABAS-II. As can be seen from Table 35, a statistically significant relationship was found between functional academics scores on the ABAS-II and total derived relations ($r=0.550$, $p<0.05$). This finding suggests that those children who scored more highly on functional academics skills were more likely to demonstrate the emergence of untaught equivalence relations. Other student characteristics measured in this study were not correlated with performance on tests for the emergence of untaught equivalence relations. These include communication scores on the ABAS-II, rote counting and counting with one-to-one correspondence skills.

Trials to Criterion

The number of trials to criterion was significantly correlated with the emergence of untaught equivalence relations. As can be seen in Table 35, the number of trials required to reach mastery in Condition A was strongly correlated with the emergence of symmetry and transitivity ($r=0.602$, $p<0.01$), as was the number of trials to criterion in Condition B ($r=0.674$, $p<0.01$). These correlations indicate that those children who acquired the taught discriminated responses more rapidly, were more likely to demonstrate the emergence of untaught equivalence relations regardless of experimental condition. As can be seen in Appendixes 7 and 8 however, trials to criterion was correlated with number of emerged relations for the children in the Autism Group only. This appears to be because there was almost no variability in the outcome variable amongst the children in the Typically Developing Group.

While most entering characteristics were not associated with performance on tests for the emergence of untaught equivalence relations, they were correlated with trials to criterion. As can be seen from Table 35, there were significant correlations between trials to criterion and functional academics scores on the ABAS-II, communication scores on the ABAS-II, rote counting and counting with one-to-one correspondence.

The correlations between trials to criterion and functional academics, counting with one-to-one correspondence and rote counting suggest that these pretest measures predicted rate of acquisition but not the likelihood of emergence of untaught equivalence relations, with the exception of the functional academics scores.

CHAPTER 4

DISCUSSION AND CONCLUSIONS

The research in this thesis was guided by four questions. The first was the question of whether children with autism spectrum disorder (ASD) will demonstrate the emergence of untaught equivalence relations. The second was to explore differences between the emergence of untaught relations in children with ASD and that in typically developing children who have been matched on level of receptive vocabulary development. The third was to assess the importance of first learning the names of discriminative stimuli in the emergence of untaught equivalence relations. The fourth was to explore variability in the emergence of untaught equivalence relations in children with ASD with the aim of identifying developmental factors that may account for such variability.

Emergence of Untaught Equivalence Relations

The present study found that only five of the ten children in the Autism Group were able to demonstrate both symmetry and transitivity during tests for the emergence of untaught equivalence relations and therefore to demonstrate the ability to form 6-member equivalence classes.

For the remaining five children with ASD, the emergence of untaught equivalence relations was variable. Two children with ASD (Child 10 and Child 5) demonstrated symmetry but not transitivity in both Condition A and Condition B teaching. Two children did not demonstrate emergence of any of the untaught relations in Condition A teaching. However, one of these students (Child 2) demonstrated symmetry and transitivity in Condition B teaching and the other child (Child 4) demonstrated symmetry but not transitivity under Condition B teaching. The final child (Child 8) only demonstrated symmetrical responding for one of the taught stimulus-response relations (C-A) in teaching Condition A but not for the other taught stimulus-response relation (B-A) in this set. This child demonstrated the emergence of both of the symmetrical relations for each of the taught stimulus-response relations following Condition B teaching. They did not demonstrate transitive responding in either teaching condition.

The results demonstrated that the likelihood of the emergence of the untaught equivalence relations varied considerably amongst children with ASD and led to the conclusion that some children with ASD are able to demonstrate the emergence of untaught equivalence relations and are capable therefore of forming equivalence classes while others are unable to do so or are only able to demonstrate the emergence of symmetrical relations under the certain teaching conditions.

Very few research studies have examined the emergence of untaught equivalence relations in children with ASD. The present finding that some children with ASD were able to demonstrate the emergence of all of the untaught equivalence relations regardless of the teaching conditions is consistent with the findings of Eikeseth and Smith (1992), Le Blanc, Miguel, Cummings, Goldsmith and Carr (2003), Noro (2005), Wynn and Smith (2003) and O'Connor et al. (2009) who also found that untaught relations emerged for some or all of the participants with ASD who were included in their investigations.

The Emergence of Untaught Equivalence Relations in Language Matched Typically Developing Children

Nine out of ten children in the language matched Typically Developing Group demonstrated the emergence of both symmetry and transitivity following both Condition A and Condition B teaching. The one child who did not show emergence of all of the untaught equivalence relations demonstrated symmetry, but not transitivity under both teaching conditions.

The finding that nine out of the ten children in the Typically Developing Group in the present study demonstrated the emergence of untaught equivalence relations was consistent with the results of previous studies which have included preschool aged children (e.g., Brady & McLean, 2000; Devany et al., 1986; Mueller et al., 2000).

When compared to the children in the Autism Group, it is apparent that those in the Typically Developing Group showed a greater likelihood of demonstrating the emergence of untaught equivalence relations even although they had been matched on language development. They also required many fewer training trials in order the master the first two discriminated responses than was the case with the children in the Autism Group.

Two other experiments have compared the equivalence acquisition of children with ASD against that of typically developing children. In the study by O'Connor et al., (2009) children with ASD and high levels of verbal competence performed in a closely similar fashion to typically developing children in that they responded accurately during testing for the emergence of untaught relations..

A second study by Gorham, Barnes-Holmes, Barnes-Holmes and Berens (2009) used the emergence of relational frames to measure derived responding in children with ASD and typically developing children. This study also found that there were very few differences (apart from the need for more extensive training on A-B relations for children with ASD) between typically developing children and those with autism in establishing and generalizing arbitrary more-than and less-than relations.

Effects of Instruction in Naming

The present investigation was designed to compare the affects of two teaching conditions on the likelihood of the emergence of untaught equivalence relations. The aim of this experiment was to determine whether teaching the names of new stimuli first increased the likelihood of emergence of untaught equivalence relations.

The effect of first teaching stimulus naming was examined by comparing the emergence of symmetrical and transitive responding following Condition A (hear-select) and Condition B (see-say) teaching. In the present investigation there was no suggestion of any significant difference between the effects of these two teaching conditions on the likelihood of emergence of the untaught equivalence relations. This result differs from that reported by Eikeseth and Smith (1992) and Wynn and Smith (2003).

Wynn and Smith (2003) taught attribute word pairs. Half of these attribute pairs were taught using expressive labelling (e.g. children were asked “what size is this?”) and half were taught receptively (e.g. “touch big” versus “touch small”). The generalization from expressive language use to receptive identification and receptive identification to expressive language use was then assessed. This study referred to the generalization across receptive and expressive tasks as cross-modal generalization. However, it has similarities with the tests for symmetry that were used in the current study. Wynn and Smith results showed that, for the majority of participants, there was a greater likelihood of generalization from expressive language use to receptive identification of attribute pairs than the reverse.

The effect of learning to name stimuli on the emergence of untaught relations was also examined by Eikeseth and Smith (1992) who found that the likelihood of the emergence of untaught equivalence relations was facilitated when participants were taught to assign a common name to the stimuli that were to become discriminative stimuli for correct responding.

There are several possible reasons why the findings of Eikeseth and Smith (1992) and Wynn and Smith (2003) were not replicated in the current study. Firstly, there were a number of procedural differences between the three experiments. Secondly, the nature of the teaching content was vastly different. In the Wynn and Smith (2003) study, participants were provided with multiple practice opportunities in order to teach only one set of relational concepts, however in the current study a greater number of stimulus-response relations were taught and tested. In the Eikeseth and Smith (1992) study, teaching participants to name stimuli was introduced as a remedial treatment for the students who had failed to demonstrate the emergence of untaught relations. This is procedurally quite different to the present study in which participants were taught and tested according to the specified teaching condition, without being provided with any additional remedial instruction. It is quite possible that these methodological differences account for the variability in the findings of the current study and those of Eikeseth and Smith (1992) and Wynn and Smith (2003).

