Towards Developing a More Extensive Construct of Intellectual Disability

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Abstract

The aim of this thesis was to re-examine the construct of Intellectual Disability (ID) in terms of not just what children with ID can do, but also to try to understand what underlying deficits exist and what cognitive processes are involved. The eventual aim of this thesis is to aid the education for children with ID. Thus, two major groups of children were examined, an ID group (low functioning children with Autism, children with Idiopathic ID and Down Syndrome) and typically developing (TD) children of similar non-verbal mental age (7 years old) as measured on the Raven’s Coloured Progressive Matrices test (RCPM) (i.e. total items correct). Total performance and Error types made on the RCPM was then compared in order to determine whether children with ID apply developmentally appropriate problem solving strategies or whether they are deviant in their approach. The results of the study reiterated that children with ID are developmentally delayed, but only deviant in the sense that they make more of the least sophisticated, though developmentally appropriate error type (i.e. selecting a response based on its position and not on its content).

Single and dual visual tasks and multisensory information were utilized in the other studies of this thesis. The results of these studies showed impaired dual target processing in the ID groups suggesting impairment in working memory capacity. This conclusion was further evident in the different problem solving approach utilised by TD children in comparison to children with ID of similar non-verbal mental age. Error type analyses suggested that when processing dual targets, TD children responded only to one salient feature of the target, as a problem solving strategy designed to cope with the extra load on working memory. However, when the task became too difficult for children with ID they continued making errors. The thesis results suggest that the RCPM is a valid means of matching children with ID to TD children on non-verbal mental age and that problem solving ability may be facilitated in children with ID with working memory training during early intervention. Further theoretical and practical implications of the thesis findings for the education of children with ID are discussed.
Acknowledgement

I would like to first and foremost express my sincere gratitude to my supervisors, Professor David Crewther and Professor Sheila Crewther for their guidance and support throughout the completion of this thesis. Their knowledge in the area of Intellectual Disability was exceptional and their passion for research was inspirational. I feel honoured and privileged to have worked alongside them.

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Declaration by candidate

I declare that this thesis contains no material which has been accepted for the award to the candidate of any other degree or diploma, except where due reference is made in the text of the examinable outcome.

To the best of my knowledge, this thesis contains no material previously published or written by another person except where due reference is made in the text of the thesis.

Disclosures of relative contribution are made in relation to any work based on joint research or publication. The thesis literature reviews (Chapter two - Part 1 and Part 2) have been published as book chapters and study 1 (Chapter three) of this thesis has been published in a peer reviewed Journal. Studies 2-5 (Chapters 4-7) of this thesis have been submitted as manuscripts to a peer reviewed journal for review. The candidate has been primarily responsible for the research and writing up of all manuscripts submitted from this thesis. Co-authors who collaborated with the candidate in the preparation of the manuscripts have been acknowledged.

Additionally I declare that the ethical principles and procedures as outlined in The Swinburne University of Technology Human Research Ethics document on Human Research and Experimentation have been adhered to in the presentation of this thesis (see Appendix A).

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CHAPTER ONE: Introduction

General background

In 1927, British psychologist and statistician, Charles Edward Spearman described intelligence (or general intelligence, also known as “g”) as a mathematically derived factor which underlies the shared variance of one’s performance on tests of mental abilities, involving the ability to reason, predict consequences and infer rules (Carroll, 1986; Jensen, 1987). General intelligence was believed to apply to psychological tests of ability, as well as real life practical and social problems alike (Blair, 2006).

General intelligence has been shown to be closely related to fluid intelligence (Blair, 2006; Carroll, 1986), a term coined by Cattell (1987) to refer to the capacity to think logically and solve novel problems without any specific experience or prior knowledge. This is in contrast to crystallized intelligence, which refers to long term stored knowledge, such as knowing a country’s capital city (Cattell, 1987). It has been suggested by Carroll (1986) that gaining sufficient amounts of fluid intelligence through general experience, education and training will enable the individual to acquire ability in symbolic systems such as language and mathematics and it is the extent to which they acquire these symbolic systems that will determine the degree of their crystallized intelligence.

