CONTEXTUAL PROCESSING OF OBJECTS: USING VIRTUAL REALITY TO IMPROVE ABSTRACTION AND COGNITIVE FLEXIBILITY IN CHILDREN WITH AUTISM

by

Michelle Jai-Chin Wang

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Graduate Department of Rehabilitation Science

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Abstract

Background: The current study investigated the efficacy of a novel virtual reality-cognitive rehabilitation (VR-CR) intervention to improve *contextual processing of objects* in children with autism. Contextual processing is a cognitive ability thought to underlie the social and communication deficits of autism. Previous research supports that children with autism show deficits in contextual processing, as well as deficits in its basic component abilities: abstraction and cognitive flexibility. **Methods:** Four children with autism participated in a multiple baseline single-subject study. The children were taught how to *see objects in context* by reinforcing attention to pivotal contextual information. One-on-one teaching sessions occurred three times per week for approximately two weeks. **Results:** All children demonstrated significant improvements in contextual processing and cognitive flexibility. Mixed results were found on the control test. Changes in context-related behaviours were reported. **Conclusions:** Further studies using virtual reality to target specific cognitive impairments in children with autism are warranted.

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List of Abbreviations

ABA	Applied Behavior Analysis
ADHD	Attention-Deficit Hyperactivity Disorder
ADOS	Autism Diagnostic Observation Scale
ASD	Autism Spectrum Disorder
CARS	Childhood Autism Rating Scale
CEFT	Children's Embedded Figures Test
CR	Cognitive Rehabilitation
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders (4^{th} edition)
DTT	Discrete Trial Training
FIST	Flexible Item Selection Task
HMD	Head Mounted Device
ID/ED	Intradimensional/Extradimensional
IT	Incidental Teaching
MBD	Multiple Baseline Design
PDD-NOS	Pervasive Developmental Disorder – not otherwise specified
PND	Percentage of Non-Overlapping Data
PRT	Pivotal Response Training
REB	Research Ethics Board
TEACCH	Treatment and Education of Autistic and related Communication handicapped Children
ToM	Theory of Mind
VABS	Vineland Adaptive Behavior Scales
VE	Virtual Environment
VR	Virtual Reality
WCC	Weak Central Coherence
WCST	Wisconsin Card Sort Task

Chapter 1
Introduction

Autism or autism spectrum disorders (ASD) refer to a group of neurodevelopmental disorders that are characterized, in differing degrees, by core deficits in social and communication skills, as well as distinct abnormal behaviours (APA, 2000). The prevalence of autism in children is approaching 1%, or approximately 1 in 110 children (Centers for Disease Control and Prevention, 2009). Although autism can be diagnosed as young as 18 months of age (Filipek, et al., 1999), the symptoms of this disorder last throughout an individual's lifetime.

Autism is both diagnosed and treated based on specific behavioural criteria (Happe, 1995). A diagnosis of autism requires deficits in three primary areas: (1) qualitative impairments in social interaction (e.g. lack of eye contact, peer relationships, emotional reciprocity); (2) qualitative impairments in communication (e.g. lack of or delay in language development and inappropriate use of language); and (3) restricted, repetitive and stereotypical behaviours and interests (e.g. inflexibility in routine changes, lack of imaginative play) (APA, 2000). The majority of autism treatments are focused on teaching and improving specific behaviours within these three areas. However, teaching specific behaviours in controlled training environments can be problematic when newly-learned skills must be transferred to novel environments. Children with autism are well-recognized for difficulties in generalizing skills beyond the training context (DiSalvo & Oswald, 2002; Howlin, 1998; Rao, Beidel, & Murray, 2008; Rogers, 2000b; Weiss & Harris, 2001). An alternative approach to treatment is to target the cognitive impairments that *underlie* the specific patterns of autistic behaviour. Remediating underlying cognitive causes may facilitate a greater capacity to learn and generalize specific social and communication behaviours (Berger, et al., 1993; Rogers, 1998a). An emerging framework, initially proposed in the field of Attention-Deficit Hyperactivity Disorder (ADHD), offers an interactive, cognitive approach to intervention (Rizzo & Buckwater, 1997). This framework focuses on remediating underlying cognitive impairments of disorders, and uses virtual reality technology to maintain a high level of engagement and attention from the children. The current study used this framework to improve a specific cognitive impairment in children with autism: *contextual processing of objects*.

Chapter 2 begins with a brief overview of the current treatments for children with autism, the recurring problem of generalization, and the evidence supporting underlying cognitive impairments in autism. The chapter then presents the virtual reality-cognitive rehabilitation (VR-CR) intervention approach, and provides the background information for how this framework was used in the current study. Chapters 3 and 4 provide details of the specific methodology and results, respectively. Finally, Chapter 5 discusses the results in the context of current theoretical frameworks and considers the implications of such results on future research.

Chapter 2
Literature Review

2.1 Current Interventions for Children with Autism

Interventions for children with autism can be grouped broadly into two major approaches: behavioural or naturalistic. The behavioural approach uses principles of repetition and reinforcement to change specific behaviours (Lovaas, 1987), while the naturalistic approach facilitates learning opportunities within natural settings, using naturalistic strategies (Cowan & Allen, 2007). Although these approaches differ on the surface, fundamentally, the outcomes of both are focused on increasing appropriate behaviours and decreasing inappropriate ones.

2.1.1 Behaviourist Approaches

Behavioural approaches are derived from Applied Behavioural Analysis (ABA), which is currently the most widely used intervention for children with autism (Howlin, 1998). ABA focuses on teaching specific behaviours by breaking them into their components and working on each component sequentially. ABA is often implemented using Discrete Trial Training (DTT) methodology. DTT deconstructs a target behaviour into its specific components, and uses one-on-one instruction to teach these components incrementally through repeated trials and schedules of reinforcement (Lovaas, 1987; Magliaro, Lockee, & Burton, 2005). There is a large body of research validating the efficacy of this approach for changing specific behaviours in autistic children, such as increasing eye contact, expressing needs, and self-care skills (Howlin, 1998; Lovaas, 1987; Magliaro, et al., 2005). The major weakness of the traditional behaviourist approach is that instruction is primarily therapist or teacher-driven, reinforcing behaviours in situations that do not necessarily simulate real-life situations (Parsons & Mitchell, 2002). In addition, reinforcers are often artificial, such as food rewards, further increasing the unnaturalness of the training environment (Koegel, Koegel & McNerney, 2001). These weaknesses are thought to impact the degree to which children transfer their newly-learned skills to novel situations (Koegel, Koegel & McNerney, 2001). Contemporary approaches of ABA focus on this problem of generalization. Pivotal response training (PRT) is one such program. PRT provides a semi-structured program, whereby certain "pivotal" behaviours are targeted. These pivotal behaviours, such as self-management or self-initiation, are considered fundamental to the development and achievement of a diverse range of more complex behaviours. Children are taught to respond to multiple cues in a diverse range of natural contexts, with progressively less support from the instructor (Koegel, Koegel & McNerney, 2001). Another class of treatments has emerged to address the problem of generalization; these interventions are typically less structured, occur in naturalistic contexts, and focus on increasing knowledge within real situations.

2.1.2 Naturalist Approaches

Naturalistic interventions aim to teach and reward behaviours within the child's natural environment (Cowan & Allen, 2007). One naturalistic approach, incidental teaching (IT), focuses on modifying the child's environment to encourage social initiations such as requests (Cowan & Allen, 2007). For example, a toy may be withheld by the instructor until the child initiates a request. Receiving the toy acts as a natural reinforcer. Other approaches, such as the FloorTime or developmental, individual-difference, relationship-based (DIR) approach (Solomon et al., 2007) and the MoreThanWords program (Girolametto, Sussman & Weitzman, 2007), also encourage parent or therapist responses to child-initiated behaviours in order to improve social reciprocity and functional-pragmatic communication. A caveat of these naturalistic approaches is that the learning trials are initiated by the child, and thus the instructor has little control of the time, place or content of learning. A comprehensive review of autism interventions reported significant gains made by children in naturalistic programs, particularly in the areas of language and communication (Ospina, et al., 2008). Similar to the behaviourist approach, the outcomes of these naturalistic approaches are focused on improving specific types of behaviours.

2.1.3 The Problem of Generalization

The most persistent problem in both categories of autism interventions is the generalization or transfer of learned skills to new environments (Howlin, 1998; Rao, et al., 2008; Rogers, 2000a). Studies often report positive results in teaching new behaviours to children with autism; however, it is difficult for children to use these behaviours outside of the training context (e.g. Leaf, Dotson, Oppeneheim, Sheldon, & Sherman, 2010; Mirenda & Donnellan, 1987). Rogers (1998b) claims that the limitation of current interventions is their focus on targeting behavioural symptoms rather than underlying causes. In the past three decades, a wealth of evidence has been generated which supports the existence of underlying cognitive impairments in children with autism (Baron-Cohen, Tager-Flusberg, & Cohen, 2000; Happé & Frith, 2006). These cognitive impairments may limit the child to learning specific sequences of behaviours within modified and restricted environments and consequently fail to help the child to generalize behaviours to new environments (Klinger & Dawson, 1995, 2001). Improving underlying cognitive deficits may provide an autistic child with the prerequisite cognitive abilities to learn and apply appropriate behaviours within a multitude of contexts (Hill, 2004; Klinger & Dawson, 1995; Rogers, 1998b). The next section provides an overview of three major theories of cognitive impairments in children with autism.

2.2 Cognitive Impairments in Autism

In their 1979 seminal epidemiological study, Wing and Gould reported that the three classes of behavioural impairments that define autism *co-occur* consistently and reliably (Wing & Gould, 1979). This finding gave rise to the proposition that the co-occurrence of these behaviours could be the result of a single underlying, cognitive deficit (Frith, Morton, & Leslie, 1991). An explosion of cognitive theories occurred shortly after the publication of Wing and Gould's findings, each proposing a single, cognitive impairment to explain the behavioural triad observed in autism (Rajendran & Mitchell, 2007). The three most prominent theories are: impairments in Theory of Mind, Weak Central Coherence and Executive Dysfunction.

2.2.1 Theory of Mind

The concept of "Theory of Mind" was originally championed by Premack and Woodruff (1978) in their studies on chimpanzees, and was extended to children with autism by Baron-Cohen and colleagues in 1985. Theory of Mind (ToM) refers to the ability to attribute mental states to oneself or others, such as beliefs, feelings, thoughts and desires, in order to predict and respond to others' behaviour (Premack & Woodruff, 1978). Tests for theory of mind require a child to be aware of other people's perspectives and beliefs in a deceptive situation. For example, in the unexpected transfer test of false belief (Baron-Cohen, Leslie, & Frith, 1985) children watch a scene acted out by dolls. One doll, Sally, places her marble in a basket and then leaves the room. Another doll, Anne, moves the marble into a box. When Sally returns, the child is asked: "where will Sally look for her marble?" By 4 to 5 years of age, typical children will provide the correct response (i.e. "in the box"); conversely, approximately 80% of both children and adolescents with autism consistently provide the wrong response (i.e. "in the basket") (Baron-Cohen, et al., 1985). The failure to take another person's mental perspective has also been demonstrated in other ToM tests (e.g. deception box test; Perner, Frith, Leslie, & Leekam, 1989). Understanding other people's perspectives and beliefs is necessary to develop key social skills such as joint-attention and empathy, and is essential in reciprocal social and communication situations (Baron-Cohen, 1989). Thus, a deficit in ToM seems adequate to explain the major social and communication impairments of autism. However, research in this area decreased substantially within the past decade. Some believe that this theory's greatest contribution has already been made: propelling the direction of autism research into the realm of developmental psychology (Rajendran & Mitchell, 2007). The next two cognitive theories discussed in this section are a product of this momentum.

2.2.2 Central Coherence

The theory of Weak Central Coherence proposed by Frith (1989) is built on the observation that typical individuals have a "built in propensity to form coherence over as wide a range of stimuli as possible, and to generalize over as wide a range of contexts as possible" (Frith, 2003, p. 159), an ability called *central coherence*. Central coherence allows one to establish and make use of context. Central coherence can be demonstrated intuitively at multiple levels: at a visuo-perceptual level (e.g. focusing attention on the whole picture, rather than its parts), at a visuo-conceptual level (e.g. understanding that certain objects belong in certain contexts), at a linguistic level (e.g. using sentence content to ascribe meaning to ambiguous words such as homographs), and at a social level (e.g. modifying social behaviours for different situations). Experts in the field have stated that the different interpretations and definitions of 'central coherence' have caused inconsistencies in methodology and difficulties in comparing results across studies (Happe & Frith, 2006; Rajendran & Mitchell, 2007).

The majority of weak central coherence studies have focused on the visuo-perceptual level, which is based on the observation that a typical person tends to focus on the whole or *gestalt* of a visual scene, rather than its parts or details. These studies assume a dichotomy between gestalt or holistic processing and detailed-focused processing. Studies have therefore used detailed-focused processing as an indirect measure of central coherence: a lack of detailed-focused implies strong central coherence; a strong attention to detail implies weak central coherence (Shah & Frith, 1983). The Children's Embedded Figures Test (CEFT; Witkin, Oltman, Raskin, & Karp, 1971) and the Block Design Test (Kohs, 1923) are based on these assumptions. The CEFT requires the child to find a hidden figure within a meaningful, complex visual scene. Children who are influenced by the meaningfulness of the scene will have more difficulty teasing it apart into its components in order to find the non-meaningful target figure. On the Block Design test, children are required to replicate a complex geometrical design by combining individual blocks. Each block displays a piece of the total image and must be arranged correctly to complete the “puzzle.” Children who are able to mentally break apart the original design into individual fragments are able to complete the task more efficiently. Some studies have found that children with autism perform superiorly on the CEFT and Block Design test, as compared to typical children (Shah & Frith, 1983). This has been taken as evidence that children with autism are less influenced by the holistic nature of the complete picture and are more concerned with specific details (Ropar & Mitchell, 2001; Shah & Frith, 1983). However, replications of these studies have been inconsistent (see Happé & Frith, 2006 for a review).

Frith (1994) asserts that the failure to understand the gestalt of a situation has profound effects on autistic children’s social functioning and communication ability. Children with autism often fail to take into account the appropriateness of their behaviours and verbalizations within specific contexts. Frith (1989) has also hypothesized a link between a detailed-focused processing style and the circumscribed nature of behaviours displayed by these children. Although the theory of weak central coherence is able to explain all three classes of behaviours in autism, in an effort to be all-encompassing, the concept central coherence has become progressively more difficult to define and study (Rajendran & Mitchell, 2007).

2.2.3 Executive Function

The final theory of cognitive impairment in autism emphasizes impairments in executive function. Executive function is an umbrella term for a number of specific cognitive abilities required for the planning and execution of goal-directed behaviour (Hill, 2004). Executive function is defined as "the ability to maintain an appropriate problem-solving set for attainment of a future goal; it includes behaviors such as planning, impulse control, inhibition of prepotent but irrelevant responses, set maintenance, organized search, and flexibility of thought and action" (Ozonoff, Pennington, & Rogers, 1991, p. 1083). Previous research has shown that children with autism perform poorly on tests of executive function, particularly those for planning, cognitive flexibility and inhibition.