The issue of when naming is important remains an unanswered question. Sidman (1994) has argued that there may be a number of reasons why children with limited language repertoires might fail to demonstrate the emergence of untaught equivalence relations. "Showing that subjects who cannot name stimuli fail to develop equivalence relations might seem definitive. Such subjects, however, may well be limited in more ways than just their inability to name stimuli; they may also suffer other deficits that are incompatible with equivalence relations" (p.306).

Variables Affecting the Emergence of Untaught Equivalence Relations

Differences in Entering Skills

As there was significant variation amongst the children with ASD in terms of the likelihood that these children would demonstrate the emergence of untaught equivalence relations, further analyses were undertaken in an attempt to identify any factors that might be correlated with this variability. The results of this analysis identified four variables that were correlated with variability in the emergence of untaught equivalence relations. These were Autism status, scores on the functional academics domain of the ABAS-II, age, and rate of acquisition.

Autism Status

The current investigation found that five out of the ten children demonstrated the emergence of both symmetry and transitivity and were therefore able to form 6-member equivalence classes. For the remaining five children the emergence of symmetrical and transitive relations was highly variable. The differences among children with ASD are difficult to explain and highlight the need for further experimental research in this area.

Functional Academics Score

In the present investigation children who scored more highly on the measure of functional academics were more likely to demonstrate the emergence of untaught relations. The Adaptive Behavior Assessment System measures adaptive functioning in ten different domains, one of which is Functional pre-academics (children 0-5 years of age) or Functional Academics (5-21 years of age). The ABAS-II has not been used in previous research so this is a new finding. Its implications are unclear and need to be explored further. Possibly the correlation between functional academics scores and the emergence of untaught equivalence relations simply reflects differences in the rate of developmental or prior experience with this kind of learning task for the children included in the present study

Chronological Age

There was considerable variability in the age of the participants with ASD who met entry criteria for this study. There was however, little variability among the typically developing 3-year old children. The present investigation found that age was significantly negatively correlated with total derived relations for children with ASD. This finding indicates that rate of development may be a strong predictor of the likelihood of emergence of untaught equivalence relations.

Rate of Acquisition

In the present study, children who required fewer teaching trials to reach mastery of the taught stimulus-response relations were significantly more likely to demonstrate the emergence of untaught equivalence relations. In fact, rate of acquisition was found to be the best predictor of the emergence of untaught equivalence relations in the present study.

Possible Causes of Variability in the Emergence of Untaught Equivalence Relations

There are two main possible explanations for why some children in the Autism Group demonstrated the emergence of untaught relations and some did not. The first is that the difference is due to the differences in rate of development. The second is that it is due to differences in prior teaching history.

Rate of Development

There is strong indirect evidence in this study that, for the children in the Autism Group, the emergence of untaught equivalence relations is related to rate of development.

Because the two groups were matched on PPVT-IV scores there was no correlation between PPVT-IV scores and the number of derived relations demonstrated. However, there was a significant and strong negative correlation between age and number of derived relations. In other words, when matched on receptive vocabulary scores, the older children in the ASD group were the children who required the greatest number of teaching trials to reach mastery criterion and were the least likely to demonstrate emergence of untaught equivalence relations. The children who were most likely to demonstrate emergence of all untaught relations were also the children with the higher functional academics scores on the ABAS-II.

In addition, the finding that those children with higher levels of pre-requisite skills (as measured by rote counting and counting with one-to-one correspondence), higher functional academics scores and higher communication scores required fewer trials to reach criterion in the present investigation provides further indirect evidence for a link between rate of development and the emergence of untaught equivalence relations.

This observation suggests that it may be the rate of development of the child and not autism per se which is the major determinant of whether or not equivalence relations will emerge during teaching. A similar conclusion was reached by O'Connor et al. (2009) who argued that children with higher levels of language skills can be expected to acquire equivalence relations more rapidly regardless of whether or not they have a diagnosis of ASD.

Prior Teaching History

A second possible explanation for the failure to demonstrate the emergence of untaught relations by half of the children in the Autism Group may possibly be found in the prior teaching history of these children. Because many of the children in the Autism Group had experienced long periods of discrete trial teaching, there is a possibility that they had received little in the way of generalization training.

Previous research suggests that additional teaching is required for some children with autism if they are to learn to generalize across and within response types. One of the key components of training to generalize is that of providing reinforcement for response variability, that is, reinforcing the child for demonstrating some variation in desired responses. Due to the highly structured nature of much of the prior teaching of the children with ASD, it is possible that they may not have experienced much in the way of reinforcement for varying their response topography. The need to reinforce variation in response topographies has been demonstrated in several research studies (e.g., Egel et al., 1984; Young et al., 1994). Cooper et al. (2007) recommend that instructors should ensure contact with reinforcement in the presence of stimuli to which generalized responding is desired in order to ensure that students will respond correctly within the generalization setting.

It is also possible for children with ASD to become dependent on the prompts used during teaching. This effect has been observed in prior investigations (e.g., Betz et al., 2010; Williams et al., 2006). In the present study, all teaching trials began with a verbal discriminative stimulus (e.g., “What number is this?”) and if the correct response was not given the child was then prompted (e.g., the teacher modelled the correct response, “It’s number three”). During testing these prompts were all abruptly removed. Both Betz et al. (2010) and Williams et al. (2006) found that children who had been taught to respond to questions (e.g., “What is she doing?”) needed additional training in order to learn to generalize responses when the verbal discriminative stimuli were faded.

It is not possible to determine whether aspects of the prior learning history of the children with ASD may have limited the likelihood of the emergence of untaught relations. However, it is possible that a combination of reinforcement history and a history of prompt dependence may have restricted generalization to untaught equivalence relations for some children in the Autism Group.

Theoretical Implications

There have been three separate attempts to explain the occurrence of derived responding. These are Sidman's theory of stimulus equivalence (Sidman, 1994), Relational Frame Theory (Hayes et al., 2001) and Naming Theory (Horne and Lowe, 1996). Each of these theories has a different explanation for the conditions responsible for the emergence of untaught relations.

Naming theorists suggest that the emergence of derived responses is mediated by language, and is made up of the symmetrical responses of verbal naming and comprehension. They go on to suggest that stimuli, and stimulus-response pairings must be assigned a common name in order for such equivalence classes to be formed. As the essential component of this theory is the ability to assign names to stimulus-response pairings, it is believed that equivalence relations will not emerge in those with little or no verbal language. The experimental teaching conditions generated for the present investigations were designed as an explicit test of this theory. The finding (in the present study) that the teaching condition (whether children were taught using the hear-select condition, or the see-say condition) had no effect on the likelihood of emergence of untaught relations fails to support the Naming Theory claim that the emergence of untaught equivalence relations is mediated by naming. In addition, the fact that there were no correlations between communication domains on the ABAS-II and the likelihood of emergence of untaught equivalence relations suggests that language ability was not a mediating factor in the likelihood of derived responding in the current study.

Sidman’s theory of stimulus equivalence argues that the emergence of untaught equivalence relations represents a new learning phenomenon – the appearance of new discriminated responses without any prior history of reinforcement for using that particular response in the presence of its controlling stimulus. The findings of the current study do not fit well within Sidman’s theoretical account of stimulus equivalence as some children in the current study did not demonstrate the emergence of untaught equivalence relations. These findings suggest that the demonstration of stimulus equivalence is not a primary behavioural function in at least some children with ASD.