In typically developing (TD) children the ability to reason logically emerges in the first 2-3 year of life and develops sequentially during the primary school years with increasing chronological age. Just as a child must be able to stand before it can walk, children must first develop through stages of seeing relationships between stimuli, such as visual patterns, before they can engage in abstract reasoning. Such discrete qualitative stages of cognitive development in children (with the given age ranges that they pertains to an approximations only) were first suggested by Piaget. The first stage can be further broken down into a half a dozen substages (Grossman & Begab, 1983). The Piaget stages of cognitive development included (Grossman & Begab, 1983): (1) Sensorimotor stage (birth-2years), in which children obtain a number of sensory motor reflexes such as grasping, a sense of the constancy of objects and the use of basic language. Individuals with Intellectual Disability (ID) who do not develop beyond this level would be considered to have severe ID; (2) Preoperational-transductive stage (2-4 years), in which children label objects, understand various object attributes, such as
‘same and different’ or ‘single and multiple’, (3) Preoperational-intuitive stage (4-7 years), in which children acquire concepts such as colour, form and size. Their judgment is still largely driven by the perceptual properties of objects rather than logical inferences. Individuals whose ID does not develop beyond this point are considered moderately ID; (4) Concrete thinking operations stage (7-11 years), in which children can reason logically though not yet in abstract form; and (5) Formal thinking operations stage (11-adulthood), in which children can reason in the abstract and thus think beyond what is physically in front of them.

Measures of intelligence, such as the commonly used Wechsler Intelligence Scale – Fourth Edition (WISC-IV) (Wechsler, 2003a) and the Raven’s Coloured Progressive Matrices (RCPM) (Raven, Court, & Raven, 1995) provide an indication of whether a child’s ability to reason is typical of their chronological age. An IQ score does not predict ability but rather refers to the rate of intellectual development. It is mental age which provides indications of ability. Mental age is derived from the IQ score and reflects intellectual level. Chronological age on the other hand, indicates how long it took the individual to achieve the intellectual stage depicted by their mental age (Zigler, Balla, & Hodapp, 1984). Thus, a person with a mental age of 6 years is able to reason like a typically developing 6 year old child. Children with ID are incorrect on most items of an intelligence measure for their chronological age. Indeed, ID, previously known as Mental Retardation, is most often classified as an Intelligence Quotient (IQ) below 70 on a standardized intelligence measure, such as the Wechsler Intelligence Scale for Children - Fourth Edition (WISC-IV) (Wechsler, 2003a), with continuing deficits in adaptive functioning throughout life (Katz & Lazcano-Ponce, 2008; Leonard, Petterson, Bower, & Sanders, 2003; Pratt & Greydanus, 2007; Salvador-Carulla & Bertelli, 2007; Shevell, 2008; World Health Organization, 1993). Individuals with ID have a significantly lower mental age than chronological age and often do not reach all the Piaget’s stages of cognitive development (Grossman & Begab, 1983).

Whether children with ID are slower to reach the Piaget’s stages than TD children (i.e. developmentally delayed) or do not progress through the stages but problem solve differently to TD children (i.e. developmentally deviant) has been a question of ongoing debate in the research literature over the last century. Difference theorists proposed that cognitive development in ID is deviant due to neurological impairments derived from brain based etiology of the ID (Bennett-Gates & Zigler, 1998; Kounin, 1941a, 1941b; Lewin, 1935; Zigler & Hodapp, 1986). Developmental
theorists suggested that cognitive development in individuals with ID of known etiology is deviant, whereas the cognitive development in individuals of unknown etiology (often referred to as cultural familial ID or Idiopathic ID) is developmentally delayed, meaning that the same cognitive developmental stages are reached but at a slower rate than TD children of the same chronological age (Bennett-Gates & Zigler, 1998; Zigler & Hodapp, 1986).

These developmental/difference models have also influenced the theoretical construct of ID (Detterman, 1987). Even though the diagnostic classification of ID is largely agreed upon in the research literature, the construct of ID remains underdeveloped (Wehmeyer et al., 2008). The hypothetical construct in this sense refers to groups of functionally related processes that predict a wide range of behaviours (Cronbach & Meehl, 1955), and answer fundamental questions regarding ID, such as: what is the developmental trajectory of ID? Is ID the same as low IQ? What are the core deficits of ID (i.e. what cognitive process/es are affected)? Can educational intervention be used to minimize these deficits etc.?