Assessments of planning skills, particularly the Tower of Hanoi test (Borys, Spitz, & Dorans, 1982), require a sequence of steps to be pre-determined and executed in succession. Children with autism performed significantly worse on these planning tests than typical children (Bennetto, Pennington, & Rogers, 1996; Ozonoff, 1991, 1995; Ozonoff & Jensen, 1999). Likewise, they performed poorly on the Wisconsin Card Sort Test (WCST; Berg, 1948; Grant & Berg, 1948), which assesses cognitive flexibility (Ozonoff, 1991; Prior & Hoffman, 1990; Rumsey, 1985). On the WCST, the children are required to sort cards according to specific perceptual criteria, such as colour, shape or size, based on feedback from the examiner. The sorting criteria changes without warning and the children are required to adapt their responses accordingly. Studies have reported that children with autism show significantly more perseveration on previous sorting criteria, which demonstrates their resistance to changes and poor mental flexibility (Ozonoff, 1991). In addition to deficits on planning and cognitive flexibility tasks, children with autism have shown replicable deficits on tasks requiring the inhibition of 'prepotent' but irrelevant responses. Prepotent responses are responses that seem the most obvious or salient. The Windows Task (Russell, Hala, & Hill, 2003; Russell, Mauthner, Sharpe, & Tidswell, 1991) assesses this type of inhibition in children. In this task, a chocolate bar is placed in one of two boxes. The child is required to point to the *empty* box, rather than the box with the chocolate, in order to receive the chocolate as a reward. Study results indicated that unlike typical children, children with autism were unable to resist pointing at the box with the chocolate, resulting in their continual failure to receive the reward. Children with autism were found to be more perseverant in their uninhibited behaviour despite negative feedback from the examiner (Hughes & Russell, 1993; Russell, et al., 1991).

In summary, specific executive deficits in planning, cognitive flexibility and inhibition have been consistently found in children with autism (Hill, 2004). Executive dysfunction has been causally implicated in all three classes of autistic behaviour; they can adequately explain poor social and communicative functioning in these children (Berger, Aerts, van Spaendonck, Cools, & Teunisse, 2003; Berger, et al., 1993; Hill, 2004), and have also been linked to the occurrence of inflexible, repetitive behaviour in autism (South, Ozonoff, & McMahon, 2007; Yerys, 2006). Thus, specific deficits in executive functioning offer explanatory power for all major behavioural symptoms of autism.

2.2.4 Problems with the Single-Impairment Hypothesis

Although many of these studies claim to support the single-underlying-cognitive-deficit hypothesis, none of the three theories offer a fully sufficient account of autism. To do so would require: (1) effective generation of hypotheses and methods for testing such hypotheses, (2) a causal account for all three classes of autistic behaviours; (3) uniqueness to the disorder of autism and (4) universality to all children with autism (Happe & Frith, 1995). The theory of mind hypothesis fulfills the first criteria and offers explanatory power for the social and communication deficits in autism. However, it does not explain the patterns of repetitive behaviour or the 20% of autistic children who consistently pass ToM tests. The weak central coherence theory provides a broad explanation of all the behavioural symptoms of autism, but its broadness creates problems in concept definition, hypothesis generation, study methodology, and cross-study comparisons. The final theory, executive dysfunction, provides a clear link to the three major behavioural impairments in autism; however, executive dysfunction is not unique to autism and is found commonly in many other special populations such as schizophrenia, attention-deficit hyperactivity disorder, and dementia. Experts now agree that there are likely multiple cognitive deficits that underlie the behavioural symptoms of autism (Happe, Ronald, & Plomin, 2006; Pennington, 2006; Rajendran & Mitchell, 2007).

As discussed previously, the outcome goals of treatments for children with autism tend to emphasize specific behaviours, such as language and social behaviours. However, some interventions have been designed to take cognitive deficits into account (Jones & Jordan, 2008). The Treatment and Education of Autistic and related Communication-handicapped Children (TEACCH; Schopler, Mesibov, & Hearsey, 1995) program is one such example. The TEACCH method addresses impairments on both cognitive and behavioural levels. For example, the program addresses executive difficulties such as planning and flexibility by incorporating strategies of visual scheduling, strict routines, and transition planning. These strategies essentially offer a "'replacement' of internal structures with external ones" (Jones & Jordan, 2008, p. 285). Therefore, while the TEACCH program does not focus on improving the actual cognitive impairments themselves, it does integrate compensatory strategies that have an impact on the child's daily functioning.

The current paper uses a traditional cognitive rehabilitation approach to remediate specific cognitive deficits in children with autism. This approach was chosen because of its effectiveness in improving similar cognitive deficits in other populations. The next section describes this approach, its efficacy in other special populations and why it may be effective to address cognitive impairments in children with autism.

2.3 Cognitive Rehabilitation

Cognitive rehabilitation includes specific therapeutic programs that target impaired cognitive functions. The theoretical backbone of cognitive rehabilitation originates from Luria's theory of brain organization, which emphasizes integrated brain function (Luria, 1980). Luria argues that cognitive function, as a whole, can be restored through repetitive training exercises that specifically target the impaired component processes. This repetition allows the lost connections to be re-learned and re-established (Luria, 1980; Sohlberg & Mateer, 1989). Thus, cognitive training usually employs methods of massed practice and drill repetition (Butler & Mulhern, 2005).

One example of a cognitive rehabilitation program is Sohlberg's (1989) Attention Process Training. The program is designed to remediate attention impairments in individuals with brain injury, and incorporates multiple exercises for all types of attention: sustained attention, alternative attention and divided attention. The exercises are graded in difficulty and administered according to individual strengths, weaknesses and progress (Sohlberg & Mateer, 1989).

Cognitive rehabilitation is used most often with adults suffering from brain injury or stroke. Two comprehensive meta-analyses reported that cognitive training strategies have been shown to be effective for improving visuo-spatial processing, cognitive-linguistic abilities, memory and attention in these individuals (Cicerone, et al., 2000; Cicerone, et al., 2005). The cognitive approach has recently been extended to adult psychiatric populations such as those with schizophrenia (e.g. Wykes, et al., 2007) as well as children suffering from acquired brain injury and central nervous system diseases such as pediatric malignancies (Butler & Mulhern, 2005; Limond & Leeke, 2005; Slomine & Locascio, 2009). A recent review of cognitive rehabilitation in children with acquired brain injury supports the use of these strategies to improve memory, unilateral neglect, speech and language and executive functioning (Slomine & Loscascio, 2009). A critical parallel is noted between these special populations and children with autism. The cognitive impairments typical of these populations overlap significantly with the impairments of children with autism, particularly in the area of executive functions. Thus, cognitive rehabilitation may be a potentially effective approach to remediating cognitive deficits in children with autism.

One major obstacle to using cognitive rehabilitation methods with children who have autism is the maintenance of engagement through intense repetition. Engagement refers to the amount of time that a child is actively participating in the activity (Hurth, Shaw, Izeman, Whaley, & Rogers, 1999), and is considered one of the most effective predictors of positive student outcomes (Iovannone, Dunlap, Huber, & Kincaid, 2003). Intense repetition of specific exercises is necessary to reorganize the brain in a particular area (Sohlberg & Mateer, 1989); however, it places immense demands on both the child and the instructor (Butler, 2007). This presents a greater problem when extending the cognitive rehabilitation approach to children with autism who are difficult to engage because they often do not share the same motivations as typical children (e.g. social motivations, see Tomasello, Carpenter, Call, Behne, & Moll, 2005). Behavioural therapies and some naturalistic methods often use artificial reinforcers, such as food; however, this may impact the probability of skill generalization from the training context to real situations. A more beneficial approach towards increasing engagement is to identify and integrate effective natural rewards (Koegel, Koegel, & McNerney, 2001). Building on the knowledge that children with autism show consistent strengths in visual processing (Kuschner, Bennetto, & Yost, 2007) and an avid interest in visual technology such as TV and computers (Bernard-Opitz, Sriram, & Nakhoda-Sapuan, 2001), incorporating interactive virtual technology into therapy may be an effective and naturally-engaging approach to administer traditional cognitive rehabilitation programs.

2.4 Virtual Reality

Virtual Reality (VR) is defined as a simulation of the real world using computer graphics (Burdea & Coiffet, 2003). The defining features of a VR program or application include *interaction* and *immersion*. Human-computer interactivity is achieved through multiple sensory channels that allow children to explore virtual environments through sight, sound, touch, and sometimes even smell (Burdea & Coiffet, 2003; Self, Rosalind, Weheba, & Crumrine, 2007). Immersion is considered the degree to which the child feels engrossed or enveloped within the virtual environment (Witmer, Jerome, & Singer, 2005). Both are important to maximize the engagement of the child.

A variety of display devices offer differing degrees of immersion and interactivity. Head-mounted devices (HMDs) have been considered the gold standard for fully immersive, three-dimensional VR systems (Holden, 2005). Typically, HMDs require the child to wear helmet-like equipment which immerses him or her completely into the virtual environment

(VE) and blocks out extraneous sights and sounds from the real environment. However, the costs associated with developing HMD systems, as well as the associated side effects (e.g. cybersickness) and the cumbersome nature of using HMDs, have lead to a surge of non-HMD systems in the field of rehabilitation (Rand, et al., 2005). While non-HMD, two-dimensional flatscreen systems do not offer the same degree of immersion, technological advances have facilitated greater on-screen visual resolution, thus increasing interaction and visual realism without full three-dimensional capabilities. Flatscreen systems have also evolved motion-capture capabilities, where a tracking camera is able to capture and project a user's motions on-screen in real-time. In some motion-capture programs, the user can see him/herself within the virtual world, and in others, their actions are performed by an on-screen avatar. A more sophisticated motion-capture, flatscreen system is the CAVE system (Cruz-Neira et al., 1992) in which the user enters a virtual environment projected within an entire room of display screens. The virtual environment is displayed on all four walls, the ceiling and the floor; the environment changes according to the user's movements (Cruz-Neira et al., 1992). Although projection and motion-capture flatscreen systems offer unique opportunities for engagement in pediatric rehabilitation programs, these systems have not yet been used with children with autism. However, HMD systems and regular flatscreen systems have been successful in improving specific behaviours to children with autism such as following directions (Rose, et al., 2000), crossing the street (Strickland, Marcus, Mesibov, & Hogan, 1996), finding a seat on the bus (Mitchell, Parsons, & Leonard, 2007), ordering coffee in a café (Mitchell, et al., 2007) and exiting a building during a fire alarm (Self, et al., 2007). Overall, virtual reality has shown potential to be an interactive, naturally-engaging and effective educational tool for children with autism. Similar to regular autism intervention programs, the virtual activities used with children with autism are focused on behavioural outcomes. The next section explores the use of virtual reality as a medium through which cognitive rehabilitation programs can be administered.

2.5 The Virtual Reality-Cognitive Rehabilitation (VR-CR) Approach

The Virtual Reality-Cognitive Rehabilitation (VR-CR) framework was first proposed by Rizzo (1997) for children with attention-deficit hyperactivity disorder (ADHD). Virtual reality makes cognitive programs accessible to children with cognitive disabilities through its capacity to engage the children, provide structured yet individualized activities, and address their weaknesses while building on their strengths (Rizzo, Schultheis, Kerns, & Mateer, 2004). The advantages of VR align themselves closely with principles of effective practice for children with autism, which include structured yet individualized programs with a focus on targeting weaknesses through demonstrated strengths (National Research Council, 2001; Rogers, 1998a).

Flexibility is essential when designing therapeutic programs because children with autism are a heterogeneous group with unique patterns of strengths and weaknesses. Due to the heterogeneity of these children, one pre-defined intervention cannot possibly address all of their needs (Rogers, 1999; Wolf, Fein, & Akshoomoff, 2007). Virtual reality adds the flexibility required to individualize the activity for each child or subgroup of children. In particular, VR can capitalize on the pattern of *strengths* in children with autism. These children frequently display superior abilities in visual learning and memory (Mesibov, Schopler, & Hearsey, 1994), and thus VR can easily incorporate visually-presented activities and extra visual supports such as video-modelling or visual reinforcement to increase the effectiveness of the program (Darden-Brunson, Green, & Goldstein, 2008).

While flexibility is useful to individualize the program, having control over the design of the VR program allows structured and systematic teaching strategies to be incorporated. Children with autism require extra supports to help them anticipate events and understand what behaviours are expected of them (Myles, Grossman, Aspy, Henry, & Coffin, 2007). Additional structures such as instructions, cues and prompts are easily integrated into each stage of the VR task, and control of the VR program allows systematic administration of the exercises. As cognitive interventions require intense repetition (Rizzo, et al., 2000; Sohlberg & Mateer, 1989), VR can lessen the burden on the instructor by presenting the exercises in a consistent and predictable manner while maintaining the child's attention and engagement.

One last advantage of using virtual reality is that it can help to address the problem of generalization. Many VR applications are fundamentally designed to simulate real life situations; hence, there is a high degree of *ecological validity*: the degree to which the virtual environment simulates the real environment (Neisser, 1978). High ecological validity increases the probability that skills learned in the simulated environment will transfer or generalize to the real world (Rizzo & Kim, 2005). Thus, creating a variety of well-controlled virtual environments, each designed to incorporate natural stimuli and natural reinforcement, is an intuitively effective approach to facilitate generalization. A more detailed discussion of the benefits of VR-CR interventions for children with autism can be found in an earlier manuscript by the current author (Wang & Reid, 2009).

Overall, virtual reality systems provide the instructor or therapist with a balance between flexibility and control of the treatment program. Thus, cognitive rehabilitation exercises can be completed with children with autism through a motivating, engaging and naturally-reinforcing tool. The current study employed this VR-CR approach to address and improve a specific cognitive impairment in children with autism: an impairment in *contextual processing*. The next section provides a review of contextual processing deficits in individuals with autism.

2.6 Applying the VR-CR Approach: Contextual Processing of Objects

The current study explores the efficacy of an interactive, cognitive rehabilitation program to improve the *contextual processing of objects* in children with autism.

As reviewed earlier, there are three major competing theories of cognitive impairment in autism. The second of these, the theory of *weak central coherence,* has been criticized for its ill-defined concepts and broad methodology (Lopez, 2008). To address this, Plaisted (2001) has provided a breakdown of central coherence into two levels: "low level" or perceptual coherence, and "high level" or conceptual coherence. The former refers to "bottom-up" processes that allow incoming sensory information to be perceived as "wholes" rather than "parts." The Children's Embedded Figures Test and Block Design Test described earlier access central coherence at the perceptual level. *Conceptual* coherence refers to the ability to determine the meaning or relevance of a piece of information within a specific context (Plaisted, 2001). This "piece of information" can vary from discrete objects to complex social behaviours. For example, a fishing rod may be out-of-context in a bathroom, but appropriate by the riverside; a hand on the shoulder can be perceived as friendly or threatening depending on the person and situation.

The interaction between the perceptual and conceptual levels comprises a predominant debate within the field (Mottron & Burack, 2001; Plaisted, 2001; Ropar, Mitchell, & Sheppard, 2008). While deficits in perceptual coherence are not reliably replicated in individuals with autism, these individuals show consistent impairments on tasks requiring conceptual coherence (Happé & Frith, 2006; Ropar, et al., 2008). Therefore, the current study focuses on the "high level" or conceptual level of central coherence: using context to determine the relevance of a piece of information. While this "piece of information" can vary widely, the current study focuses on discrete objects.

Rather than proposing a resolution between perceptual and conceptual levels of central coherence in order to clarify the definition of central coherence, this paper uses the term *contextual processing of objects*. The term contextual processing narrows the focus to conceptual coherence in the realm of visual object processing; it can be loosely translated as "seeing objects in context." This terminology is consistent with studies of visual information processing in typical individuals (Bar, 2003, 2004).