Relational Frame theorists (Hayes et al., 2001) argue that for derived responding to be demonstrated, an individual requires a history of reinforcement for bi-directional responding. An essential component of the formation of equivalence relations is the use of multiple exemplar training. It is believed that through a history of multiple exemplar training individuals come to learn about the bi-directional stimulus-response relationships that make up equivalence classes. It is argued that without this prior learning history individuals will be unable to demonstrate derived responding. Although multiple exemplar training was not used and relational concepts were not taught, it is felt that the results of the current study can best be explained by the theory of derived responding proposed by Hayes et al. (2001). The finding in the current study that those children with ASD who required fewer trials to reach mastery criterion, and had higher functional academics scores were more likely to demonstrate the emergence of untaught equivalence relations provides indirect support for the argument of Hayes et al. (2001) that derived responding is a function of a prior history of reinforcement for this kind of responding. It seems likely that those children who acquired skills more rapidly and had more advanced functional academics skills may have received the most practice and the most reinforcement for responding in a variety of ways. This history of practice and reinforcement theory is further supported by the fact that those who acquired skills more rapidly had more advanced entry skills with respect to rote counting and counting with one-to-one correspondence.

An important implication of this finding is that it is possible in the current study that the children who did not demonstrate the emergence of untaught equivalence relations may have done so if they had been given additional generalization practice. In addition, those individuals who did not demonstrate emergence of the untaught relations may have begun to demonstrate derived responding if they had been prompted and reinforced for bi-directional responding during the experimental teaching.

When each of the three theoretical accounts are considered, and in the absence of a unified field theory, the findings of the current study are more consistent with a Relational Frame Theory interpretation then they are with a Naming Theory account or a Sidman type basic learning mechanism account. However, all three theories view operant principles as being at the core of this type of responding and both Hayes et al (2001) and Sidman (1994) view repertories of derived responding as being the foundation for a variety of complex verbal repertories.

It is also worth noting that recent fMRI research has begun to examine the emergence of untaught equivalence relations and is suggesting that specific areas of the brain may be activated during derived responding (Schlund, Hoehn-Saric, & Cataldo 2007). For example, Schlund et al. asked whether frontal-subcortical and frontal-parietal networks which have been found to be associated with conditional discrimination may be involved in derived responding. This study found activation in multiple prefrontal regions including the caudate, thalamus, and putamen during derived responding tasks. It was also discovered that each unique derived relation resulted in activation in a different area of the brain.

If children with ASD are not demonstrating emergence of untaught equivalence relations it is possible that the areas of the brain which are normally activated during derived responding could be areas which have been compromised in children with ASD. Further research in this area could help us to understand the mechanisms or areas in the brain that may underlie the emergence of derived responses and whether these specific areas of the brain are areas which have been affected in children with ASD.

Practical Implications of the Present Research

The present research has implications for both the teaching of children with ASD and for the teaching of children in general.

Implications for the Teaching of Children with ASD

When compared with typically developing children, children with ASD take a significantly longer period of time to acquire new discriminated responses. In addition, children with ASD tend to have greater difficulty in generalizing across responses and stimuli and often require additional teaching in order to learn to do so. The finding that some children with ASD are able to demonstrate the emergence of untaught equivalence relations has profound implications for the teaching of sets of stimulus equivalences and for facilitating generalization in children with ASD and other developmental disabilities. If teaching two stimulus-response relations leads to the emergence of four additional stimulus-response relations without having to directly teach these discriminated responses, then we can greatly improve the efficiency with which we can teach new skills to children who require remedial instruction.

Secondly, the evidence that some children with ASD did not demonstrate the emergence of untaught equivalence relations also has important implications. The first is that some children with ASD will be able to generalize (demonstrate symmetry and transitivity) and they will be able to be taught using an efficient teaching procedure. Others however, will not and these children will need to be systematically taught all six discriminated responses for each concept. The second is that it may be necessary to conduct an assessment in order to determine whether a particular child is able to be taught using an efficient teaching method or whether the direct teaching of each discriminated response will be required. The third is that, if particular children fail to demonstrate the emergence of untaught equivalence relations then it may be valuable to explore and implement strategies that facilitate the development of this kind of generalization. The finding that the emergence of symmetrical and transitive responding may be related to learning history and/or the teaching method utilised suggests that we should ensure that the appropriate method is implemented when teaching discriminated responses. For example, new skills should be practised using a range of relevant discriminative stimuli and response modalities, pre-requisite skills that need to be taught should, in fact, be taught, and appropriate reinforcement procedures should be implemented to facilitate the emergence of untaught skills for those who are still learning to generalize in this way.

Finally, the results of the current study have implications for the teaching of language and communication skills. There are a number of research studies which have applied the principles of Relational Frame Theory to successfully teach derived language responses such as intraverbals (Perez-Gonzalez, Herszlikowicz, & Williams, 2008), mands (Murphy, Barnes-Holmes & Barnes-Holmes, 2005; Murphy & Barnes-Holmes, 2009; 2010; Rosales, & Rehfeldt, 2007; Sigafoos, Doss, & Reichle, 1989; Sigafoos, Reichle, Doss, Hall, & Pettitt, 1990) and tacts (Nuzzolo-Gomez & Greer, 2004). The principles of Relational Frame Theory have also been applied to the teaching of second languages, including Spanish vocabulary (Ramirez & Rehfeldt, 2009). This research has highlighted the potential utility of a training protocol that facilitates derived responding. Prior research has primarily used procedures outlined by relational frame theorists and has applied this to developmentally delayed populations whose verbal behaviour could remain substantially impaired without these key repertoires of derived relational responding. As children with ASD often have delayed language development a method that increases the rate at which children acquire new language concepts, in a way that also enhances the comprehension and meaning behind new language could greatly improve outcomes for children with ASD.

Further research clarifying the variables which are likely to facilitate the emergence of untaught discriminated responses is required if we are to provide educators with a knowledge of the teaching strategies and teaching conditions that are likely to be most effective in developing language in children with developmental disabilities.

Implications for the Teaching of Children in General

The findings of the present research have implication not only for children with disabilities, but also for typically developing children. These implications apply to individual instruction, whole class instruction, curriculum design and teaching efficiency.

One of the primary implications of the stimulus equivalence research is that the existence of sets of equivalence relations holds the potential to greatly improve teaching efficiency. Knowing how to structure teaching so that the minimum amount of teaching generates the maximum number of discriminated responses can greatly improve teaching efficiency across a range of curriculum areas. For example, if we are trying to teach a student to tell the time, we only need to teach two discriminated responses (matching the analogue time to the digital time and matching the dictated time to the analogue clock) and as a result the child should acquire four new discriminated responses (reading the time on an analogue clock, reading the time on a digital clock, matching the digital time to the analogue clock, and matching the dictated time to the digital clock). If we are trying to teach Maori language, and the participants are taught to match the dictated word to the written word and the dictated word to its corresponding picture, then we would expect the child to then be able to read the written word aloud, name the picture orally, and also to match the word to the picture and the picture to the word, thus demonstrating comprehension of new Maori vocabulary.

In each of the above examples, we can teach two new discriminated responses, but get four new stimulus-response relations without any additional teaching. When applying these principles to areas such as music, foreign languages, mathematics, chemistry, and reading, where large amounts of vocabulary and a large number of concepts need to be taught, the impact is significant and is cumulative. For example, if we have ten new foreign words that we are trying to teach, then teaching these ten words using two different stimulus-response relations, could result in the emergence of 40 new discriminated responses that did not need to be taught. As the field develops, teachers can begin to give effect to Sidman's (2009) observation that "the direct addition of just one new member to the class produces an enormous increase in the number of indirectly established new relations. A small amount of teaching can yield a tremendous amount of learning".