**The Developing Construct of Intellectual Disability**

It is evident that significant shifts in the conceptualization of ID in the past one hundred years have had serious implications for the education and livelihood of individuals with ID, influencing such outcomes as whether children with ID receive an education and whether they are institutionalized and how they could be integrated into mainstream society (Hutt & Gibby, 1979). This is reflected in the changing classification and naming of individuals with ID by the American Association on Intellectual Disability (AAIID) (Cuskelly, 2004), from being previously labeled by the AAIDD as mentally retarded, mentally deficient, mentally subnormal and currently as intellectually disabled.

One of the earliest significant shifts in the conceptualization of ID was in 1921, when the American Association on Mental Retardation (AAMR) first classified children who scored significantly below the majority of the population on the Binet Intelligence Scale, as being intellectually disabled, rather than as “mentally ill” (Doll, 1962; Scheerenberger, 1987). Historically, ID has been classified as an IQ of 2 standard deviations below the norm, which is merely a matter of convention rather than theoretical significance (Zigler et al., 1984). Given most of the research in the past and current literature on ID is based on a cut off of 2 standard deviations on a standardized IQ test, this definition will be used throughout this current thesis. Thus, ID is classified
as an IQ score of below 70.

The next breakthrough in the theoretical understanding of ID came with the discovery that children with ID could still learn and remember, albeit more slowly and at a lower level than same age TD children (Detterman, 1987). This led many researchers in the 1960s to focus on finding core cognitive impairments that might constitute what underlies the cause(s) of ID (Detterman, 1987). This research approach has been referred to as the deficit model of mental retardation (Detterman, Gabriel, & Ruthsatz, 2000). A number of different cognitive processes have been nominated as the primary cause of ID, with researchers focusing on deficits in attention and working memory (Detterman et al., 2000).

In the 1960s researchers attempted to identify which component of working memory (e.g. verbal short term memory or rehearsal period) was impaired in ID and found deficits in all areas of working memory (Detterman et al., 2000). Zeaman and House (1963) were the first of a number of theorists (Denny, 1964, 1966; Luria, 1963; O'Connor & Hermelin, 1963) to suggest that attention, was the core deficit in ID. In their study, Zeaman and House grouped children with ID who had a mean mental age between 2-9 years into slow and fast learners according to the number of days they took to learn a series of discrimination tasks (i.e. learning to discriminate between a pair of objects differing in colour and form). A learning curve was plotted, which included number of trials plotted against percentage correct for each group. For the ID group, the learning curves were made up of an initial flat curve followed by a sharp rising proportion. The authors suggested that this initial phase represented the attention phase, where the participants were allocating their attention to the relevant task stimuli and the sharp rising proportion of the curve was indicative of discriminative learning.

The results of the Zeaman and House (1963) study showed that slow learners required more trials during the attention phase than fast learners. This same pattern was seen between higher and lower mental age groups. Thus, as intelligence increased, so did the ability to sustain attention successfully, if indeed the first trial phase was a reflection of sustained attention. The first phase of the trial could have reflected the participants’ level of task comprehension. From their findings, Zeaman and House concluded that impaired problem solving ability in individuals with ID was characterized by an impaired ability to sustain attention. Increased distractibility in individuals with ID in the initial learning phase reduced their attention to relevant stimuli and thus reduced their rate of learning in comparison to TD children. Zeaman
and House’s attentional theory assumes that if children with ID could successfully maintain sustained attention on relevant stimuli, they may have the capacity to learn at a comparable rate to individuals with TD of the same level of mental capacity.

A more recent construct of ID has been proposed by Anderson (1992, 2001) who suggests that impaired problem solving ability in ID is fundamentally due to relatively slow information processing speed. According to Anderson, both the developmental and difference positions apply to ID. Anderson agrees with the developmental model in that children with ID pass through the same cognitive developmental stages as TD children but at a slower pace. Similarly, this proposal was recently supported by Facon and Nuchadee (2010) who showed that the RCPM was equally difficult for children with Down Syndrome, Idiopathic ID and TD children of similar non-verbal mental age (i.e. as measured by RCPM overall correct performance). However, Anderson also agrees with the developmental model in suggesting that children with ID are deficient within each development stage due to slow information processing, which does not change in ID despite increasing maturation.