Contextual processing of objects is defined as the ability to determine an object's meaning or relevance in a particular context (Bar, 2004; Loth, Gomez, & Happe, 2008). Objects are inherently multi-dimensional; each encompasses simple, concrete qualities such as colour, shape, and size, as well as more complex, abstract dimensions such as roles, functions and spatial arrangements (Bar, 2004). To determine an object's meaning or significance in a multi-object context, one must take into consideration the relationships that make a target object relevant within a context, as well as adapt flexibly to changing contexts.

The three major types of dimensional relationships between objects and their contexts are: perceptual (colour, shape, size), spatial (location) and functional (role or use) (Bar, 2004; Blaye & Bonthoux, 2001). The relevant relationships between an object and its context are, in large part, determined by top-down attentional control that is formed from a person's expectations and stored mental representations of that object (Cohen & Shoup, 1997; Garner, 1974; Maruff, Danckert, Camplin, & Curries, 1999; Remington & Folk, 2001; Rossi & Paradiso, 1995).

Contextual processing can be deconstructed into three elementary cognitive abilities: (1) the ability to determine what the context is; (2) the ability to judge a target object as relevant or congruent with the established context; and (3) the ability to adapt these judgments to different or changing contexts. The first skill is referred to as *abstraction*, or the ability to extract and integrate the relevant qualities and relationships within a multi-object environment. This creates a mental representation of the context itself. The second skill requires a *comparative judgment* between the target object and the context to determine if there is a meaningful relationship between the two. The third skill is referred to as *cognitive flexibility*, or the ability to switch between multiple mental representations of a single object in response to changing contextual factors. Abstraction, comparative judgment and cognitive flexibility all fall under the umbrella term of *executive functions*. Thus, contextual processing represents a link between high-level central coherence and specific executive functions. The deconstruction of central coherence into executive functions is illustrated in Figure 1.

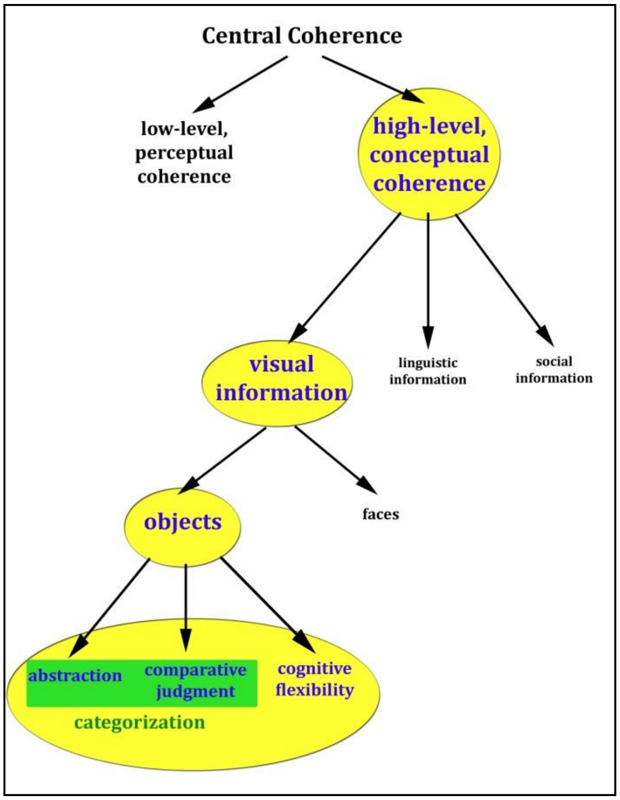


Figure 1. This figure shows the breakdown of the central coherence into the executive functions: abstraction, comparative judgment and cognitive flexibility. Contextual processing is represented by the components highlighted in yellow. As shown, contextual processing can be defined as high-level central coherence in the visual object processing realm, which can be broken down into abstraction, comparative judgment and cognitive flexibility. Also shown, abstraction and comparative judgment are often grouped together as the process of categorization.

As illustrated by the figure, *abstraction* and *comparative judgment* are often grouped together under the process of *categorization*. Categorization is a "cognitive process that allows persons to organize information into conceptual groupings" (Klinger & Dawson, 2001, p. 111). A *context* is essentially a type of "conceptual grouping" and is thus a product of the categorization process. Thus, studies investigating abstraction and comparative judgment often employ categorization tasks, in which the child is required to assign objects to groups based on specific sorting criteria. Objects may be sorted according to various dimensions, such as colour, location or function. Tasks that do not explicitly provide the sorting criteria for the child provide a measure of *internally-generated* or spontaneous abstraction. The categorization task can also evaluate cognitive flexibility if the child is asked to *change* sorting criteria. Changing criteria requires the child to make a mental switch between multiple object representations.

The ability to "see objects in context" typically emerges between the ages of 3 to 5 years (Blaye & Bonthoux, 2001; Jacques, 2001); however, this process of conceptual development is delayed or deviant in children with autism. The next section reviews studies investigating contextual processing of objects in individuals with autism. The available evidence supports the claim that contextual processing is impaired in children with autism, specifically in abstraction and cognitive flexibility, but not comparative judgment.

2.6.1 Establishing the context: abstraction and comparative judgment

Two studies used the sorting task to investigate comparative judgment in children and adults with autism. Soulieres and colleagues (2007) asked sixteen adults with high-functioning autism to categorize simple geometric stimuli – ellipses – according to two provided categories: thin ellipses and wide ellipses. The results indicated that sorting simple geometric stimuli into pre-defined categories did not differ between the adults with autism and the control group. Similarly, Gastgeb and colleagues (2006) compared the performance of twenty-eight children with autism, mean age of 10 years, to a control group of typical children on an object sorting task. The participants were asked to judge a target object as being a member or non-member of a given category. The category name was explicitly provided, (e.g. "cat"). The children with autism demonstrated slower responses than the control group, although the pattern of accuracy of their responses did not differ. Taken together, these two studies indicate that individuals with autism, both children and adults, are able to perform comparison judgments on target objects if the context (or category) is *explicitly provided*. Providing the category names or characteristics precludes the need for abstraction.

Investigating abstraction requires administering the categorization task without providing sorting criteria. This was done by Ropar and Peebles (2007) to investigate the spontaneous sorting preferences of children with autism. The children were asked to sort a stack of books into two groups. The books could be sorted into either concrete categories (e.g. colour or size) or abstract categories (e.g. type of sport or game). However, these labels were *not explicitly given* to the children. Compared with the control group, the children with autism displayed a prominent tendency to sort using concrete characteristics. This study provides emerging evidence that children with autism may have difficulty abstracting more complex object categories.

Klinger and Dawson (2001) proposed that children with autism fail to conceptualize objects based on abstract criteria due to their difficulty in forming abstract summaries of complex categories (i.e. prototypes). Prototypes are essentially summary representations of categories that cannot be defined by a strict set of rules (Rosch, 1978). Klinger and Dawson (2001) tested their theory with twelve children with autism. The authors found that during rule-based category learning tasks, the children performed as well as typical controls. However, their performance significantly decreased during prototype-based category learning tasks. As prototype creation involves abstracting and integrating relevant information from members of a category, these results further the notion that children with autism fail to integrate information at an abstract level. Multiple studies corroborate the result that children and adults with autism are impaired on categorization tasks that require the formation of an abstract category (Gaigg, Gardiner, & Bowler, 2008; Molesworth, Bowler, & Hampton, 2008; Shulman, Yirmiya, & Greenbaum, 1995).

Alternatives to the categorization test include two novel assessments created by Jolliffe and Baron-Cohen (2001) to evaluate contextual processing in adults with autism. The first test was the Object Integration test, in which five discrete objects were displayed, one of which was incongruent with the other four. The test required the participants to identify this incongruent object by establishing a common context with the remaining four objects. The commonalities between the four contextual objects were based on either spatial or functional relationships. The second test was the Scenic Integration test which presented a complex visual scene in which one object was incongruent. The participants were required to identify the incongruent object. Results showed that adults with autism made significantly more errors and took more time to complete both tests as compared to typical controls. The authors concluded that the individuals with autism failed to use context to complete the tests (Jolliffe & Baron-Cohen, 2001). Overall, the Object Integration test and Scenic Integration test provide excellent alternatives to the sorting and memory tasks to evaluate context abstraction impairments in adults with autism.

Although the reviewed studies have provided strong support for impaired abstraction ability in individuals with autism, Lopez and colleagues (2003) reported no differences between typical and autistic children on their Visual Context Task. On this task, the children were first shown a context scene, and then had to verbally identify/label an image of a target object. For both typical and autistic children, target objects that were related to the contextual scene were labelled faster than objects unrelated to the scene. The authors cited this as evidence that children with autism *do* process information in context. However, there remains a critical difference between this study and the studies reviewed above. The studies reviewed above require the participant to make a *conscious* establishment of context and subsequent judgment of congruity between the target object and context. Although the Visual Context task in Lopez (2003) provided a visual context that influenced the children's responses, it was not a task of contextual processing. The children were not required to abstract relevant contextual cues between the object and the given context. The results do offer clarification, however, that while children may have difficulty *consciously* forming and using contextual information, this information *is* being processed at a lower level.

2.6.2 Switching contexts: cognitive flexibility

Cognitive flexibility is the third elementary component of contextual processing. It is defined as "the ability to shift to a different thought or action according to changes in a situation" (Hill, 2004, p. 197). Like abstraction, research has shown pervasive impairments in cognitive flexibility in individuals with autism. The most common test of cognitive flexibility in children is the Wisconsin Card Sorting Task (WCST; Berg, 1948; Grant & Berg, 1948). This is similar to the categorization or sorting tasks described previously; however, in addition to sorting cards based on particular dimensions (e.g. colour, shape, size), the child must *change* sorting criterion according to feedback received by the experimenter. The degree of perseveration, or failure to switch sorting criteria, is an effective indication of cognitive flexibility. A high degree of perseveration on the original and computerized WCST in children and adults with autism have been well-replicated (e.g. Kaland, Smith, & Mortensen, 2008; Minshew, Meyer, & Goldstein, 2002; Ozonoff, 1991; Prior & Hoffman, 1990).

Hughes and colleagues (1993) used a different task to assess cognitive flexibility in children and adolescents with autism called the intradimensional-extradimensional (ID/ED) shift task from Cambridge Neuropsychological Test Automated Battery (Fray, Sahkkian, & Robbins, 1996). This task is simpler than WCST and requires the child to discriminate between up to four stimuli, and shift sets either within a single dimension (e.g. different pink shapes) or between dimensions (e.g. pink shapes and white lines). Hughes and colleagues (1993) compared children and adolescents with autism with two control groups: one matched for age and learning disability; the other matched for verbal and non-verbal mental ages. The autistic group performed significantly worse than both control groups on the *extra-dimensional* shift task, which required a shift *between* different sets. There were no significant differences reported for shifting *within* a single set. Thus, the authors concluded that there existed an autism-specific "stuck in set" type of perseveration, rather than a global impairment in cognitive flexibility (Hughes & Russell, 1993).

Although the WCST and ID/ED tasks do not evaluate cognitive flexibility beyond simple, concrete object dimensions, they do provide evidence that even at this simple categorization level, cognitive flexibility, in the realm of object processing, is impaired.

2.6.3 Summary

In summary, the evidence strongly supports the existence of contextual processing impairments in children with autism. These studies demonstrate impairments in the ability to abstract relevant contextual information and the ability to flexibly switch mental representations as a function of changing contexts. The current study aimed to address these cognitive impairments.

2.7 Summary of Literature Review

This chapter provided an overview of behavioural and naturalistic approaches to intervention. It also provided a review of the three major theories of cognitive impairments in autism: Theory of Mind, Central Coherence and Executive Function. A synthesis of the literature revealed a general emphasis on behaviour-focused treatments, despite evidence of underlying cognitive deficits. The problem of generalization was discussed. A framework combining virtual reality (VR) and cognitive rehabilitation (CR) was described and a rationale was provided for its application to children with autism. The current study used the VR-CR framework to develop an intervention to target a specific cognitive deficit in autism. The intervention focused on remediating overall deficits in contextual processing of objects, as well as improving its elementary components: abstraction and cognitive flexibility.

2.8 The Current Study

2.8.1 Purpose

The purpose of the current pilot study was to design and evaluate a Virtual Reality-Cognitive Rehabilitation (VR-CR) intervention for children with autism that targeted impaired contextual processing of objects. The purpose of the VR-CR intervention was to improve the ability of children with autism to abstract relevant perceptual, spatial and functional contextual information to evaluate a target object within a multi-object visual context, and to respond flexibly to changing contexts.

2.8.2 Objectives and Hypotheses

The **first objective** was to demonstrate the efficacy of the VR-CR intervention for improving contextual processing of objects in children with autism.

Hypothesis #1: The children will show significant improvements, relative to baseline, in contextual processing of objects on perceptual, spatial, and functional dimensions as measured by the Virtual Reality-test of contextual processing of objects (VR-test). The children will improve on the VR-test items in the order they are taught: perceptual, spatial and functional categories.

Hypothesis #2: The children will show significant improvements in abstraction and cognitive flexibility, relative to baseline, as measured by the modified version of the Flexible Item Selection Task (FIST-m).

The **second objective** was to demonstrate that the VR-CR intervention specifically targeted contextual processing of objects in children with autism.

Hypothesis #3: The children will show significant improvements in sustained attention, relative to baseline, as measured by the Attention Sustained subtest (control test) if the intervention is non-specific.

The **third objective** was to explore parent perceptions of behavioural changes that may have occurred during the study.

Hypothesis #4: The children will show improvements in context-related behaviours as reported by parents on the Final Feedback Questionnaire at the completion of the study.

These hypotheses were tested in a single-subject study with four children with autism. The next chapter provides details of the design and methodology of the study.

Chapter 3
Methods

3.1 Design

This pilot intervention study explored changes in contextual processing of objects using a single-subject design with non-concurrent multiple baselines across subjects. Each child was studied over an extended period of time; the outcome variable was measured at repeated points during this period. Using a single-subject design allowed the unique characteristics and history of each individual to be described in detail. This was particularly important because autism as a disorder is very heterogeneous (Odom et al., 2003). The multiple-baseline approach to this design involved introducing the intervention at staggered points in separate children, controlling for maturation or extraneous events that may have occurred outside of treatment. A non-concurrent approach was used to address the difficulties associated with recruiting individuals that fit complex eligibility criteria (Watson and Workman, 1981). Using non-concurrent multiple baselines involved pre-determining the lengths of baselines and then randomly assigning these lengths to each child upon enrolment (Ottenbacher, 1986; Watson et al., 1981). Thus, children were enrolled into the study on an on-going basis, allowing for flexibility in administering the study as a whole. Overall, the single-subjects non-concurrent multiple baseline design was chosen because it focused on practical clinical application as well as significant treatment effects within individuals.

Four children were enrolled in the pilot study. Each child was studied over four to six weeks. The outcome variables were measured at repeated points for the duration of the study. The study consisted of a baseline phase, training phase and follow-up session. Enrolment occurred on a rolling basis: three of the participants were enrolled in the fall of 2009, while the final participant was enrolled in January 2010. The multiple baselines of 3, 4, 5 and 6 sessions were randomized prior to participant enrolment. They were assigned in the following order: 4, 5, 3, and 6 sessions. The training phase was introduced based on the assigned baseline. The training phase for each child comprised of 4 to 5 training sessions, depending on the speed of their progress. A follow-up session was administered 2 weeks subsequent to the last training session. The overall study design for one hypothetical participant is shown in Figure 2.