There are several different types of curriculum content that can be taught using a stimulus equivalence teaching paradigm and stimulus equivalence has application across most domains of instruction. A review of the literature by Rehfeldt (2011) demonstrated that the majority of the research on derived responding to date has looked at areas of reading and basic vocabulary. A recommendation of the Rehfeldt (2011) review was that future research investigate how programming for relational repertoires can be used to teach mathematics concepts. Mathematics is an academic area which consists of a large array of interrelated concepts. The present study demonstrates that mathematical concepts can be taught as three pairs of equivalence relations two of which involve comprehension. The application of a stimulus equivalence teaching paradigm to the teaching of maths concepts has the potential to improve both the effectiveness and the efficiency of mathematics teaching.

Stimulus-equivalence teaching has been used to teach a variety of concepts in addition to language responses, Braille (Toussaint & Tiger, 2010), vocabulary acquisition in deaf children (Hollis, Fulton, & Larsen, 1986), a variety of academic concepts, PECS (Picture Exchange Communication System) (Rosales & Rehfeldt, 2007), advanced mathematics concepts (Hall, DeBernardis, & Reiss, 2006; Fields, Travis, Roy, Yadlovker, de Aguiar-Rocha, & Sturmey, 2009; Lynch & Cuvo, 1995), geography (Hall et al., 2006; Le Blanc et al., 2003), and relational concepts (Murphy & Barnes-Holmes, 2009; 2010).

The stimulus equivalence teaching procedure can equally be applied to teaching other academic areas including daily living skills, music, chemistry, foreign languages, and telling the time. For example, within music, there are several pairs of equivalence relations including, hearing the note being played and naming the note, hearing the dictated name for the note and playing the note, hearing the note being played and playing that note, seeing the written note and playing that note, seeing the written note and naming the note. Within chemistry there are stimulus-response relationships between the oral chemical names, written names and chemical symbols. If teachers could apply a stimulus equivalence teaching paradigm to such teaching tasks they could substantially decrease the amount of time required to teach vocabulary in a variety of academic domains.

The emergence of untaught symmetrical relations has been demonstrated not only in a 1:1 direct teaching setting, but it has also been demonstrated in observational learning situations (Ramirez & Rehfeldt, 2009). In the Ramirez and Rehfeldt experiment a 9-year old child was taught to match dictated Spanish names to pictures. During this teaching the child's 10-year old brother observed. Both the child who was directly taught, and the child who had observed the teaching demonstrated symmetrical responding by demonstrating oral naming of the picture in Spanish. This finding has major implications for the use of stimulus equivalence in the classroom setting as it demonstrates that a stimulus equivalence teaching paradigm can be applied in a group setting to more efficiently teach new vocabulary. Further research is needed to enhance our knowledge of how to effectively apply this procedure within a classroom.

Another related point worthy of note is that strategies to disseminate information related to the use of the stimulus equivalence teaching paradigm need to be explored. Currently, an increasing amount of research has focused on equivalence relations and other forms of derived responding and so strategies are necessary to ensure that the practical applications of this approach are disseminated to teachers.

Future Research Directions

While the present research has contributed towards our understanding of some of the variables that may affect the emergence of untaught equivalence relations, there is still much to be learned. First more work needs to be done in developing a theory of stimulus equivalence. There are currently three theories that attempt to explain derived responding. Each of these attempts to clarify the variables that account for derived responding. However, we still do not completely understand the processes involved, or the mediational processes responsible for the emergence of derived responses and none of these three theories provide a conclusive explanation for each of the findings obtained in this study. If we are to effectively apply this teaching paradigm then we need a better understanding of the conditions responsible for this type of generalization.

A second area that requires further investigation relates to the applications of stimulus equivalence. This includes developing a greater understanding of the teaching procedures which will result in the emergence of untaught discriminated responses. We need to enhance our understanding of how its use may apply, or be adapted to apply, across various curriculum areas when utilized in small-group or whole class instruction, and when used with different populations of children and adults. The utility of this approach for teaching in each of these areas and the necessary teaching conditions responsible for emergence requires further investigations.

The third area that we need to develop is our understanding of the variables that affect the likelihood of emergence of untaught equivalence relations. Developing a greater understanding of the variables that facilitate the emergence of untaught relations has particular implications for children with special learning needs and/or language limitations. Increasing our understanding in this area will enable teachers to implement strategies that will facilitate the emergence of untaught skills, subsequently increasing the utility of this approach and ultimately, leading to more efficient teaching.

Conclusions

The current study made several important discoveries. One of these findings is that there is variation among children with autism spectrum disorders (ASD) in terms of the likelihood that they will demonstrate the emergence of untaught symmetrical and transitive relations. Some children with ASD were able to demonstrate the emergence of all of the untaught relations regardless of the teaching condition that was used. Some however, demonstrated symmetrical responding but not transitivity. With a group of typically developing 3-year old children, however, nine out of ten children demonstrated the emergence of each of the untaught equivalence relations in both experimental teaching conditions.

The variable that was most strongly related to performance on tests for the emergence of untaught equivalence relations was the number of teaching trials that it took for children to reach mastery criterion for the taught stimulus-response relations. Functional academics scores on the ABAS-II, chronological age, and group membership (whether a child was typically developing or had ASD) were also significantly correlated with the emergence of untaught equivalence relations.

In the present investigation instruction in stimulus naming had no effect on the likelihood of emergence of untaught equivalence relations. This finding differed from that reported in prior research which has indicated that instruction in stimulus naming may facilitate the emergence of derived relations.

The finding that those children with ASD who demonstrated symmetrical and transitive responding scored more highly on functional academics, acquired discriminated responses more rapidly, and were of a younger age provides support for Hayes et al (2001) theory of derived responding. The correlation between each of these variables and total derived relations suggests that it may have been the children's rate of development and/or prior experience that affected the likelihood of emergence of untaught relations.

The demonstration of stimulus-equivalence has several important implications for teaching and learning. Firstly, increased understanding of the conditions which affect the emergence of untaught equivalence relations will enable teaching to be structured so that the teaching of one or two discriminated responses results in the emergence of two or four discriminated responses without any further teaching. Secondly, a greater understanding of the variables affecting the emergence of untaught equivalence relations could help to guide us on a broader scale in devising and designing classroom curriculum as well as intervention programmes for children which allow for and promote the automatic generalization of skills. Thirdly, there are several different types of curriculum content that can be taught using a stimulus equivalence teaching paradigm and stimulus equivalence has applications across a range of instructional domains. Fourthly, the finding that some children with ASD are able to demonstrate the emergence of untaught equivalence relations has profound implications for teaching and facilitating generalization in children with ASD and related disorders. If teaching two stimulus-response relations leads to emergence of four additional stimulus-response relations without having to directly teach these discriminated responses then we can greatly improve the efficiency with which we conduct remedial instruction.

Several areas of stimulus equivalence require further investigation if we are to more adequately understand the theoretical underpinnings of equivalence relations and the strategies that facilitate the emergence of untaught equivalence relations. These include, further development of the theory explaining the emergence of untaught equivalence relations, investigation into the limitations of this teaching paradigm, and further examination of the variables that affect the emergence of untaught equivalence relations.

REFERENCES

Alpert, C. L., & Kaiser, A. P. (1992). Training parents as milieu language teachers. *Journal of Early Intervention, 16,* 31-52.

American Psychiatric Association. (2000). Diagnostic and statistical manual of mental disorders (4th ed., Text Revision). Washington, DC: Author.

Amaral, D. G., Mills-Schumann, C., Wu Nordahl, C. (2008). Neuroanatomy of Autism. *Trends in Neuroscience, 31,* 137-145.