The current research focus in the ID literature has been on the cognitive profiling of different etiologies of ID (e.g. Down Syndrome and lower functioning children with Autism) and tailoring educational resources to suit each ID group (Fuchs, 2006; Silverman, 2007). Current research seeks to identify the cognitive processes that differ between ID groups of different (genetically defined) etiologies, rather than identify what the similar deficits are in group of ID compared to mental aged matched TD children. Certainly, there is sufficient evidence in the literature to suggest that slow information processing speed is characteristic of children with ID (as suggested by Anderson, 1992, 2001; Bennett-Gates & Zigler, 1998; Brewer & Smith, 1990; Kail, 1992), however, what has yet to be resolved is whether children with ID eventually problem solve using similar strategies and cognitive process/es as TD children of similar mental maturation or whether they use a different problem solving approach altogether. And if both the developmental and deviance models both apply to problem solving ability in ID children, the question that still remains is what cognitive processes are developmentally delayed and which are deviant?

Theoretical Construct of Fluid Intelligence

It is difficult to discuss the concept of ID without discussing the concept of intelligence, as the two concepts are undeniably related (Zigler & Hodapp, 1986). After all ID is characterized by a low score on an intelligence scale. Thus how we
conceptualize intelligence will inevitably influence how we conceptualize ID.

David Wechsler was a clinician who received statistical training from Spearman in the late 1930s (Kaufman, Flanagan, Alfonso, & Mascolo, 2006). This influenced his creation of the widely used test of intelligence in children, known as the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) (Kaufman et al., 2006; Wechsler, 2003a). The WISC-IV is the latest edition of the Wechsler scales. The first Wechsler scale was the Wechsler-Bellevue Intelligence Scale, devised in 1939. The more recent WISC-IV is made up of 5 indexes or categories, measured by 3-4 individual subtests, which include: (1) Verbal Comprehension Index, as measured by Similarities, Vocabulary and Comprehension subtests; (2) Perceptual Reasoning Index, as measured by Block Design, Picture Concepts and Matrix Reasoning subtests; (3) Working Memory Index, as measured by Digit Span and Coding subtests and (4) Processing Speed Index, as measured by Letter-Number Sequencing and Symbol Search subtests. Wechsler used Spearman’s g theory when constructing the Wechsler scales; however his primary motivation was to create an efficient and easy to use test for clinical purposes (Kaufman et al., 2006).

As a student of Spearman, John Carlyle Raven also was highly influenced by Spearman’s g theory (Carroll, 1986). Raven set out to develop an intelligence test that was theoretically based on Spearman’s g theory, culture free and easy to administer. With this in mind, Raven created the Raven Progressive Matrices, which are non-verbal measures of reasoning ability. The original Raven’s Coloured Progressive Matrices (RCPM) (Carroll, 1986; Raven et al., 1995) was designed in 1938 for TD children from ages 5-11 years, the elderly and individuals with intellectual disability, hearing impairment and/or physical disability as well as individuals who did not speak English as their first language (Raven et al., 1995). The Raven’s Standard Progressive Matrices (RSPM) (Raven, Court, & Raven, 1992) was designed for adolescents and young adults and the Raven’s Advanced Progressive Matrices (RAPM) (Raven, 1965a) was designed for adulthood, particularly those who could already complete the RSPM effectively.

Neither Wechsler nor Raven explicitly identified the cognitive process/s that underlies performance on their respective tests. However, a common thread running through most theories of intelligence beginning from the time of test designs is the role of information processing speed, attention and working memory capacity (Ackerman, Beier, & Boyle, 2005; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle, Tuholski, Laughlin, & Conway, 1999; Kane et al., 2004; Kyllo nen & Christal, 1990).
These factors appear to be fundamental to any prediction of the level of intelligence in children and adults alike, and how these factors are related to one another and to intelligence is what primarily differentiates the various theories of intelligence from one another.