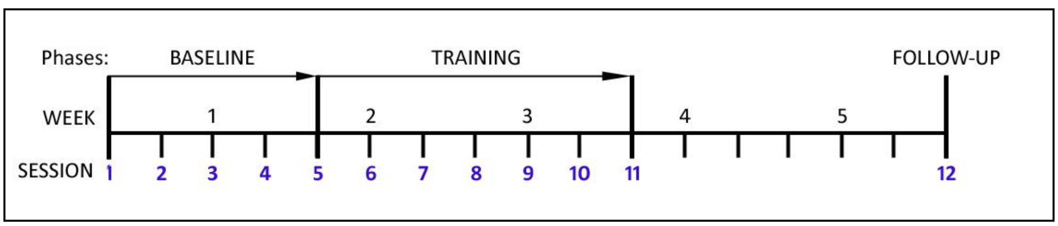


Figure 2. Overall study design for a hypothetical participant with a 5-session baseline phase, 6-session training phase and 2-week follow-up session.

3.2 Participants

3.2.1 Recruitment

Participants were recruited by advertising through a local children's rehabilitation centre, a local autism centre and a provincial autism newsletter. Self-referred parents contacted the researcher* who is a Master's student in the Graduate Department of Rehabilitation Science at the University of Toronto. The researcher scheduled an in-home meeting with the

* In this paper, the "researcher" refers to the author, a Master's student.

interested parents and child to administer the eligibility assessments. Based on these assessments, eligible children were invited to participate in the study.

3.2.2 Inclusion and Exclusion Criteria

The inclusion criteria for an eligible child were: (1) diagnosis of an autism spectrum disorder (ASD) by a pediatric neurologist, pediatrician, psychologist or psychiatrist; (2) chronological age between 5 and 10 years old; (3) autism severity classification of mild-to-moderate; and (4) average or above-average non-verbal IQ. The first and second criteria were verified by requesting a copy of the child's diagnostic report from the parents. The third criterion was verified by administering the Childhood Autism Rating Scale (CARS; Schopler, Reichler, & Renner, 1988), on which the child had to obtain a score of 30-36 to be classified as mild-to-moderate. The last criterion was verified by administering the Brief-IQ battery of the Leiter International Performance Scale – Revised (Roid & Miller, 1997), on which the child's non-verbal IQ score had to be equal to or above 85. IQ scores below 85 are suggestive of co-morbid cognitive disability or mental retardation.

Children were excluded from the study if they had uncorrected vision problems, a co-morbid cognitive or neurological diagnosis (such as attention-deficit hyperactivity disorder or cerebral palsy) or any physical condition that precluded them from engaging the virtual reality task. In addition, the study was not continued with children who performed at mastery on the VR-test on two consecutive baseline sessions (over 80% on all items) or failed to complete the VR-test independently after 4 consecutive sessions.

3.2.3 Ethical considerations

Ethical approval for the current study was obtained from the following Research Ethics Boards (REBs): Bloorview Kids Rehab, University of Toronto and Geneva Centre. A two-step consent process was employed. The parents first provided written consent to administer the two eligibility assessments: Childhood Autism Rating Scale (Schopler et al., 1988) and Leiter Brief-IQ battery (Roid & Miller, 1997). If the child was eligible, the parents then provided written consent to enrol him/her in the study. Verbal assent was also obtained by the child and confirmed in writing by the parent. Consent forms and de-identified data will be stored in Dr. Denise Reid's lab at the University of Toronto until publication of the study, at which time all information will be destroyed.

3.2.4 Participant Demographics

Fifteen parents contacted the researcher to obtain information regarding the study. After obtaining this information by telephone or email, nine parents consented to the initial screening process. The screening tests were administered to these nine children, and based on the results of these tests, two children were not eligible for the study. The remaining seven children were invited to enrol in the study. The parent of one child decided not to enrol in the study. The remaining six children were enrolled in the study. Two of these children did not complete the study. One of these children scored 100% on the VR-test during the first two baseline sessions. The second child was not able to complete the VR-test after four consecutive sessions.

The four remaining children are described below and summarized in Table 1. The order in which they are described reflects increasing baseline length, not order of enrolment.

Kevin[†] was a boy aged 6 years and 7 months. He scored 32.5 on the CARS and achieved a nonverbal IQ of 98. For the duration of the study, he was in school (grade 1) for 30 hours per week. He received one-on-one tutoring for academic subjects for 1 to 2 hours per week. He had an older brother aged 9 years and 5 months. Both of his parents had Bachelor degrees. His father also had post-graduate education. The primary language spoken at home was English.

Linda was a girl aged 8 years and 11 months. She scored 32.5 on the CARS and achieved a nonverbal IQ of 111. For the duration of the study, she was in school (grade 4) and daycare for 40 to 45 hours per week. She participated in the following weekly after-school and weekend activities: swimming class for 30 minutes per week, cooking class for 1.5 hours per week and therapeutic horseback riding for 1 hour per week. She had a younger sister aged 6 years 1 month. Her mother had a doctoral degree and her father had a Bachelor degree. The primary language spoken at home was Mandarin Chinese.

Justin was a boy aged 6 years and 1 month. He scored 30 on the CARS and achieved a nonverbal IQ of 139. For the duration of the study, he was in school (grade 1) for 32.5 hours per week. He participated in a weekly social skills group specifically for children with autism for 1 to 2 hours per week. He had no siblings. Both his mother and father had Bachelor degrees. The primary language spoken at home was Mandarin Chinese.

Richard was a boy aged 7 years 11 months. He scored 33 on the CARS and achieved a nonverbal IQ of 119. For the duration of the study, he was in school (grade 2) for 24 hours per week. He did not participate in any extra-curricular activities or therapy. He had an older

[†] All names have been changed for the purposes of confidentiality.

sister aged 9 years and 11 months. Both his father and mother had Bachelor degrees. The primary language spoken at home was English.

Table 1. Participant demographic information

	Kevin	**Linda**	**Justin**	**Richard**
Gender	Boy	Girl	Boy	Boy
Age	6 years, 7 months	8 years, 11 months	6 years, 1 month	7 years, 11 months
Grade	1	4	1	2
Diagnosis	ASD	ASD	ASD	ASD
CARS Score	32.5	32.5	30	33
Non-verbal IQ	98	111	139	119
Baseline length	3 sessions	4 sessions	5 sessions	6 sessions

Abbreviations: CARS (Childhood Autism Rating Scale; Schopler et al., 1988), ASD (Autism Spectrum Disorder). Note: non-verbal IQ scores are derived from the Brief-IQ screener from the Leiter International Performance Scale (Roid & Miller, 1997)

3.3 Materials

3.3.1 Setting and Equipment

The study was conducted in the children's homes. The virtual reality training programs and virtual reality tests were displayed on a 15" Acer TravelMate 8204 laptop computer. Motion-capture technology was incorporated using a tracking webcam (Logitech QuickCam Pro 9000) to capture and project the child's image and movements into the virtual environment. All software programs were programmed using Flash 8 with the programming language Actionscript 2.0. The graphic editing software used was Photoshop CS. The programs were run using Macromedia Flash Player. The sessions were administered in a quiet room in the house. The child was seated in front of the laptop computer, while the researcher positioned herself to the side, out-of-view of the tracking camera.

3.3.2 Assessment tools

3.3.2.1 Demographic Questionnaire

This general information form was used to obtain the following child demographic information: (1) age, (2) language spoken at home, (3) hours of school or daycare, (4) siblings, (5) parent education level and (6) other therapies. The information obtained from this form was used to create a descriptive profile for each child. Trends such as age and performance were noted; however, no statistical analyses were performed using these data. Factors such as *other treatments received* were identified as possible confounds. This form was completed by a parent before commencing the study. See Appendix A for a copy of the form.

3.3.2.2 Childhood Autism Rating Scale (CARS; Schopler et al., 1988)

The CARS is a 15-item pencil-and-paper measure which is used to rate the severity of behaviours associated with autism (Schopler, et al., 1988). Each item is scored on a scale from 1 ("normal") to 4 ("severely abnormal"). In psychometric studies, evaluation of CARS reliability and validity was performed on 537 autistic children. Internal consistency was high with a reliability coefficient alpha of 0.94 and the average inter-rater reliability was 0.71. CARS showed good validity, with high correlations (over 0.80) with physician, child psychologist and child psychiatrist ratings. It was also able to distinguish significant differences between two groups of autistic children and other developmentally disabled groups (Schopler et al., 1980). In addition, CARS displayed a 92% correlation with the DSM-III-R for a sample that met the diagnostic criteria of autism (Gottam, et al., 1974). In this study, the CARS scale was scored by direct behavioural observations of the child as well as parent interview data.

3.3.2.3 Leiter International Performance Scale-Revised (Roid & Miller, 1997)

The Leiter-IQ scale provides a cognitive profile for children who cannot be tested with traditional IQ tests due to a lack of verbal skills. It is a reliable and valid nonverbal measure of intelligence for ages 2 to 21 years and uses tasks that do not involve verbal instructions or responses. In psychometric studies, test-retest reliability varied from 0.70 to 0.81, Cronbach's alpha for internal consistency varied from 0.66 to 0.91 and correlation to the WISC-III Full Scale-IQ and Performance-IQ was 0.85 (Roid & Miller, 1997). In this study, the Brief-IQ screener was used to obtain an estimate of nonverbal intelligence for the participating children. Four subtests were administered for the screener: figure-ground, form completion, sequential order and repeated patterns.

3.3.3 Outcome measures

3.3.3.1 Virtual Reality-test of the Contextual Processing of Objects (VR-test)

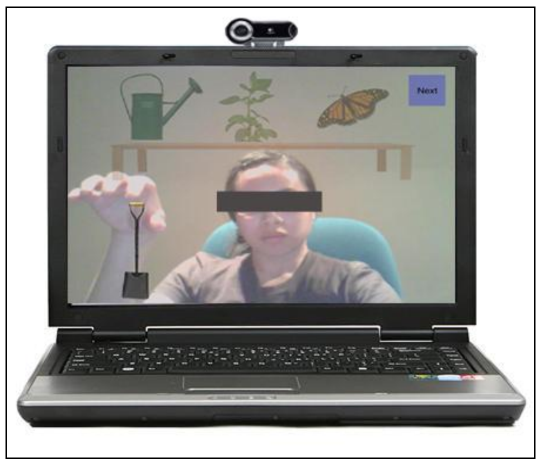
The VR-test was developed for the purposes of the current study to evaluate contextual processing of objects in children between ages 5 and 10. To complete the task, the child is required to make a comparative judgment between one target object and a multi-object context. The multi-object context highlights a particular object dimension: perceptual (e.g. colour, shape), spatial (e.g. kitchen, bathroom), or functional (e.g. objects used to cut). The purpose of the task is to determine if the target object is meaningful in the given context (i.e. if it shared the same relevant dimension). The target and context images are shown on the computer screen. The motion-capture virtual technology allows the child to see him/herself on-screen and to indicate responses through gestures.

The visual stimuli for the VR-test were chosen from the Peabody Picture Vocabulary Test – Version III (Dunn & Dunn, 1997). The items were chosen to be understood by typical 5 year old children. The VR-test items were pilot-tested with 15 typical grade one students (age group 6 to 7 years). Both the object+context associations and the difficulty of the associations were verified. Matches that were too difficult (more than 50% did not answer correctly) were discarded from the test items. See Appendix B for the procedure and results of the pilot study.

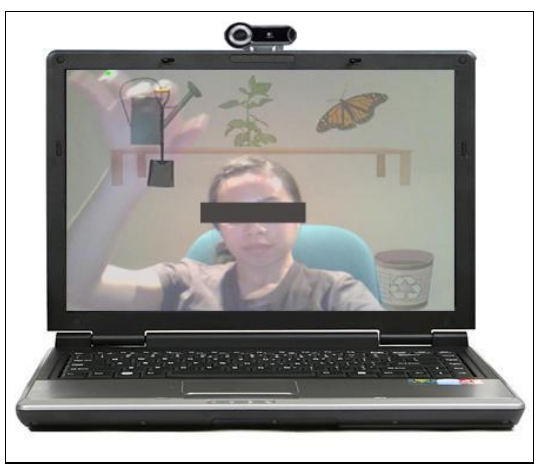
There are two equivalent versions of the VR-test. Each version is composed of 18 test items (object-context pairs). Six pairs are matched based on perceptual relationships, six pairs are matched based on the spatial dimension and six pairs are matched based on functional characteristics. Half of the pairs are matched correctly, half are matched incorrectly. The 18 test items are randomized differently for each test version. See Appendix C for details of each version.

Each test item (object-context pair) is presented through a sequence of three screens: (1) context screen, (2) target object screen, and (3) selection screen. The first screen is the context screen, which is composed of three objects that are similar on one dimension (e.g. same colour, same function). All three context objects are positioned on a virtual table located at the top one-third of the screen. The first screen provides time for the child to process the contextual information. The examiner clicks ‘next’ to move to the second screen which displays the target object. The target object can be moved around the screen; its movements are mapped onto the movements of the child. For example, if a child reached to the top left corner of the screen, the target object is ‘dragged’ to that corner as well. The examiner clicks ‘next’ to move to the selection screen. In this final screen, a garbage pail appears in the lower right-hand corner of the screen. The child indicates a *correct* match between the object and context by ‘dragging’ the target object *up* to the table. The child indicates an *incorrect* match by ‘dragging’ the target object *down* to the garbage pail. The response is recorded when the target object “touches” either the table or garbage pail. The sequence of screens for the next test item then continues. An example from VR-test 2 is shown in Figure 3.

(a)



(b)



(c)

<u>Figure 3.</u> (a) *Context Screen*. The context items (<u>watering can, plant, butterfly</u>) are displayed on the table at the top of the screen. The user's image is projected onto the screen.(b) *Target Object Screen*. The target (<u>shovel</u>) appears and can be moved within the screen by the user's hand motions.(c) *Selection Screen*. A garbage pail appears in the lower right-hand corner. The user moves the target object up to the table to indicate a correct match. The screen automatically continues to the next test item when a response is made.

The child receives a score out of 18 for each VR-test administration, which is translated into a percentage accuracy score. The software program and the researcher independently record the correct and incorrect responses for each test item.

The child does not receive feedback for his or her responses on the VR-test, thus minimizing the occurrence of learning effects as a result of repeated administration. To further control for the effects of repeated testing, two equivalent versions of the VR-test were created: VR-test 1 and VR-test 2. There were also three sub-versions of VR-test 1 (VR-test 1A, 1B, and 1C) which were all composed of the same test items, in randomized order.

3.3.3.2 Modified version of the Flexible Item Selection Task (FIST-m)

The original Flexible Item Selection Task (FIST; Jacques, 2001) is based on two tests, the Wisconsin Card Sorting Test (Berg, 1948) and the Verbal-Visual Test (Feldman & Drasfow, 1951), which are traditional tests of executive function, particularly cognitive flexibility. The FIST was designed as an executive function test for preschoolers. It focuses on the abilities of abstraction and cognitive flexibility within the realm of visual object processing. On each trial, children are shown three items (e.g. red fish, blue fish, red telephone). For Selection 1, the child is asked to point to two objects that "go together". These two items match on one relevant dimension (e.g. common object: red fish and blue fish). For Selection 2, the child is asked to point to a different pair of objects that "go together". This new pair matches on a different dimension (e.g. common colour: red fish and red telephone). The common item in both pairs is the 'pivot item' (e.g. red fish). Selection 1 involves the ability to internally abstract a relevant dimension to identify the pairs. Although Selection 2 also requires abstraction, it is a good measure of cognitive flexibility, as the child must disengage from the first pair to identify the second pair with the same pivot item. The original FIST was tested on 197 children between the ages of 2 to 5. The test accurately differentiated the different age groups according to the normal developmental progress of executive function (Jacques, 2001).