Anderson, G. M. (2005). Serotonin in Autism. In M. L. Bauman & T. L. Kemper (Eds.), *The neurobiology of autism (2nd ed.).* (pp.303-318). Baltimore, MD: Johns Hopkins University Press.

Autism New Zealand Inc. (2008). *Autism: A different way of thinking. How common are Autism Spectrum Disorders?* Retrieved from http://www.autismnz.org.nz/Autism-New-Zealand/More-About-Autism.

Bachelli, E., & Maestrini, E. (2006). Autism spectrum disorders: Molecular genetic advances. *American Journal of Medical Genetics Part C:Seminars in Medical Genetics , 142C,* 13-25.

Bailey, A., Le Couteur, A., Gottesman, I., & Bolton, P. (1995). Autism as a strongly genetic disorder: Evidence from a British twin study. *Psychological Medicine: A Journal of Research in Psychiatry and the Allied Sciences, 25,* 63-77.

Bailey, A., Phillips, W., & Rutter, M. (1996). Autism: Towards an integration of clinical, genetic, neuropsychological, and neurobiological perspectives. *Journal of Child Psychology and Psychiatry, 37,* 89-126.

Bayley, N. (1993). *Bayley Scales of infant development* (2nd ed.). San Antonio, TX: The Psychological Corporation.

Bauman, M. L., & Kemper, T. L. (Eds.). (2005). *The neurobiology of autism (2nd ed.).* Baltimore, MD: Johns Hopkins University Press.

Betz, A. M., Higbee, T. S., & Pollard, J. S. (2010). Promoting generalization of mands for information used by young children with autism. *Research in Autism Spectrum Disorders, 4,* 501-508.

Brady, N. C., & McLean, L. K. (2000). Emergent symbolic relations in speakers and nonspeakers. *Research in Developmental Disabilities, 21,* 197-214.

Carr, D., Wilkinson, K. M., Blackman, D., & McIlvane, W. J. (2000). Equivalence classes in individuals with minimal verbal repertoires. *Journal of the Experimental Analysis of Behavior, 74,* 101-114.

Clayton, M. C., & Hayes, L. J. (1999). Conceptual differences in the analysis of stimulus equivalence. *The Psychological Record, 49,* 145-161.

Cohen, H., Amerine-Dickens, M., & Smith, T. (2006). Early intensive behavioural treatment: Replication of the UCLA model in a community setting. *Journal of Developmental Behavioral Paediatrics, 27,* 145-155.

Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied Behavior Analysis* (2nd ed.). Upper Saddle River, NJ: Pearson/Merrill-Prentice Hall.

Courchesne, E., Karns, C. M., Davis, H. R., Ziccardi, R., Carper, R. A., Tigue, Z. D., ... Courchesne, R. Y. (2001). Unusual brain growth patterns in early life in patients with autistic disorder: An MRI study. *Neurology, 57,* 245-254.

Cowley, B. J., Green, G., & Braunling-McMorrow, D. (1992). Using stimulus equivalence procedures to teach name-face matching to adults with brain injuries. *Journal of Applied Behavior Analysis, 25,* 461-475.

Craighead, E. W., O'Leary, D. K., & Allen, J. S. (1973). Teaching and generalization of instruction-following in an "autistic" child. *Journal of Behavior Therapy and Experimental Psychiatry, 4,* 171-176.

D'Amato, M. R., Salmon, D. P., Loukas, E., & Tomie, A. (1985). Symmetry and transitivity of conditional relations in monkeys (Cebus appella) and pigeons (Columba livia). *Journal of the Experimental Analysis of Behavior, 44*, 35-47.

Daniel, L S. (2004). *E-News: Reconciling personal beliefs with a greater understanding of applied behaviour analysis: Teaching children with autism spectrum disorders.* Retrieved from http://www.ttac.vt.edu/autism/ documents/E-News_January_05-1.pdf.

De Rose, J. C., & De Souza, D. G. (1996). Teaching reading and spelling exclusion and stimulus equivalence. *Journal of Applied Behavior Analysis*, *29,* 451-469.

Devany, J. M., Hayes, S. C., & Nelson R. O. (1986). Equivalence class formation in language-able and language-disabled children. *Journal of the Experimental Analysis of Behavior, 46,* 243-257.

Dugdale, N. A., & Lowe, C. F. (1990). Naming and Stimulus Equivalence. In D. E. Blackman & H. Lejeune (Eds.), *Behavior Analysis in Theory and Practice. Contributions and Controversies* (pp. 115-138). Hove, Sussex: Lawrence Erlbaum Associates.

Dunlap, G., Kern, L., & Worcestor, J. (2001). ABA and academic instruction. *Focus on Autism and other Developmental Disabilities, 16,* 129-136.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test (4th ed.).* San Antonio, TX: Pearson.

Egel, A. L., Shafer, M. S., & Neef, N. A. (1984). Receptive acquisition and generalization of prepositional responding in autistic children: A comparison of two procedures. *Analysis and Intervention in Developmental Disabilities, 4,* 285-298.

Eikeseth, S., & Smith, T. (1992). The development of functional and equivalence classes in high-functioning autistic children: The role of naming. *Journal of the Experimental Analysis of Behavior, 58,* 123-133.

Engelmann, S., & Carnine, D. (1991). *Theory of instruction: Principles and applications* (Rev. ed.). Eugene, OR.: ADI Press.

Fields, L., Travis, R., Roy, D., Yadlovker, E., de Aguiar-Rocha, L., & Sturmey, P. (2009). Equivalence class formation: A method for teaching statistical interactions. *Journal of Applied Behavior Analysis, 42,* 575-593.

Fombonne, E. (2003). The prevalence of Autism. *The Journal of the American Medical Association, 289,* 87-89.

Fombonne, E. (2005). Epidemiological studies of pervasive developmental disorders. In F. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.). *Handbook of Autism and Pervasive Developmental Disorders* (pp. 42-69). Hoboken, NJ: Wiley.

Gast, D. L., Munson Doyle, P., Wolery, M., Jones Ault, M., & Kolenda, J. L. (1994). Instructive feedback: Effects of number and type. *Journal of Behavioural Education, 4,* 313-334.

Gorham, M., Barnes-Holmes, Y., & Barnes-Holmes, D. (2009). Derived comparative and transitive relations in young children with and without autism. *The Psychological Record, 59,* 221-246.

Gresham, F. M., Beebe-Frankenberger, M. E., & MacMillan, D. L. (1999). A selective review of treatments for children with autism: Description and methodological considerations. *School Psychology Review, 28,* 559-575.

Griffiths, R., & Huntley, M. (1996). *Griffiths Mental Development Scales-Revised: Birth to 2 years*. Oxford, UK: Hogrefe.

Hall, S. S., DeBernardis, G. M., & Reiss, A. L. (2006). The acquisition of stimulus equivalence in individuals with fragile X syndrome. *Journal of Intellectual Disability Research, 50,* 643-651.

Handleman, J. S. (1979). Generalization by autistic-type children of verbal responses across settings. *Journal of Applied Behavior Analysis, 12,* 273-282.

Handleman, J. S. (1981). Transfer of verbal responses across instructional settings by autistic type children. *Journal of Speech and Hearing Disorders, 46,* 69-76.

Haring, T., Kennedy, C., Adams, M., & Pitts-Conway, V. (1987). Teaching generalization of purchasing skills across community settings to autistic youth using video tape modelling. *Journal of Applied Behavior Analysis, 20,* 89-96.

Harrison, P. L., & Oakland T. (2003). *Adaptive Behavior Assessment System (2nd ed.).* San Antonio, TX: Harcourt Assessment.

Hart, B., & Risley, T. R. (1980). In vivo language intervention: Unanticipated general effects. *Journal of Applied Behavior Analysis, 13,* 407-432.