Short-term memory is usually defined as the ability to maintain new information for short periods of time, whilst working memory has been described as the information in short-term memory exposed to controlled attentional processing (Engle et al., 1999; Schweizer & Moosbrugger, 2004). Working memory is assumed to consist of separate components that each play a role to ensure that information is temporarily stored (in limited capacity) and readily accessible for only a short period of time (Baddeley, 1986, 1992; Baddeley & Hitch, 1974). These components include the phonological loop (responsible for storing phonological representations), the visuo-spatial sketchpad (responsible for storing visuo-spatial information), with the episodic buffer (integrates information from working memory and long-term memory) (Baddeley, 2000) and the central executive, which provides the attentional control needed to maintain information in working memory and to suppress ongoing exogenous distractions. Engle (Engel de Abreu, Conway, & Gathercole, 2010; 2002; Engle et al., 1999) suggested that level of intelligence is largely dependent on the capacity of the central executive component of working memory capacity, and thus, a variation in attention control is the contributing factor that determines the relationship between working memory and fluid intelligence. Other theories suggest that differences in the time to access and retrieve information from working memory contributes to level of intelligence (Mogle, Lovett, Stawski, & Sliwinski, 2008). Information processing speed on the other hand refers to the time taken to make a simple perceptual judgment. It is often measured using inspection time tasks, such as determining which of two parallel lines on a computer screen is longer. Indeed, processing time or inspection time correlates strongly with measures of intelligence and working memory tasks regardless of the test used (Anderson, 2001).

Anderson (1992) has limited the concept of general intelligence (or Spearman’s g) to two independent variables: cognitive development and information processing speed. The time at which children pass thorough cognitive development stages (e.g. as proposed by Piaget) differentiates individuals (differing on chronological age) who score high on a measure of intelligence, compared to those who score lower. Piaget’s (1976) four stages of cognitive development in primary school aged children have been shown to parallel increased total correct performance on the RCPM (Sigmon, 1984).
According to Anderson, difference in speed of information processing is what differentiates individuals (of similar chronological age) who score high on an IQ measure from those who score lower.

An alternative view of intelligence is taken by Fry and Hale (1996), who proposed a developmental cascade model to account for the relationship between working memory, processing speed and fluid intelligence. The model suggested that processing speed underlies working memory capacity, which then determines level of intelligence. Fast information processing time allows multiple streams of information to be held in working memory for sufficient time to facilitate reasoning before it is entirely forgotten. On the other hand, slow information processing would mean some information would be lost from working memory before it has the chance to be encoded and processed accordingly. Thus, slow speed of information processing is expected to limit working memory capacity and thus fluid intelligence. A problem for Fry and Hale’s (1996) developmental cascade model however, is that it was based on adult data. Indeed, a study (Miller & Vernon, 1996) found that the performance of TD children (4-6 years old) on a test of intelligence showed a stronger correlation with their performance on a working memory measure than an information processing measure, which suggests that working memory may be a more significant predictor of fluid intelligence than speed of information processing in early childhood. Unfortunately this question has not received much further investigation.