In the current study, the items of the FIST have been modified for the older 5-to-10 age group. In addition, because the original FIST only tested simple perceptual dimensions: shape, size, colour, and number, the modified version of the FIST (FIST-m) incorporated new items that tested both spatial dimensions and functional dimensions. The FIST-m comprised of 12 test items in total (same number as the original FIST) and included three test items from the original test. The FIST-m items were chosen based on age-appropriate test items from the Peabody Picture Vocabulary Test – Version III (Dunn & Dunn, 1997). None of the items on the FIST-m overlapped with the VR-test or any of the training sessions. The testing paradigm of the FIST-m remained identical to the original FIST. See Appendix D for details of the items of the FIST-m.

3.3.3.3 Attention Sustained Subtest (Roid & Miller, 1997)

The Attention Sustained subtest from the Leiter International Performance Scale – Revised is a cancellation test which measures prolonged visual attention, visual scanning and visuo-motor inhibition. It consists of four separate test trials that require the child to colour a target shape or pattern (e.g. a square) within a complex array of different shapes. This subtest is part of a larger Attention and Memory Battery which is used as a tool to identify children with Attention Deficit Hyperactivity Disorder. In a study with 1,890 children, of which 87 were identified with ADD or ADHD, the Leiter-R subtests were able to successfully distinguish the ADHD or ADD groups from the control group, particularly using results from the Attention Sustained subtest (Roid & Miller, 1997). None of the cognitive constructs evaluated by this subtest were explicitly taught in this study, thus it acted as a control test.

3.3.3.4 Final Feedback Questionnaire

The Final Feedback Questionnaire was created for the current study to provide subjective parental impressions of changes in behaviours associated with contextual processing. The questionnaire was comprised of 7 general categories of behaviour including behaviour in public contexts, language and communication in social contexts and flexible use of objects. These categories of behaviour were chosen based on reported correlations between these behaviours and cognitive impairments (Berger et al., 1993; Berger et al., 2003; Happé & Frith, 2006; Lopez, Lincoln, Ozonoff, & Lai, 2005). The examples for each category are modified items from the Vineland Adaptive Behaviour Scale (VABS; Sparrow, Balla, & Cicchetti, 1984). See Appendix E for a copy of the form.

3.4 Procedure

3.4.1 Intervention Protocol

The study was divided into three phases: baseline, training and follow-up. The baseline phase varied from 3 to 6 sessions. The VR-test was administered at every baseline session, while the FIST-m and Attention Sustained subtest were administered during the first baseline session only. The training phase consisted of 3 discrete lessons; however, the actual length of the training phase varied from 4 to 5 sessions, depending on the progress of the child. The VR-test was administered every training session, while the FIST-m and Attention Sustained subtest were administered, for the second time, during the last training session only. Lastly, a follow-up session was scheduled 2 weeks subsequent to the last training session, during which all outcome measures were administered. The progression of the study and the test schedule are illustrated in Figure 4.

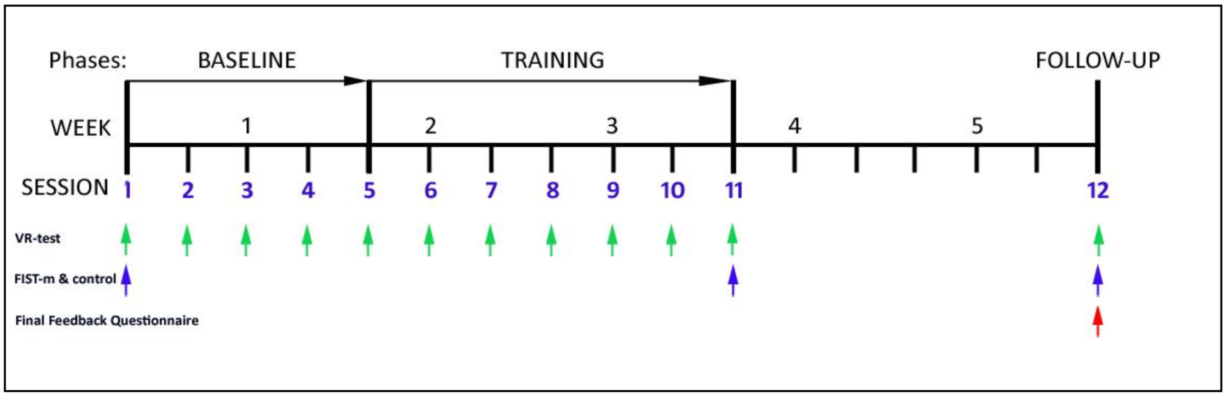


Figure 4. This figure illustrates the overall study design and the test administration schedule for a hypothetical subject with a 5 session baseline and 6 session training phase. Note that there are three sessions held per week. The schedules of test administration are indicated by the arrows.

3.4.2 Baseline phase

Before the VR-test was administered for the first time, the children were provided with pre-baseline training to ensure that they understood the instructions associated with the VR-test. The pre-baseline training included 10 simplified items (shapes only) presented in the same format as the VR-test. The child received modeling, prompting and reinforcement during this pre-training task. When the child was able to complete 3 pre-baseline training items in a row without assistance, the first baseline VR-test was administered. The pre-training task was administered at the beginning of each baseline session to ensure the children remembered how to complete the VR-test.

3.4.3 Training phase

The training phase comprised of three discrete lessons. One lesson was administered per session. The three lessons were associated with the target characteristics of objects: perceptual, spatial and functional dimensions. The lessons were taught in that order, and mastery on the preceding lesson was required to advance to the next. Each training session involved a 10-minute teaching protocol during which the researcher provided the child with one-on-one instruction. Only one lesson was taught per session. The training sessions were designed to support the child's understanding and performance on the task. Verbal instructions, modelling, prompting, repetition and reinforcement were the teaching strategies that were utilized. See Appendix F for sample teaching scripts used during the sessions.

The lessons were comprised of a set of 10 training items. The training items were presented in the same 3-screen sequence format as the VR-test: (1) the multi-object context screen was shown; (2) the target object appeared and could be moved through the child's gestures; and (3) the selection screen displayed a garbage pail and child made his/her response by "dragging" the target object *up* to the table (if correct) or *down* to the garbage pail (if incorrect). There were two major differences between the training program and the VR-test procedure. Firstly, the child received instruction from the researcher during the training sessions, and secondly, visual reinforcement was built into the training program; correct responses were rewarded with a happy face, while incorrect responses were discouraged with a sad face. In addition, there was no overlap in the items used on the VR-test and those used in the training sessions.

After completion of each lesson, the VR-test was administered. After each test administration, the VR-test was analyzed according its separate components: perceptual, spatial and functional items. The criterion for *mastery* was: over 80% response accuracy on each of the three categories (perceptual, spatial and functional).

The goal of each lesson was to teach the child to flexibly attend to object dimensions of a particular class. Figure 5 shows a flowchart of the teaching protocol. Lesson 1 was focused on teaching the child to attend to the perceptual features of objects (e.g. colour, shape or size). The child was taught to determine if the contextual items shared a relevant perceptual dimension with the target object. If the child scored over 80% on the VR-test perceptual items after Lesson 1, she/he would progress to Lesson 2. A child who failed to achieve 80% on the VR-test perceptual items after Lesson 1 repeated that lesson. Those who progressed to Lesson 2 were taught to focus their attention on the spatial characteristics of objects. The child was required to achieve over 80% on the spatial items on the VR-test before progression to Lesson 3. During Lesson 3, the child's understanding of objects was focused on the functional aspects of objects. The training phase was ended when the child achieved over 80% on each category of the VR-test. The same researcher administered all sessions for all children.

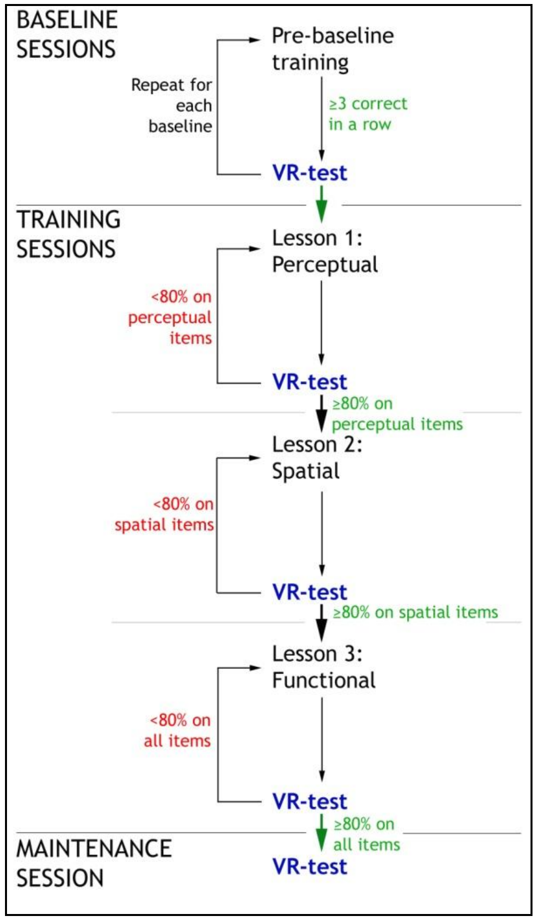


Figure 5. This figure illustrates the protocol through the training sessions and the scores required on the VR-test to progress to the next lesson.

3.4.4 Treatment Intensity

The baseline and training sessions were conducted 3 times per week. The total number of sessions depended on the baseline length assigned to the child and the number of sessions that he/she required to achieve mastery on the training tasks. The maximum duration of the training phase was predetermined to be 8 training sessions, although none of the children in the current study required more than 5 training sessions to reach mastery. Each training session consisted of 10 minutes of one-on-one instruction. Therefore, to achieve mastery on the tasks, the average total instruction time required was 45 minutes within 2 weeks.

3.5 Data Collection and Analysis

3.5.1 Hypothesis #1: improvements in contextual processing

VR-test 2 was administered at the first baseline session, last training session and follow-up session. VR-tests 1A to 1C were randomized for the remainder of the baseline and training sessions. Thus, one version of the VR-test was administered during every session.

The children received a score out of 18 for each VR-test administration, which was translated into a percentage accuracy score. The software program and the researcher independently recorded the correct and incorrect responses for each test item. Agreement between both sources was verified immediately following VR-test administration. Discrepancies on a particular test item resulted in the re-administration of that item to the child.

The percentage accuracy scores from the VR-test were analyzed through visual inspection, descriptively noting baseline and treatment patterns. The Percentage of Non-overlapping Data method (PND; Mastropieri & Scruggs, 1985-86; Scruggs & Mastropieri, 1998) was used to statistically analyze the VR-test results. The PND statistic was calculated by determining the percentage of intervention data points that exceed the highest baseline data point. The following ranking system was used to evaluate the results: scores over 90% denoted highly effective treatments, scores between 70-90% denoted effective treatments, scores between 50-70% denoted questionable treatments and scores below 50% denoted ineffective treatments (Scruggs & Mastropieri, 1998).

To confirm the absence of learning effects from repeated administration of the same test, each child's post-training performance on VR-test 1 and VR-test 2 was compared. VR-test 1A, 1B and 1C were administered throughout the training phase, while VR-test 2 was only administered once at the end of the training phase. If a child performed similarly on both versions of the test at the end of the study, there were likely minimal learning effects due to repeated administration of VR-test 1A, 1B and 1C.

Lastly, the three components of the VR-test were broken down and analyzed separately. The pattern of performance on perceptual, spatial and functional test items was noted.

3.5.2 Hypothesis #2: improvements in abstraction and cognitive flexibility

The modified version of the Flexible Item Selection Task (FIST-m) was administered at three points during the study: first baseline session, last training session and follow-up session. The FIST-m was analyzed separately for improvements in abstraction and cognitive flexibility. The number of correct responses was recorded for both Selection 1 (abstraction) and Selection 2 (cognitive flexibility). Although Selection 2 also requires abstraction, it was assumed that abstraction ability was sufficiently captured by performance on Selection 1. Therefore, only the cognitive flexibility component of Selection 2 was analyzed. As Selection 2 is necessarily dependent on making an accurate Selection 1 choice, a response for Selection 2 was considered correct if the child was accurate in *both* selections for that test item. The total number of test items was 12. The data were transformed into percentage accuracy scores for Selection 1 and Selection 2 separately.

3.5.3 Hypothesis #3: specificity of intervention

The specificity of the VR-CR intervention was investigated with a control test. The Attention Sustained subtest was administered at three points during the study: first baseline session, last training session and follow-up session. The Attention Sustained subtest required the child to colour target objects (shapes) in a mixed array. The data collected were: the number of correct target objects identified and the number of errors made. These were converted into scaled scores according to the Leiter manual (Roid & Miller, 1997).

3.5.4 Hypothesis #4: parent perceptions of behavioural change

The Final Feedback Questionnaire was administered once at the end of the study to explore parental perceptions of changes in context-related behaviours after the training program. The results of this questionnaire were summarized in a descriptive manner, with the responses for each category tallied up and the general themes from the open-ended questions summarized. This questionnaire was not designed to be analyzed qualitatively.

Chapter 4
Results

4.1 Description of Results

4.1.1 Hypothesis #1: improvements in contextual processing

4.1.1.1 VR-test: visual analysis and percentage non-overlapping data (PND)

The VR-test percentage accuracy scores are presented for each child across each session (Figure 6). The patterns of performance on the VR-test and PND calculations are described below for each child.

During the baseline phase, Kevin demonstrated an unstable baseline, displaying incremental improvements on the VR-test before any instruction (56%, 61% and 72%). At the start of the training phase, Kevin showed no improvements, maintaining 72% during the first and second sessions. His scores then increased to 94%, 83% and 89% for the following three training sessions, and were generally maintained at 83% during follow-up. Kevin's performance data indicated 60% non-overlapping data.

Linda was the oldest of the four children and displayed the highest baseline scores (78%, 83%, 83% and 83%), reaching a stable level of 83%. During the baseline sessions, Linda already fulfilled the mastery criteria for spatial and functional items; however, she only performed at 50% on perceptual items. After the first training session, her performance immediately jumped to 100%. Linda maintained her high performance for the remaining sessions and at follow-up. Her performance data indicated 100% non-overlapping data.

Justin displayed a very stable baseline (72%, 67%, 72%, 78% and 72%). Upon the introduction of the training phase, his performance jumped sharply, although he never obtained 100% during the training phase. Justin's performance fell to 89% on the last training phase, but reached 100% again at follow-up. Justin's performance data indicated 100% non-overlapping data.

Similar to Kevin, Richard displayed an unstable baseline (39%, 61%, 22%, 44%, 56% and 61%), although his baseline phase was the longest. His highest baseline was lower than the average baselines for the other three children. Richard displayed progressive improvements through the training phase (89%, 89%, and 92%) until reaching 100% accuracy, which was maintained at follow-up. Richard's performance data indicated 100% non-overlapping data.