Hayes, S. C., Barnes-Holmes, D., & Roche, B. (2001). *Relational Frame Theory: A Post-Skinnerian account of human language and cognition*. New York: Plenum Press.

Hollis, J. H., Fulton, R. T., & Larsen, A. D. (1986). An equivalence model for vocabulary acquisition in profoundly hearing-impaired children. *Analysis and Intervention in Developmental Disabilities, 6,* 331-348.

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65,* 185-241.

Horner, R. H., Carr, E. G., Strain, P. S., & Reed, H. K. (2002). Problem behaviour interventions for young children with autism: A research synthesis. *Journal of Autism and Developmental Disabilities, 32,* 423-446.

Jackson, M., Williams, L. W., & Biesbrouck, J. (2006). Equivalence relations, the assessment of basic learning abilities and language: A synthesis of behavioural research and its implications for children with autism. *The Journal of Speech and Language Pathology – Applied Behavior Analysis, 1,* 27-42.

Jones, E. A., Feeley, K. M., & Takacs, J. (2007). Teaching spontaneous responses to young children with autism. *Journal of Applied Behavior Analysis, 40,* 565-570.

Kadesjo, B., Gillberg, C., & Hagberg, B. (1999). Brief report: Autism and Asperger syndrome in seven-year-old children: A total population study. *Journal of Autism and Developmental Disorders, 29,* 327-331.

Kennedy, C. H., Itkonen, T. & Lindquist, K. (1994). Nodality effects during equivalence class formation: An extension to sight-word reading and concept development. *Journal of Applied Behavior Analysis,27,* 673-683.

Klauck, S. M. (2006). Genetics of autism spectrum disorder. *European Journal of Human Genetics, 14,* 714-720.

Koegel, L. K., Camarata, S. M., Valdez-Menchaca, M., & Koegel, R. L. (1998). Setting generalization of question-asking by children with autism. *American Journal of Mental Retardation, 102,* 346-357.

Koegel, L. K., Koegel, R. L., Harrower, J. K., & Carter, C. M. (1999). Pivotal response intervention I: Overview of approach. *The Journal of the Association for Persons with Severe Handicaps, 24,* 174-185.

Kok, A. J., Kong, T. Y., & Bernard-Opitz, V. (2002). A comparison of the effects of structured play and facilitated play approaches on preschoolers with autism: A case study. *Autism, 6,* 181-196.

Le Blanc, L. A., Miguel, C. F., Cummings, A. R., Goldsmith, T. R., & Carr, J. E. (2003). The effects of three stimulus-equivalence testing conditions on emergent U.S. geography relations of children diagnosed with autism. *Behavioral Interventions, 18,* 270-289.

Lipkens, R., Kop, P. F. M., & Matthijs, W. (1988). A test of symmetry and transitivity in the conditional discrimination performances in pigeons. *Journal of the Experimental Analysis of Behavior, 49,* 395-409.

Lovaas, I. O. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychology, 55,* 3-9.

Lovaas, I. O., & Schreibman, L. (1971). Stimulus over-selectivity of autistic children in a two stimulus situation. *Behaviour Research and Therapy, 9,* 305-310.

Lovaas, I. O., Schreibman, L., Koegel, R., & Rehm, R. (1971). Selective responding by autistic children to multiple sensory input. *Journal of Abnormal Psychology, 77,* 211-222.

Lynch, D. C., & Cuvo, A. J. (1995). Stimulus equivalence instruction of fraction-decimal relations. *Journal of Applied Behavior Analysis, 28,* 115-126.

Mackay, H. A. (1985). Stimulus equivalence in rudimentary reading and spelling. *Analysis and Intervention in Developmental Disabilities. 5,* 373-387.

Maydak, M., Stromer, R., Mackay, H. A., & Stoddard, L. T. (1995). Stimulus classes in matching to sample and sequence production: The emergence of numeric relations. *Research in Developmental Disabilities, 16,* 179-204.

McConnell, S. R. (2002). Interventions to facilitate social interaction for young children with autism: Review of available research and recommendations for educational intervention and future research. *Journal of Autism and Developmental Disorders, 32,* 351-372.

McDonagh, E. C., McIlvane, W. J., & Stoddard, L. T. (1984). Teaching coin equivalences via matching to sample. *Applied Research in Mental Retardation, 5,* 177-197.

McEachin, J.J., Smith, T., & Lovaas, I. O. (1993). Long-term outcome for children with autism who received early intensive behavioural treatment. *American Journal of Mental Retardation, 97,* 373-391.

McGee, G. G., Krantz, P. J., Mason, D., McClannahan, L. E. (1983). A modified incidental-teaching procedure for autistic youth: Acquisition and generalization of receptive object labels. *Journal of Applied Behavior Analysis, 16,* 329-338.

Miranda-Linne, F., & Melin, L. (1992). Acquisition, generalization, and spontaneous use of color adjectives: A comparison of incidental and discrete-trial procedures for children with autism. *Research in Developmental Disabilities, 13,* 191-210.

Mudford, O., Blampied, N., Phillips, K., Harper, D., Foster, M., Church, J., ...Wilczynski, S. (2009). *Technical review of published research on applied behaviour analysis interventions for people with autism spectrum disorders.* Wellington, New Zealand: Ministry of Education.

Mueller, M. M., Olmi, D. J., & Saunders, K. J. (2000). Recombinative generalization of within-syllable units in prereading children. *Journal of Applied Behavior Analysis, 33,* 515-531.

Mullen, E. M. (1995). *Mullen Scales of Early Learning.* San Antonio: TX. Pearson.

Murphy, C., Barnes-Holmes, D., & Barnes-Holmes, Y. (2005). Derived manding in children with autism: Synthesizing Skinner's verbal behaviour with relational frame theory. *Journal of Applied Behavior Analysis, 38,* 445-462.

Murphy, C., & Barnes-Holmes, D. (2009). Derived more-less mands in children diagnosed with autism. *Journal of Applied Behavior Analysis, 42,* 253-268.

Murphy, C., & Barnes-Holmes, C. (2010). Establishing five derived mands in three adolescent boys with autism. *Journal of Applied Behavior Analysis, 43,* 537-541.

National Research Council: Committee on Educational Interventions for Children with Autism, (2001). *Educating Children with Autism.* Washington DC: National Academy Press.

Newschaffer, C. J., Croen, L. A., Daniels, J., Giarelli, E., Grether, J. K., Levy, S. E., ... Windham, G. C. (2007). The epidemiology of autism spectrum disorders. *Annual Review of Public Health, 28,* 235-258.

New Zealand Ministry of Health (2008). *New Zealand Autism Spectrum Disorder Guideline.* Wellington, New Zealand: Ministry of Health.

Noro, F. (2005). Using stimulus equivalence procedures to teach receptive emotional labelling to a child with autistic disorder. *Japanese Journal of Special Education, 42,* 483-496.

Nuzzolo-Gomez, R., & Greer, D. R. (2004). Emergence of untaught mands or tacts of novel adjective-object pairs as a function of instructional history. *The Analysis of Verbal Behavior, 20,* 63-76.

O'Connor, J., Rafferty, A., Barnes-Holmes, D., & Barnes-Holmes, Y. (2009). The role of verbal behaviour, stimulus nameability, and familiarity on the equivalence performances of autistic and normally developing children. *The Psychological Record, 59,* 53-74.

O'Donnell, J., & Saunders, K. J. (2003). Equivalence relations in individuals with language limitations and mental retardation. *Journal of the Experimental Analysis of Behavior, 80,* 131-157.

Pellechia, M., & Hineline, P. N. (2007). Generalization of mands in children with autism from adults to peers. *The Behavior Analyst Today, 8,* 483-491.

Perez-Gonzalez, L. A., Herszlikowicz, K., & Williams, G. (2008). Stimulus relations analysis and the emergence of novel intraverbals. *The Psychological Record, 58,* 95-121.

Ramirez, J., & Rehfeldt, R. A. (2009). Observational learning and the emergence of symmetry relations in teaching Spanish vocabulary words to typically developing children. *Journal of Applied Behavior Analysis, 42,* 801-805.

Rehfeldt, R. A. (2011). Toward a technology of derived stimulus relations: An analysis of articles published in the Journal of Applied Behavior Analysis, 1992-2009. *Journal of Applied Behavior Analysis, 44,* 109-119.

Rehfeldt, R. A. & Root, S. (2004). The generalization and retention of equivalence relations in adults with mental retardation. *The Psychological Record, 54,* 173-186.

Rincover, A., & Koegel, R. L. (1975). Setting generality and stimulus control in autistic children. *Journal of Applied Behavior Analysis, 8,* 235-246.

Rogers, S. J. (1998). Intervention for young children with autism: from research to practice. *Infants and Young Children, 12,* 1-16.

Rosales, R., & Rehfeldt, R. A. (2007). Contriving transitive conditioned establishing operations to establish derived manding skills in adults with severe developmental disabilities. *Journal of Applied Behavior Analysis, 40,* 105-121.

Rutter, M., LeCouteur, A., & Lord, C. (2003). *Autism Diagnostic Inventory – Revised.* Torrance: CA. Western Psychological Services.

Sallows, G. O., & Graupner, T. D. (2005). Intensive behavioural treatment for children with autism: four-year outcome and predictors. *American Journal of Mental Retardation, 110,* 417-438.

Saunders, R. R., & McEntee, J. E. (2004). Increasing the probability of stimulus equivalence with adults with mild mental retardation. *The Psychological Record, 54,* 423-435.

Schlund, M. W., Hoehn-Saric, R., & Cataldo, M. F. (2007). New knowledge derived from learning knowledge: Functional-anatomic correlates of stimulus equivalence. *Journal of the Experimental Analysis of Behavior, 87,* 287-307.

Schopler, E., Reichler, R., & Rochen-Renner, B. (1993). *Child Autism Rating Scale*. Los Angeles: CA. Western Psychological Services.

Schopler, E., Short, A., & Mesibov, G. (1989). Relation of behavioural treatment to "normal functioning": Comment on Lovaas. *Journal of Consulting and Clinical Psychology, 57,* 162-164.

Secan, K. E., Egel, A. L., & Tilley, C. S. (1989). Acquisition, generalization, and maintenance of question-answering skills in autistic children. *Journal of Applied Behavior Analysis, 22,* 181-196.

Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research, 14,* 5-13.

Sidman, M. (1994). *Equivalence relations and behaviour: A research story*. Boston, MA: Authors Cooperative.

Sidman, M. (2000). Equivalence relations and the reinforcement contingency. *Journal of the Experimental Analysis of Behavior, 74,* 127-146.

Sidman, M. (2004). The analysis of human behaviour in context. *The Behavior Analyst, 27,* 189-195.

Sidman, M.(2009). Equivalence relations and behaviour: An introductory tutorial. *The Analysis of Verbal Behavior, 25,* 5-17.

Sidman, M., & Cresson, O. (1973). Reading and cross-modal transfer of stimulus equivalences in severe retardation. *American Journal of Mental Deficiency, 77,* 515-523.

Sidman, M., Cresson, O., & Willson-Morris, M. (1974). Acquisition of matching to sample via mediated transfer. *Journal of the Experimental Analysis of Behavior, 22,* 261-273.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37,* 5-22.

Sidman, M., Willson-Morris, M., & Kirk, B. (1986). Matching-to-sample procedures and the development of equivalence relations: The role of naming. *Analysis and Intervention in Developmental Disabilities, 6,* 1-19.

Sigafoos, J., Doss, S., & Reichle, J. (1989). Developing mand and tact repertoires in persons with severe developmental disabilities using graphic symbols. *Research in Developmental Disabilities, 10,* 183-200.

Sigafoos, J., Reichle, J., Doss, S., Hall, K., & Pettitt, L. (1990). "Spontaneous" transfer of stimulus control from tact to mand contingencies. *Research in Developmental Disabilities, 11,* 165-176.

Sparks, B. F., Friedman, S. D., Shaw, D. W., Aylward, E. H., Echelard, D., Artru, A. A., ... Dager, S. R. (2002). Brain structural abnormalities in children with autism spectrum disorder. *Neurology, 59,* 184-193.

Sparrow, S., Cicchetti, D., & Balla, D. (2005). *Vineland Adaptive Behavior Scales* (2nd ed.). Minneapolis, MN: Pearson Assessment.

Spradlin, J. E., Cotter, V. W., & Baxley, N. (1973). Establishing a conditional discrimination without direct training: A study of transfer with retarded adolescents. *American Journal of Mental Deficiency, 77, 556-566.*

Sponheim, E., & Skjeldal, O. (1998). Autism and related disorders: Epidemiological findings in a Norwegian study using ICD-10 diagnostic criteria. *Journal of Autism and Developmental Disorders, 28,* 217-227.

Steffenburg, S., Gillberg, C., Hellgren, L., Andersson, L., Gillberg, C., Jakobsson, G., & Bohman, M. (1989). A twin study of autism in Denmark, Finland, Iceland, and Norway, and Sweden. *Journal of Child Psychology and Psychiatry, 30,* 405-416. .

Stokes, T. F., & Baer, D. M. (1977). An implicit technology of generalization. *Journal of Applied Behavior Analysis, 10,* 349-367.

Stromer, R., & Mackay, H .A. (1992). Spelling and emergent picture-printed word relations established with delayed identity matching to complex samples. *Journal of Applied Behavior Analysis, 25,* 893-904

Stromer, R., Mackay, H. A., & Stoddard, L. T. (1995). Classroom applications of stimulus equivalence technology. *Journal of Behavioral Education, 2,* 225-256.

Toussaint, K.A., & Tiger, J. H. (2010). Teaching early Braille literacy skills within a stimulus equivalence paradigm to children with degenerative visual impairments. *Journal of Applied Behavior Analysis, 43,* 181-194.

Virues-Ortega, J. (2010). Applied behaviour analytic intervention for autism in early childhood: Meta-analysis, meta-regression, and dose-response meta-analysis of multiple outcomes. *Clinical Psychology Review, 30,* 387-399.

Vismara, L. A., & Rogers, S. J. (2010). Behavioral treatments in autism spectrum disorder: What do we know? *Annual Review of Clinical Psychology, 6,* 447-468.

Wechsler, D., & Naglieri, J. A. (2006). *Wechsler Nonverbal Scale of Ability*. San Antonio, TX: Pearson.

Westling D. L., & Floyd, J. (1990). Generalization of community skills: How much training is necessary? *The Journal of Special Education, 23,* 386-405.

Williams, K. T. (2007). *Expressive Vocabulary Test (2nd ed.).* San Antonio, TX: Pearson.

Williams, G., Carnerero, J. J., & Perez-Gonzalez, L. A. (2006). Generalization of tacting actions in children with autism. *Journal of Applied Behavior Analysis, 39,* 233-237.

Wynn, J. W., & Smith, T. (2003). Generalization between receptive and expressive language in young children with autism. *Behavioral Interventions, 18,* 245-266.

Young, J. M., Krantz, P. J., McClannahan, L. E., & Poulson, C. L. (1994). Generalized imitation and response-class formation in children with autism. *Journal of Applied Behavior Analysis, 27,* 685-697.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of Autism in the first year of life. *International Journal of Developmental Neuroscience, 23,* 143-152.