Overall, the line graphs for each child (Figure 6) illustrate improvements in contextual processing ability from baseline to treatment, with average increases from 15% to 46%. With the exception of Kevin, all children demonstrated 100% non-overlapping data. Furthermore, all children maintained a high level of performance at the 2-week follow-up assessment.

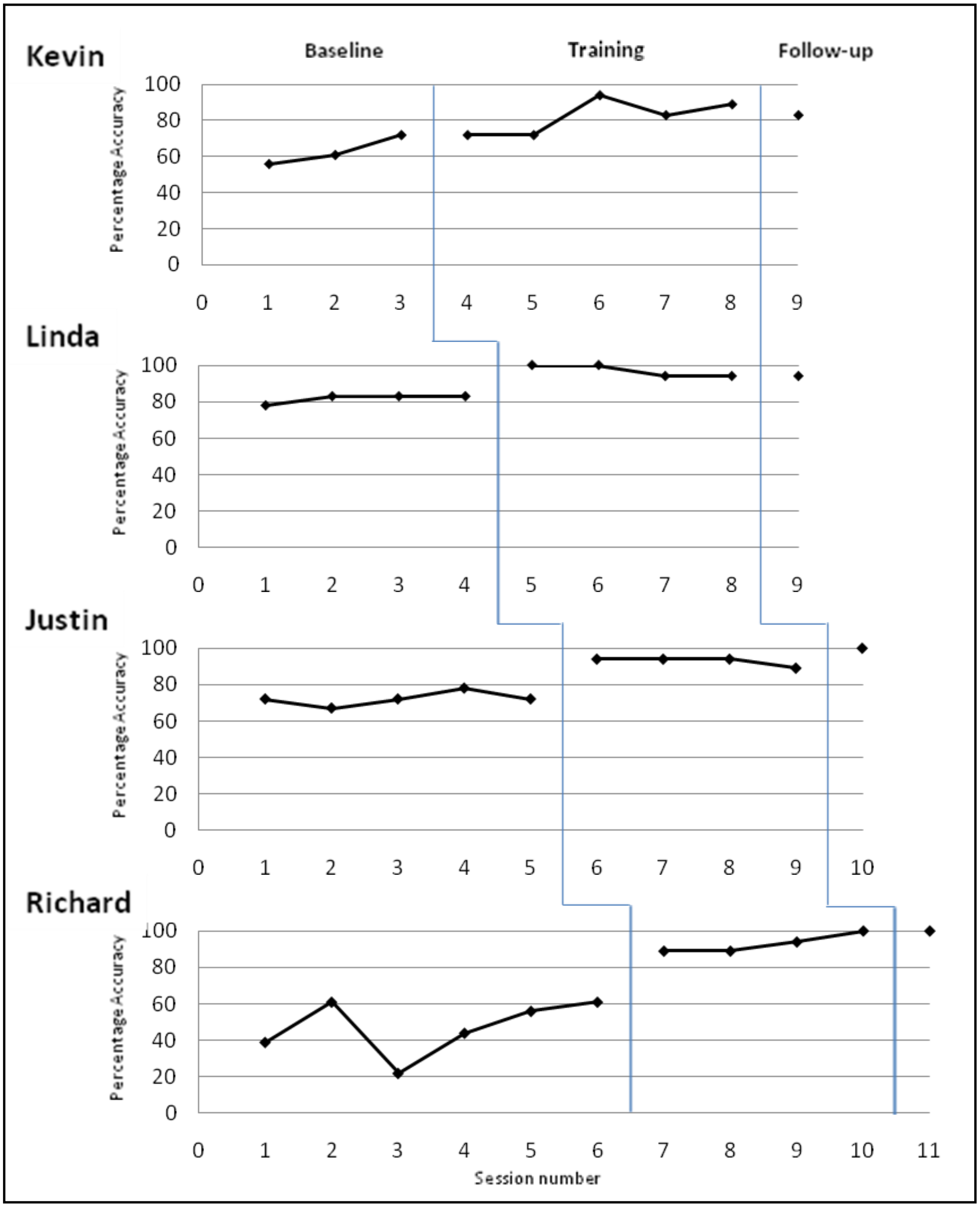
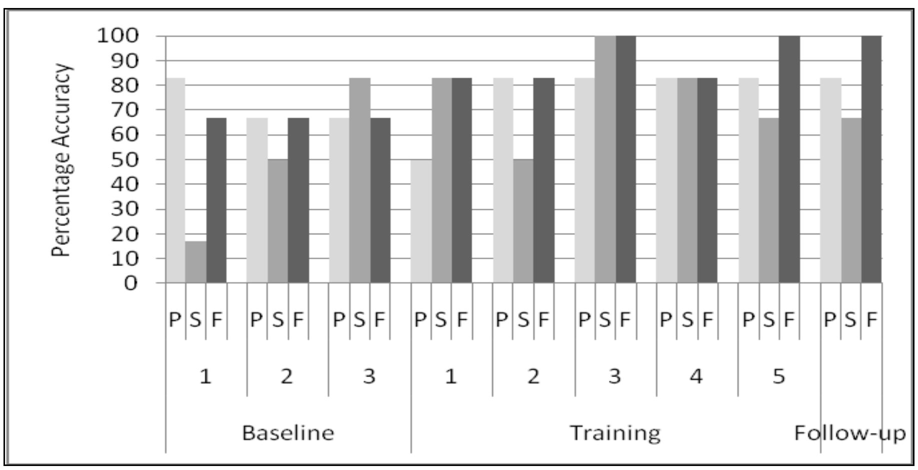


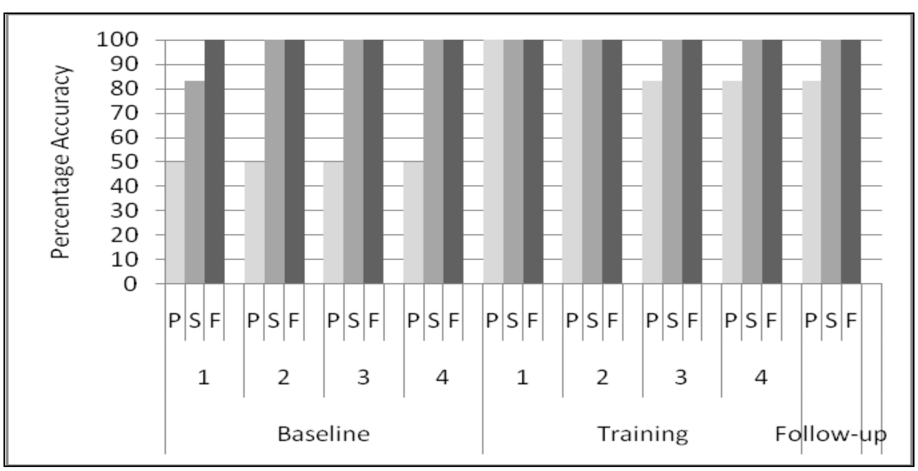
Figure 6. Percentage accuracy on the VR-test demonstrated by each child across all phases of the study.

4.1.1.2 VR-test breakdown: perceptual, spatial and functional items

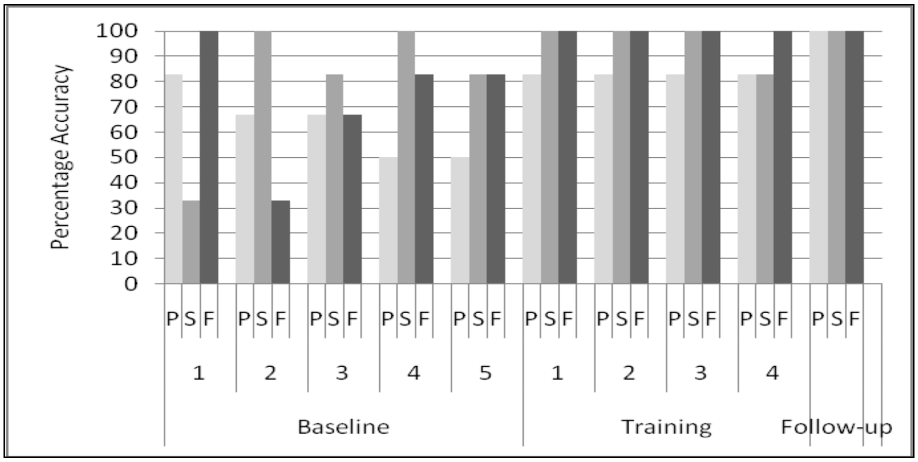
Figure 7 shows the breakdown of VR-test performance for each child into the categories of perceptual, spatial and functional test items. During the baseline phase, there was no prevailing pattern of performance across the three categories. During the training phase, improvements in perceptual, spatial and functional test items did not correspond to the material taught in the lessons. For Linda, Justin and Richard, improvements in all categories occurred after only the first training lesson. For Kevin, improvements in all categories were less consistent. Linda showed high performance on the spatial and functional items at baseline, but performed only at 50% on the perceptual items.



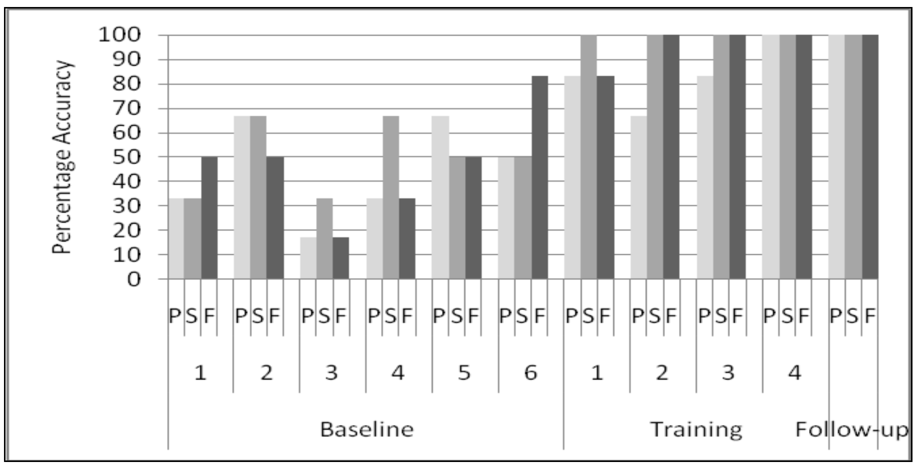
Kevin



Linda



Justin



Richard

Figure 7. Percentage accuracy on the VR-test within each session on the three categories. Abbreviations: 'P' is perceptual, 'S' is spatial, 'F' is functional.

4.1.2 Hypothesis #2: improvements in abstraction and cognitive flexibility

Percentage accuracy scores were calculated for pre-training and post-training administrations of the FIST-m. Table 2 shows these data for Selection 1 and Selection 2 separately.

Table 2. Percentage accuracy scores for Selections 1 and 2 of the FIST-m at pre-training, post-training and follow-up for each child.

	Selection 1	Selection 2
Kevin		
Pre-training	92	55
Post-training	92	73
Follow-up	75	100
Linda		
Pre-training	100	50
Post-training	100	100
Follow-up	92	100
Justin		
Pre-training	100	83
Post-training	100	92
Follow-up	100	92
Richard		
Pre-training	100	33
Post-training	92	100
Follow-up	100	100

All four children displayed ceiling or close to ceiling scores on Selection 1 (abstraction) scores at pre-training. These high scores were maintained post-training and at follow-up, with the exception of Kevin, whose follow-up score decreased from 92% to 75%. Linda's score decreased slightly (8%) between post-training and follow-up.

All children showed improvements on Selection 2 (cognitive flexibility). Kevin made progressive improvements on Selection 2. He scored 55% at baseline, improved to 73% at post-training and achieved 100% at follow-up. Linda doubled her baseline score of 50%, and maintained 100% at follow-up. Justin scored 83% at baseline. He showed improvement to 92% post-training and maintained this at follow-up. Richard more than tripled his baseline score from 33% to 100%, and maintained the high score at follow-up.

4.1.3 Hypothesis #3: specificity of intervention

Table 3 shows the scaled scores for the children's performance on the Attention Sustained subtest. Scaled scores for Correct Responses and Error Responses are shown separately.

Table 3. Scaled scores for Correct Responses and Error Responses of the Attention Sustained subtest at pre-training, post-training and follow-up for each child.

	Scaled scores of Correct Responses	Scaled scores of Error Responses
Kevin		
Pre-training	1	10
Post-training	1	10
Follow-up	1	10
Linda		
Pre-training	1	12
Post-training	1	12
Follow-up	1	12
Justin		
Pre-training	10	8
Post-training	16	7
Follow-up	16	7
Richard		
Pre-training	1	3
Post-training	1	3
Follow-up	1	3

Kevin, Linda and Richard showed no changes in performance on both the scaled scores for correct responses and error responses. Justin showed an increase of 6 points on scaled correct responses from baseline to post-training, and a decrease in 1 point in scaled error responses at post-training.

4.1.4 Hypothesis #4: parent perceptions of behavioural change

The parents of both Kevin and Richard reported no changes on any of the items on the Final Feedback Questionnaire.

Linda's mother reported changes in the category *Appropriate language and communication in social contexts*. She reported that Linda "seems to initiate social interaction with more appropriate language (e.g. Hi. What's your name? I like your hair style rather than ... what colour is your nail polish?)."

Justin's mother noted the most changes on the Final Feedback Questionnaire. Changes were reported in the following categories: *Appropriate language and communication in social contexts* (Justin "can answer question[s] appropriately"); *Flexible behaviour* (Justin is "flexible to schedule"); *Flexible use of objects* (Justin "can tell several functions of one object"); and *Mental perspective* (Justin "understand[s] different people have different feelings"). Overall, Justin's mother reported that since the beginning of the study, Justin "is more flexible and like[s] to try something new."

4.2 Summary of Results

Overall, three of the four children showed 100% non-overlapping data on the VR-test. The fourth child showed 60% non-overlapping data. The patterns of improvement did not occur in order that they were taught. No changes were found on the control test for three children, while the fourth child showed significant improvements on this test. Finally, two of the four parents reported changes in the behavioural category: appropriate social behaviours. The implications of these results are discussed in the next chapter.

Chapter 5
Discussion

The purpose of this pilot study was to evaluate a virtual reality-cognitive rehabilitation (VR-CR) program designed to improve *contextual processing of objects* in children with autism. Improvements in two of its elementary component abilities – abstraction and cognitive flexibility – were also sought. A single-subject study with four participants was implemented to determine the efficacy of the VR-CR program with the following subgroup of children: ages 6 to 8, mild-to-moderate autism and average or above-average non-verbal intelligence. The results of this study are discussed in the context of the four initial hypotheses.

5.1 Discussion of Results

5.1.1 Hypothesis #1: improvements in contextual processing

The primary objective of the study was to determine if the novel VR-CR intervention could improve contextual processing in children with autism. According to the standards set by Logan and colleagues (2008), the highest level of evidence for single-subject research designs (Level 1) can be achieved by: "concurrent or non-concurrent multiple baseline designs (MBD) with clear-cut results; generalizability if the MBD design consists of a minimum of three subjects, behaviours or settings." In determining "clear-cut results," Scruggs and Mastropieri (1998) assert that a treatment outcome with over 90% non-overlapping data can be considered a "highly effective treatment." The results of this study demonstrate clear 100% non-overlapping data for three children with three different, non-concurrent baseline lengths. Thus, the current study fulfills the criteria for a Level 1 single-subject design study.

The fourth child in the study, Kevin, achieved only 60% non-overlapping data. It is suggested that Kevin's performance may be due to a mild learning delay, as he did not show any improvements until the third training session, at which point his performance spiked. The slight plateau in performance prior to a substantial improvement is a learning trend that has been found in studies of children with mild cognitive delays (e.g. Preast, 2009). A learning delay would also explain why Kevin was not able to achieve 100% on the VR-test for any session, unlike the other three children. Further cognitive testing would be required to explore this hypothesized learning delay.

Analyzing the performance on the multiple versions of the VR-test provide further support that all four children improved in contextual processing. As described in Chapter 3, version 2 of the VR-test was used only during the last training session. This was done to verify that the improvements in performance over the training sessions, as measured by VR-tests 1A, 1B and 1C, were not due to memory effects from repeated testing (e.g. Barber, Rajaram, & Marsh, 2008). If overall learning had occurred, it was expected that there should not be a significantly different level of performance on VR-test 2. The results indicated that the children's performance did not change significantly between the second-last and the last training sessions. This confirms that the improvements were not due to repeated administration of the VR-test version 1.

An interesting and unexpected pattern emerged from the breakdown of the VR-test. Based on traditional theories of visual processing (for a review, see Humphreys & Riddoch, 2006), improvements on perceptual test items were hypothesized to occur first because they are thought to be the most salient and easily-accessed object characteristics. In addition, attention to perceptual dimensions was the focus of the first lesson. However, analysis of the VR-test breakdown illustrates that improvements in perceptual, spatial and functional items occurred *together*. This suggests that these three types of object representations were accessed with equal ease in these children.

Moshe Bar's visual processing theory of contextual facilitation provides a plausible explanation of the results obtained (Bar, 2004). In this model, the first stage of contextual processing requires the activation of a relevant *context frame*. A context frame is a type of mental representation that contains "prototypical information about a unique context, and contains information about the identities and typical spatial arrangements of objects that tend to appear within that context" (Bar, 2004, p. 625). This information includes discrete objects and their properties, relationships, locations and functions. A context frame can be activated by specific objects that are strongly associated with it. For example, a *toothbrush* can activate a spatially-related context frame for "bathroom," which can subsequently activate individual representations of associated objects, such as *toothpaste, floss, sink, toilet* and *shower*. The *toothbrush* can also activate a functionally-related context frame encompassing "brush-like objects" such as a *hairbrush, shoe brush, dog brush* and *broom.* Furthermore, if the toothbrush is *red*, it may activate a perceptually-related context frame of "red objects." There are an infinite number of *possible* associations between objects and context frames (e.g. a telephone can presumably be found in a bathroom, although it is statistically unlikely). However, only the most *probable* associations, based on the frequency with which they are encountered, are activated by a context frame. Perceptual, spatial and functional representations are considered among the strongest associations, as these are usually the attributes of objects that are the most meaningful to people (Bar, 2004; Blaye & Bonthoux, 2001). Activated context frames form top-down *expectations* of what objects are relevant in a certain context (Bar, 2004). These top-down expectations are then tested against incoming, bottom-up information regarding the target object. The intersection of bottom-up and top-down processing determines the relevant link (or lack thereof) between a target and a context (Bar, 2004). The intersection between bottom-up and top-down processing allows the conscious mind to become cognizant of specific associations between the object and context.

An example of how Bar's theory applies to this study's VR-CR program is illustrated in Figure 8. In this example, the multi-object context is comprised of a park bench, work chair and sofa. Each contextual object individually activates multiple context frames. For example, the park bench can activate context frames for "objects made of wood" (perceptual) or "objects found in a park" (spatial). Each context frame contains information regarding the prototypical objects belonging to that context. The most strongly activated frame becomes the most relevant. In this example, all three context objects individually activate the context frame "objects used to sit on" (functional). This context frame then forms top-down expectations of other objects that may be relevant within that frame. Bottom-up information of the target object (wooden chair) is then evaluated against these expectations. In this example, the judgment made at the intersection point between top-down and bottom-up processing concludes that the wooden chair *is* relevant in the functionally-associated context frame: "objects used to sit on."

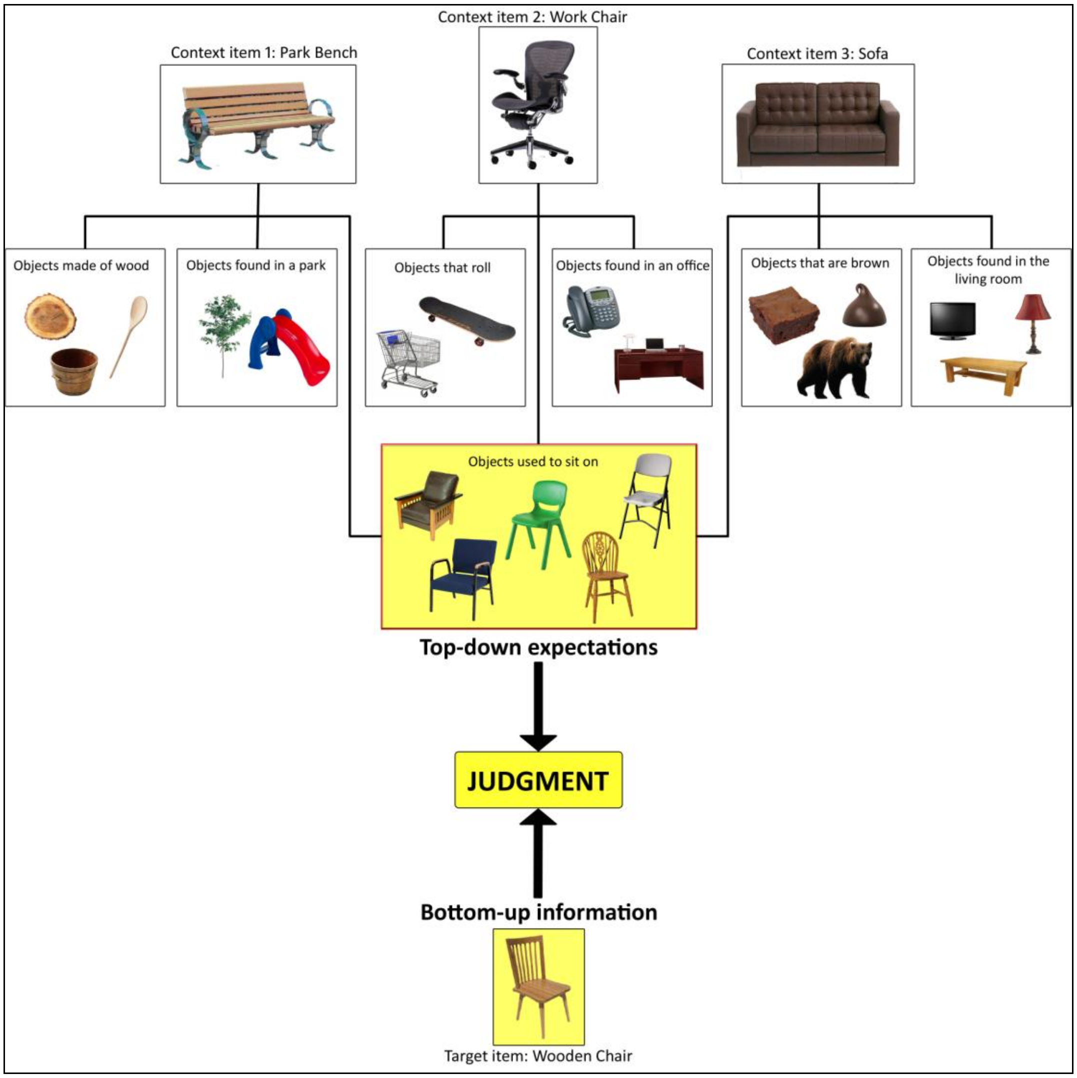


Figure 8. This figure shows the hypothesized mechanism of contextual processing as applied to item #2 on VR-test 2. Each item in the multi-object context (park bench, work chair, sofa) activates multiple context frames. The context frame "objects used to sit on" is activated by all three context objects and therefore forms the top-down expectations that are used to evaluate bottom-up information about the target object (wooden chair).

Bar's contextual facilitation mechanism allows the pattern of VR-test results to be understood more clearly. Based on this mechanism, the current VR-CR program may not have reinforced *specific* associations between objects and contexts; however, it may have reinforced the *general* mechanism of top-down processing that required activation of a relevant context frame and subsequent evaluation of the target object's association with that context. Simultaneous activation of perceptual, spatial and functional dimensions during top-down processing would explain why improvements on all three items occurred concurrently on the VR-test.

5.1.2 Hypothesis #2: improvements in abstraction and cognitive flexibility

The second objective of the study was to determine if improvements occurred in the elementary component abilities of contextual processing: abstraction and cognitive flexibility. As expected, initial performance on Selection 2 (cognitive flexibility) was low. Three children performed at chance (50%) or below. After the training phase, all children displayed substantial improvements and maintained a high level of performance at follow-up. Kevin's slow progress on the FIST-m and continued improvement at follow-up is consistent with his hypothesized learning delay. Both Linda and Richard showed notable improvements on Selection 2 on the FIST-m, doubling and tripling their scores, respectively. Justin also showed improvements; however, his performance on Selection 2 at baseline was initially high. Although there is no normative data available for comparison, studies performed on the original FIST showed that during a crucial phase of cognitive flexibility development in typical children (between 4 and 5 years), 5-year-olds performed almost 18% better than 4-year-olds on Selection 2 (Jacques, 2001). The difference reflects the rapid development in cognitive flexibility within that one-year span. Three children, Linda, Richard and Kevin, matched or exceeded this spike in development within only two weeks. Thus, this is emerging evidence that cognitive flexibility can be improved in this subgroup of children.

Impairments in abstraction have been demonstrated consistently in the literature (Gaigg, et al., 2008; Molesworth, et al., 2008; Shulman, et al., 1995); however, the children in the current study demonstrated unexpectedly high abstraction performance (Selection 1) at baseline. Findings from Ropar and Peebles (2007) indicate that autistic children have difficulty accessing “high-level” abstract categories such as sports or games. Although the current VR-CR intervention required the children to abstract qualities *above* the salient or perceptual, it may not have demanded an equivalently high level of abstraction as in Ropar and Peebles (2007).

When defining “high-level” versus “low-level” abstraction, Klinger and Dawson (2001) draw the distinction between prototype-based and rule-based categories. Mental representations of complex categories require the *abstraction* of a prototype, or a generalized representation of that category. Essentially, the prototype encompasses the defining features of the category without reducing them to a list of rules. On the other hand, lower-level categories can be *more easily* reduced to specific rules, particularly if they involve common examples of that category (e.g. a bright red apple in the category of “red objects”). However, even with low-level categories, rules may not always be prescriptive (e.g. is a blood orange considered *red* or *orange*?) Children with autism have consistently performed poorly on categorization tasks that require the abstraction of a prototype in the absence of defining rules (Klinger & Dawson, 2001; Shulman, et al., 1995).

It was expected that the children in this study would show similarly poor performance on the abstraction component of the FIST-m. However, the obtained results do not seem to support the previous claim made that children with autism have difficulty abstracting at high levels. In this study, the children were able to abstract perceptual, spatial and functional dimensions easily on the FIST-m. However, the task did not eliminate the possibility of rule-use. Rules can be used effectively with objects that are almost exclusively associated with a particular context. For example, in the context “bathroom,” the rule “objects that are found in a bathroom” could be used as an inclusion criterion. This rule applies easily to a “toothbrush” which is commonly found in a bathroom, but does not apply as strongly to “telephone.” The current study only used familiar examples as both target and context objects, thus, affording opportunities for rule-use. Future studies need to expand beyond these exemplary objects and contexts. They need to focus on improving high-level abstraction abilities that cannot be learned through rules.

The implications of improving “high-level” abstraction and cognitive flexibility are important for children with autism (Klinger & Dawson, 2001). Complex behaviours, particularly social behaviours, cannot be learned effectively through rules or by memorizing specific instances. Abstraction allows the brain to maximize efficiency so that every instance of a certain situation does not require a unique mental representation. Abstraction creates summary mental representations of behaviours as generalized concepts which encompass the “gist” of their basic defining features. These stored cognitive generalizations can then be used to make inferences between previously consolidated experiences and new situations (Klinger & Dawson, 2001). In order to *apply* abstract generalizations to formulate appropriate behaviour, one requires the mental adaptiveness to accommodate frequent contextual changes. Cognitive flexibility “allows children to switch from one response mode to another and thus to find the most appropriate solution to the problem at hand” (Blaye & Bonthoux, 2001, p. 396). Thus, the ability to create high-level abstractions, and to apply these abstractions flexibly, may facilitate the ability to generalize complex behaviours to new situations. This connection between cognitive improvements and behavioural changes is an area that future studies should explore.

5.1.3 Hypothesis #3: specificity of intervention

The third objective of the study was to determine the specificity of the VR-CR intervention for improving only the contextual processing of objects. On the control test, the Attention Sustained subtest, three of the four children showed no changes over the course of the study. However, one child, Justin showed significant improvements on one component of the subtest from pre-training to post-training. Justin improved by 6 points, which resulted in a 10-13% increase in his ranked percentile. This change is significant and may have been influenced by a couple of factors. Firstly, the improvements on the VR-test, FIST-m and control test may have been due to maturational effects. Alternatively, the researcher perceived that Justin's comfort level with her increased significantly throughout the study. This was evidenced by increased social interaction, communication and engagement. This may have played a role in Justin's increased motivation to perform on the Attention Sustained subtest, as he expressed motivation to impress the researcher. Although this type of rapport was also noted with the other three children, it was not expressed at the same intensity. From a therapeutic standpoint, this relationship highlights an important interpersonal element of any program. A positive relationship between instructor and child has been shown to be a key factor in the therapeutic success of a program (Shirk & Karver, 2003). Rather than discrediting this element as a confound, future studies should consider incorporating it as a measure of therapeutic effectiveness. Overall, based on the results of the control test, the VR-CR intervention demonstrated specificity to contextual processing for three of four of the children.

5.1.4 Hypothesis #4: parent perceptions of behavioural change

The final objective was to explore changes in context-related behaviours that may have occurred during the course of the study. The comments obtained by parents on the Final Feedback Questionnaire were mixed. Kevin and Richard's parents reported no behavioural changes that occurred between the start and completion of the study. Linda and Justin's mothers reported changes in the category *Appropriate language and communication in social contexts*. Berger and colleagues (2003; 1993) have provided two studies supporting a significant correlation between cognitive flexibility and social functioning. As this study presents cognitive flexibility as an elementary component of contextual processing, the presence of perceived changes in appropriate social behaviours is consistent with the claims made by Berger and colleagues. However, when considering the activities that Linda and Justin were receiving during the time of the study, it is noted that both were engaged in weekly social activities. In particular, Linda participated in weekly swimming, cooking and therapeutic horseback riding classes, all of which were group activities with children of a similar age. Justin participated in a social skills workshop every week that was specifically focused on improving social interaction skills between children with autism. Conversely, Kevin and Richard were not participating in any extracurricular social activities during the study. Thus, the connection between the treatment program and the parental report of behavioural changes is likely due to the other interventions in which the children were concurrently involved.

5.2 Limitations of Study

Although three replications of 100% non-overlapping data were reported by the current study, a major limitation is the high baseline levels achieved by all the children prior to intervention. This indicates that the participating children were already showing high levels of contextual processing ability before the study. The breakdown of the VR-test and performance on Selection 1 of the FIST-m indicate that developed *abstraction* ability was likely responsible for the high performances. Thus, the children exceeded the level of "readiness" that would allow them to benefit maximally from the intervention. Assessing performance on the VR-test prior to enrolment would help to exclude children from the study who are already performing at high levels on the task. In addition, as cognitive and language development are often considered interdependent (see Vygotsky, 1986), determining language levels or verbal intelligence at baseline may help to clarify those children who would benefit maximally from this type of cognitive intervention.