APPENDIX 1

University of Canterbury Human Ethics Approval Letter

Ref: HEC 2009/6/CoEdn

8 April 2009

Laura-Lee K McLay
36 Bewdley Street
Spreydon
CHRISTCHURCH

Dear Laurie

Thank you for providing the revised documents in support of your application to the College of Education Ethical Clearance Committee. I am very pleased to inform you that your research proposal "A study of teaching strategies that facilitate stimulus generalisation in children with Autism" has been granted ethical approval.

Please note that should circumstances relevant to this current application change you are required to reapply for ethical approval.

If you have any questions regarding this approval please let me know.

We wish you well for your research.

Yours sincerely

Dr Missy Morton
Chair

Ethical Clearance Committee

APPENDIX 2

Summary Data Sheet (taught skills) – Equivalence Relations

Target skill:__________________ **Participant:___________________**

	Date tested	Percentage Correct (Yes/No)	Mastery Achieved (Yes/No)	Total test trials
Target numeral/quantity:				

APPENDIX 3

Summary Data Sheet (untaught skills) – Equivalence Relations

Target skill:___________________ Participant:____________________

	Date tested	Percentage Correct (Yes/No)	Mastery Achieved (Yes/No)	Total test trials
Target numeral/quantity:				

APPENDIX 4

Trial by Trial data – Taught Equivalence Relations

Target skill:________________________________ Participant:_____________

Date:																								**Percentage correct**

C = Correct independent response I = Incorrect response P = Prompted response N = No response/off-task

TOTAL TEACHING TRIALS:___________

COMMENTS:

APPENDIX 5

Trial by Trial data – Test for Emergence of Untaught Equivalence Relations

Target skill:________________________________   **Participant:_____________**

Date:																								**Percentage correct**

C = Correct independent response   I = Incorrect response   P = Prompted response   N = No response/off-task

COMMENTS:

APPENDIX 6

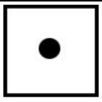
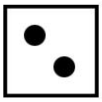
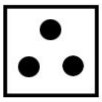
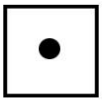
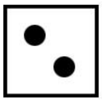
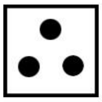
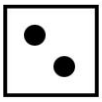
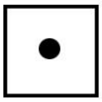
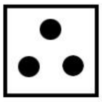
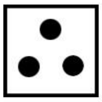
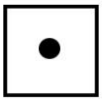
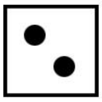
The Relations Taught to Child 2 during Condition Treatment A+B

Condition A (the Hear-Select Condition)

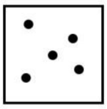
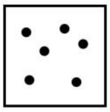
Taught relations	***SD***	***Possible responses Correct response***	***Incorrect responses***	
	Hears	***Selects:***	***Selects:***	
AB1	"One"	•	• •	• • •
AB2	"Two"	• •	•	• • •
AB3	"Three"	• • •	•	• •
AC1	"One"	1	2	3
AC2	"Two"	2	1	3
AC3	"Three"	3	1	2

The equivalence relations which were tested following mastery of the Hear-Select relations for the numbers 1 to 3 in Condition A for Child 2.

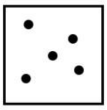
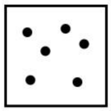
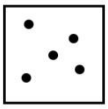
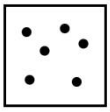
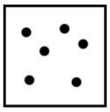
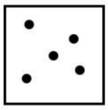
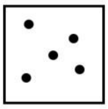
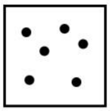
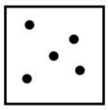
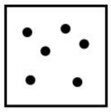
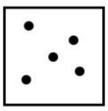
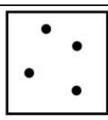
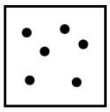
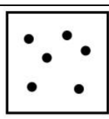
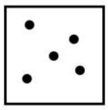
Tested relation	**SD**	**Possible responses Correct response**	**Incorrect responses**
	Sees	**Says:**	**Says:**
BA1	•	"One"	"Two" or "Three"
BA2	• •	"Two"	"One" or "Three"
BA3	• • •	"Three"	"One" or "Two:
CA1	1	"One"	"Two" or "Three"
CA2	2	"Two"	"One" or "Two"

CA3	3	"Three"	"Two" or "Three"	
	Sees	**Selects**	**Selects**	
BC1		1	2	3
BC2		2	1	3
BC3		3	1	2
CB1	1			
CB2	2			
CB3	3			

Condition B (the See-Say Condition)

Taught Relations	***SD***	***Possible responses Correct response***	***Incorrect responses***
	Sees	***Says:***	***Says:***
BA4		"Four"	"Five" or "Six"
BA5		"Five"	"Four" or "Six"
BA6		"Six"	"Four" or "Five:
CA4	**4**	"Four"	"Five" or "Six"
CA5	**5**	"Five"	"Four" or "Six"
CA6	**6**	"Six"	"Four" or "Five"

The equivalence relations which were tested following mastery of the Hear-Select relations for the numbers 1 to 3 in Condition B for Child 2.

Tested Relations	***SD***	***Possible responses*** ***Correct Response***	***Incorrect Response***	
	Hears	***Selects:***	***Selects:***	
AB4	***"Four"***			
AB5	***"Five"***			
AB6	***"Six"***			
AC4	***"Four"***	4	5	6
AC5	***"Five"***	5	4	6
AC6	***"Six"***	6	4	5
	Sees	***Selects***	***Selects***	
BC4		4	5	6
BC5		5	4	6
BC6		6	5	4
CB4	4			
CB5	5			
CB6	6			

APPENDIX 7

Results of the Correlation Analysis for Children in the Autism Group (n=10)

	Total Derived Relations	Treatment Group	Age in Months	PPVT-IV Age Equivalent Score	Functional Academics Score	Commun-ication Score	Rote Counting	One-to-one Counting	Trials to Criterion A	Trials to Criterion B
Treatment Group	.211									
Age (in months)	-.527	-.258								
PPVT-IV Age Equivalent Score	.168	-.144	.113							
Functional Academics Score	.408	.000	-.734*	-.293						
Communication Score	.203	.394	-.350	.193	.378					
Rote Counting	.510	.167	-.119	.289	.338	.468				
One-to-one Counting	.539	.262	-.245	.266	.473	.630	.933**			
Trials to Criterion A	-.636*	-.531	.508	.157	-.442	-.485	-.575	-.639*		
Trials to Criterion B	-.939**	-.272	.419	-.321	-.417	-.372	-.643*	-.694*	.659*	
Total Trials to Criterion	-.855**	-.488	.511	-.075	-.472	-.474	-.667*	-.730*	.921**	.900**

** *p = <.01* **p = <.05*

APPENDIX 8

Results of the Correlation Analysis for Children in the Typically Developing Group (n=10)

	Total Derived Relations	Treatment Group	Age in Months	PPVT-IV Age Equivalent Score	Functional Academics Score	Commun - ication Score	Rote Counting	One-to-one Counting	Trials to Criterion A	Trials to Criterion B
Treatment Group	-.333									
Age (in months)	.300	.328								
PPVT-IV Age Equivalent Score	.738*	-.177	.372							
Functional Academics Score	.274	-.523	-.328	.513						
Communication Score	-.171	-.205	-.336	.261	.748*					
Rote Counting	-.042	-.252	.153	.133	.564	.372				
One-to-one Counting	.135	.024	.582	.475	.424	.477	.623			
Trials to Criterion A	.100	.551	.679*	.394	-.168	-.006	-.015	.627		
Trials to Criterion B	-.116	-.338	-.406	-.456	-.378	-.608*	-.381	-.786**	-.530	
Total Trials to Criterion	-.083	-.099	-.111	-.323	-.535	-.718*	-.455	-.584	-.082	.889**

** $p = <.01$ *$p = <.05$