A second major limitation of the study is a lack of standardized outcome measures. With the exception of the Attention Sustained subtest, the other outcomes of the study were non-standardized, which limits the degree to which the results can be compared across similar studies. In addition, standardized tools often have data regarding their reliability and validity, and are also more accessible for researchers.

A final limitation of this study is the lack of multiple, independent assessors. The development of rapport between the researcher and each child was likely to have influenced the degree of therapeutic effectiveness and test performance. As discussed earlier, this relationship factor likely influenced Justin's post-training performance on the Attention Sustained subtest. To minimize the effect of researcher bias, all of the chosen outcome measures required objective scoring. There were no subjective rating scales involved. In addition, scoring of the VR-test was verified through computer records. Therefore, although only one researcher performed all assessments and training sessions, there was likely minimal impact of a personal bias on the results. Future studies that incorporate subjective measures such as behavioural rating scales would benefit from the use of multiple, blind assessors.

5.3 Recommendations for Future Studies

Based on the theoretical developments discussed in this chapter, there are two major directions of research. Firstly, future studies should further clarify the profile of children most likely to benefit from the intervention. This will address the high-baseline limitation present in the current study. Addressing this problem can be done by determining the characteristics of children with autism who achieve baselines scores within 10% to 50% on the VR-test. These children would be considered in the "readiness" stage for the intervention. This is equivalent to Vygotsky's "zone of proximal development," which is the level at which the children have the necessary prerequisite skills to benefit from the teaching program (Vygotsky, 1978). Alternatively, the high-baseline problem can be addressed by increasing the difficulty of the program material. As discussed previously, the level of abstraction was not difficult enough to preclude the use of category rules. The difficulty of the material can be increased by focusing on object categories that require the formation of abstract prototypes. Identification and incorporation of the language and cognitive strategies used by both typical and atypical children on this task may increase the effectiveness of the program.

The second direction of future research should investigate the causal links between improved contextual processing and behavioural outcomes. In this paper, two areas of behavioural improvements were discussed: (1) improvements in behaviours that comprise the diagnostic criteria of autism, and (2) improvements in the ability to generalize new behaviours to novel contexts.

All of these initial studies would benefit from the use of single-subject methodology. Single-subject studies will help to create a characteristic profile of children who may benefit the most from a given intervention. In addition, they help to develop hypotheses for larger, controlled group studies (Jones & Jordan, 2008; Odom, et al., 2003; Rajendran & Mitchell, 2007; Towgood, Meuwese, Gilbert, Turner, & Burgess, 2009). In time, specific VR-CR interventions may then be combined into a comprehensive, manualized program and evaluated through large-scale clinical trials.

5.4 Contributions of the Current Study

Overall, the current study makes the following contributions:

- The current study provides a testable link – contextual processing – between two theories of cognitive impairment in autism: the theory of weak central coherence and the theory of executive dysfunction.
- The current study is the first exploration of using the VR-CR approach with children with autism.
- The results of the current study support the continued exploration of the VR-CR approach for improving contextual processing in children with autism.

Chapter 6
Conclusion

This pilot study evaluated a novel intervention combining virtual reality technology with traditional cognitive rehabilitation methods to address impairments in *contextual processing of objects* in children with autism. Three children who participated in the VR-CR program demonstrated significant improvements in overall contextual processing ability, as well as improvements in one of its elementary components, *cognitive flexibility*. These results were discussed in the context of Bar's mechanism of contextual processing, which illustrates the interplay between top-down and bottom-up information processes.

The implications of contextual processing on generalization were discussed. Future studies should focus on investigating the impact of improved higher-level contextual processing on the severity of autistic behaviours as well as the influences on the degree of post-training behavioural generalization.

Overall, this study opens the door to further interest in using the VR-CR approach with children with autism. The hope is that the development of comprehensive interventions to target *both* cognitive and behavioural levels of impairment in autism will lead to greater overall improvements in the daily functioning and quality of life of these children.

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Appendices

Appendix A. Participant Demographic Information Form

Completion date: ______________________________

General Information Form

______________________________ ______________________________ □ M □ F

Child's Study ID Number Date of Birth

Parent completing the form:
□ Mother □ Father

The parent completing this form may choose not to answer any/all of the questions below.

1) What is the language that your child speaks with you at home?
   □ English
   □ Other *(please specify)* ____
2) Is your child in day care or school?
   □ Yes
   □ No
   If Yes,
   (a) How many hours per week of day care and/or school (combined)? _________________________
   (b) How long has your child been in day care and/or school? __________________________________
   (c) What grade is your child in? ___________________
3) How many brothers and sisters does your child have? Please check if the sibling is 'male' or 'female' and write in their ages in years and months:
   Child 1: Male □ Female □ Age: ________years________months
   Child 2: Male □ Female □ Age: ________years________months
   Child 3: Male □ Female □ Age: ________years________months
   Child 4: Male □ Female □ Age: ________years________months
   Child 5: Male □ Female □ Age: ________years________months
4) What is the highest grade or level of education that you have ever completed? _________________
5) What is the highest grade or level of education your partner/spouse has completed (if applicable)? ___________________
6) What other therapies or activities is your child currently participating in? ____

Thank you for answering these questions

<u>Appendix B.</u> Procedure and Results from VR-test Pilot Testing

Generation of test items: The following 20 target items were chosen from the Peabody Picture Vocabulary Test – 4th edition (PPVT-4; Dunn & Dunn, 1997): broom, TV, drum, dolphin, bee, car, candle, chair, pencil, duck, dog, shovel, cow, tree, lamp, gift, toothbrush, book, bird and knife. These items are appropriate to the 5-year-old age group.

Perceptual, spatial and functional contexts, each comprised of three objects, were created for each target object. The following is an example for the target "chair":

Perceptual context: wooden chest, wooden bat, wooden cup ("objects made of wood")

Spatial context: table, stove, fridge ("objects found in the kitchen")

Functional context: park bench, work chair, sofa ("objects used to sit on")

This process resulted in 60 contexts. The contexts were then matched with a target object. This resulted in 60 object-context pairs. Half of the object-context pairs were considered "correct matches," while the other half were considered "incorrect matches."

Testing protocol: The 60 object-context pairs were pilot tested on 15 grade one students at St. Columba Elementary School (Toronto Catholic District School Board). Ethical approval from the Principal of the school and written consent from all students' parents were obtained prior to the administration of the pilot testing.

The object-context pairs were colour-printed into paper booklets. The students were asked to indicate on their paper copies if the target object and the given context "go together”. Each object-context pair was tested 3 times (total of 180 test items). Thus, each student was required to complete 12 randomly-assigned test items.

Results: A test item was discarded if the students responded incorrectly 2 out of 3 times. 12 of the object-context pairs did not pass this criterion. This resulted in 8 target items being rejected from the list: cow, tree, lamp, gift, toothbrush, book, bird and knife.

Conclusion: The remaining 12 target items were used in the final VR-test versions. Four of the rejected target items were revised and used as training material (toothbrush, book, bird and knife).

<u>Appendix C.</u> VR-test: test items

<u>VR-test 1A</u>

	Target object	**Context objects**	**Context theme: "things that..."**	**Match?**
1	Broom	Mop bucket, rubber gloves, cleaning spray	...are used to clean	Yes
2	Broom	Artichoke, rose, duster	...have a long handle and knobbed end	Yes
3	TV	Computer screen, iPhone, portable DVD player	...have a display screen	Yes
4	TV	Duster, dust pan, mop	...are used to clean	No
5	Car	Bike horn, cymbals, megaphone	... make loud noises	No
6	Dolphin	TV remote, couch, coffee table	...are found in the living room	No
7	Car	Grey mug, grey pencil, grey sock	...are the colour grey	No
8	Bee	Honey, sunflower, beehive	...are found near bees	Yes
9	Drum	Mosquito, house fly, bee	...buzz	No
10	Bee	Yellow/black caterpillar, yellow/black jersey, yellow/black sock	...are black and yellow	Yes
11	Drum	Candle, soup can, soup pot	...are cylindrical	Yes
12	TV	Red apple, red shoe, red crayon	...are red	No
13	Car	Traffic light, stop sign, road lines	...are seen when driving	Yes
14	Dolphin	Turtle, fish, seal	...swim	Yes
15	Broom	Jellyfish, sea urchin, seaweed	...are found in the sea	No
16	Dolphin	Analog television, flatscreen television, high-definition television	...are used to watch movies	No
17	Bee	Tractor, truck, school bus	...are used to drive	No
18	Drum	Saxophone, guitar, trumpet	...are used to play music	Yes

Note: VR-tests 1B and 1C include the same target objects and contexts in a different randomized order. Interested readers are invited to contact the author for a complete list.

<u>VR-test 2</u>

	Target object	**Context objects**	**Context theme: "things that..."**	**Match?**
1	Candle	Fireplace, lighter, camp fire	...burn	Yes
2	Chair	Bench, work chair, sofa	...are used to sit on	Yes
3	Duck	Pen, marker, crayon	...are used to write	No
4	Duck	Lily pad, fish, frog	...are found in a pond	Yes
5	Candle	Coffee pot, kitchen table, stove	...are found in the kitchen	No
6	Dog	Lily pad, kayak, sailboat	...float	No

7	Duck	Duck, goose, platypus	...have a duckbill	Yes
8	Shovel	Yellow hat, yellow banana, yellow balloon	...are yellow	No
9	Candle	Black and white expresso maker, cow, black and white house	...are black and white	No
10	Dog	knife, key, pot	...are metal	No
11	Shovel	Watering can, plant, butterfly	...are found in a garden	Yes
12	Dog	Birthday cake, balloon, gift	...are found at a birthday party	No
13	Chair	Wooden chest, baseball bat, wooden eggcup	...are made of wood	Yes
14	Pencil	Fire hydrant, fireman's hat, fire truck	...are found near a fireman	No
15	Pencil	Nail, baguette, baseball bat	...are long and hard	Yes
16	Chair	Dog house, dog bone, dog bowl	...are found near dogs	No
17	Shovel	Hoe, rake, pitchfork	...are used for gardening	Yes
18	Pencil	Notebook, pencil sharpener, eraser	...are found at school	Yes

<u>Appendix D.</u> Flexible Item Selection Task: modified test items

Trial #			
1	**One purple sock**	One purple telephone	Two purple socks
2	Two pink fish	Three purple fish	**Two purple fish**
3	**Small purple sock**	Small purple fish	Large purple sock
4	Christmas lightbulb	Pear	**Lightbulb**
5	Graphing calculator	**Cellphone**	Telephone
6	Fire	Birthday cake	**Candle**
7	Shovel	Fork	**Pitchfork**
8	Scissors	**Pliers**	Hammer
9	**Orange**	Baseball	Banana
10	**Paperclip**	Binder clip	Trombone
11	Ball	Hockey stick	**Hockey puck**
12	**Wrist watch**	Bracelet	Clock

Pivot items are indicated in bold.

For test administration details, refer to the protocol outlined by Jacques (2001).

<u>Appendix E.</u> Final Feedback Questionnaire

Completion date: ______________________________

Participant Identifier: ____________________________

Parent completing the form: □ Mother □ Father

Final Feedback Questionnaire

PART A

Please consider the following behaviour categories and indicate if your child has shown any changes in these behaviours since the start of the study:

Behaviour Category	**Any changes noted?**	**If yes, please elaborate:**
Appropriate behaviour in public contexts Examples: - Not screaming in public - Not taking off clothes in public - Avoiding repetitive movements (i.e. rocking, flapping)	☐ Yes ☐ No ☐ N/A	
Appropriate behaviour in social contexts Examples: - Making eye contact when being spoken to - Maintaining proper physical distance from other people - Acting according to the emotional state of the other person (i.e. smiling when the other person is happy)	☐ Yes ☐ No ☐ N/A	
Appropriate language and communication in social contexts Examples: - Using greetings "hi" (when someone comes) and "bye" (when someone leaves) - Answering a question appropriately	☐ Yes ☐ No ☐ N/A	
Flexible behaviour Examples: - Adapting to changes in routine without resistance - Stopping one behaviour (i.e. brushing hair) when asked to perform another (i.e. brushing teeth) - Playing with more than one toy	☐ Yes ☐ No ☐ N/A	
Flexible use of objects (both functional and in make-believe) Examples: - Using a fork to eat food (functional use) and	☐ Yes ☐ No ☐ N/A	

also using it as a pretend comb (make-believe use) - Using a toy shovel to dig sand in the sandbox (functional) and also using it to "pretend shovel" when there is no sand (make-believe)		
Taking the perspective of another person (physical perspective) Examples: - Understanding that the parent cannot see the TV if he/she is in another room - Understanding that the parent does not know what happened at school because he/she was not there	☐ Yes ☐ No ☐ N/A	
Taking the perspective of another person (mental perspective) Examples: - Understanding that different people have different "likes" and "dislikes" - Understanding words such as "think", "feel", "believe"	☐ Yes ☐ No ☐ N/A	

PART B

1. Have you noticed changes in any other behaviours since the beginning of the study?

2. Do you have any other comments regarding the study?

3. Would you like to receive information about the study outcome?
   ☐ Yes
   ☐ No

Thank you for answering these questions

Appendix F. Sample Teaching Scripts

Sample VR teaching script from Lesson 1: Perceptual dimensions, item 6

(1) Context Screen: red umbrella, red rose, red paperclip
"Look! All of these are red!" [*Point to context objects*]
"What's next?" [*Continue to next screen*]
(2) Target Object Screen: red toothbrush
"Is this red too?" [*Point to target object. Wait for child's response. Continue to next screen.*]
(3) Selection Screen
"Does the toothbrush go on the table or in the garbage?" [*Wait for the child's response.*]
"Okay, put it on the table!" or "Okay, put it in the garbage!" [*Wait for the child's response.*]
(4) Feedback Screen
"Great job!" or "Let's try that one again"

Sample VR teaching script from Lesson 2: Spatial dimensions, item 9

(1) Context Screen: inflatable whale toy, scuba flippers, water wings
"Look! All of these are found in the swimming pool!" [*Point to context objects*]
"What's next?" [*Continue to next screen*]
(2) Target Object Screen: goggles
"Is this found in the swimming pool too?" [*Point to target object. Wait for child's response. Continue to next screen.*]
(3) Selection Screen
"Do the goggles go on the table or in the garbage?" [*Wait for the child's response.*]
"Okay, put it on the table!" or "Okay, put it in the garbage!" [*Wait for the child's response.*]
(4) Feedback Screen
"Great job!" or "Let's try that one again"

Sample VR teaching script from Lesson 3: Functional dimensions, item 3

(1) Context Screen: floss, toothpaste, electric toothbrush
"Look! All of these things are used to brush your teeth!" [*Point to context objects*]
"What's next?" [*Continue to next screen*]
(2) Target Object Screen: boat
"Is this used to brush your teeth too?" [*Point to target object. Wait for child's response. Continue to next screen.*]
(3) Selection Screen
"Does the boat go on the table or in the garbage?" [*Wait for the child's response.*]
"Okay, put it on the table!" or "Okay, put it in the garbage!" [*Wait for the child's response.*]
(4) Feedback Screen
"Great job!" or "Let's try that one again"