**Attention and working memory in the brain: separate processes?**

Fluid intelligence has been demonstrated to develop rapidly in childhood and then continue to increase steadily, but less rapidly in adolescence (Ferrer, O'Hare, & Bunge, 2009). This developmental trend corresponds with structural and functional and neurological changes in the brain. Imaging studies have consistently shown the frontal lobe, parietal cortex and the rostrolateral prefrontal cortex (RLPFC) to be activated during completion of reasoning items on the Raven’s Progressive Matrices (Crone et al., 2009; Ferrer et al., 2009; Shaw et al., 2008). Structurally, there is a reduction in the density of synapses and an increase in myelination of axons, from the dorsal parietal to the dorsal frontal regions (and including the RLPFC) between childhood and late adolescence (Ferrer et al., 2009). Functionally, the RLPFC is of importance and shows decreased activation for simple reasoning problems with age, so that during childhood, the RLPFC is activated for simple and more complex reasoning problems, whereas during adulthood, it shows selective activation for more complex items (Ferrer et al.,
Frontal and parietal regions of the brain are associated with working memory capacity, which supports the role of working memory in predicting fluid intelligence. A biological model of intelligence, known as the Parietal-Frontal Integration Theory (P-FIT) of intelligence (Jung & Haier, 2007), suggests that efficient function of working memory predicts intelligence. Working memory has been shown to contribute to higher performance on IQ measures such as the Raven’s matrices (Jung & Haier, 2007). This finding has been supported by a wider research literature. For example, Prabhakaran and colleagues (1997) investigated the neural substrates of fluid intelligence by using fMRI in 7 young adults during the completion of three types of items (i.e. figural, analytical and pattern matching problems) from the Raven’s Standard Progressive Matrices test (RSPM) (Raven et al., 1992). Figural problems were solved using visuospatial analysis and analytical problems required analytical reasoning. Pattern matching problems only required matching identical figures, and were used to control for perceptual motor activation during visuospatial and analytical problem solving, where as figural items were associated with activation of the bilateral parietal regions and analytical items were associated with activation of the bilateral frontal and left parietal, occipital and temporal regions. The majority of these regions have been associated with working memory, indicating that working memory or the attention that it requires are major components of fluid intelligence (Owen, McMillan, Laird, & Bullmore, 2005).

The P-FIT theory of intelligence (Jung & Haier, 2007) has recently been supported and extended by Rypma and Prabhakaran (2009), who used fMRI to show that greater dorsolateral PFC activation was associated with slower performance time on an inspection time task designed to measure processing speed, whereas the opposite pattern of brain activation was found in individuals with faster processing time. This finding was thought to suggest that more direct neuronal connections between dorsolateral PFC and relevant brain regions may be associated with faster and more efficient speed of information processing than numerous connections to both relevant and irrelevant regions of the brain. In fact, Rypma and Prabhakaran suggested that white matter impairment may be associated with slower speed of information processing, as shown to be the case in individuals with multiple sclerosis.

Although the role of attention was not explicitly implicated in either Anderson’s (Anderson, 1992, 1998, 2001) or Fry and Hale’s (1996) models of intelligence, much evidence demonstrates its importance to successful performance on measures of fluid
intelligence (Schweizer, Moosbrugger, & Goldhammer, 2005; Schweizer, Zimmermann, & Koch, 2000). Distinct attentional processes have been identified in the literature, such as sustained attention (active vigilance to target goal/s) and transient attention (involuntary capture of attention by an external potentially evolutionary salient sensory stimuli) (Ling & Carrasco, 2006). The information constantly surrounding us is transient and fast, thus, transient attention captures relevant information and sustained attention keeps information on task, for working memory to store and maintain (i.e. keep accessible online) (Astle & Scerif, 2010; Ikkai & Curtis, 2010; Ricciardi et al., 2006). According to the Magnocellular Advantage Hypothesis (Laycock, Crewther, & Crewther, 2008) transient attention, such as in rapid onset of stimuli or motion initiates attention to incoming information processing and has the potential to allow faster action and cognitive activation. Evidence from multifocal visual evoked potentials (VEPs) indicate that subcortical magnocellular visual projections arrive in the primary visual cortex (V1) up to 20 milliseconds prior to the arrival of the parvocellular signals (Klistorner, Crewther, & Crewther, 1997), facilitating activation of the parieto-frontal attention mechanisms prior to object recognition in the ventral stream (Laycock et al., 2008; Laycock, Crewther, & Crewther, 2007).

Conceptually and anatomically there is an overlap between attention and working memory processes, which raises the question of whether they make independent contributions in predicting intelligence. The central executive component of working memory constantly involves attentional functions. Indeed, it is the role of attention in maintaining information online that separates working memory from short-term memory. Interestingly, imaging studies of the brain suggest that attention and working memory share similar neurological underpinnings in the brain, raising the question of whether they are indeed separate constructs (Astle & Scerif, 2010; Ikkai & Curtis, 2010; LaBar, Gitelman, Parrish, & Mesulam, 1999; Owen et al., 2005; Ricciardi et al., 2006) or temporally related consequences of the same neural network. In other words, what seems to separate attention and working memory function (behaviourally speaking) is their temporal order of activation. Attention proceeds object recognition, learning and laying down the neurological changes necessary for encoding of memories (Laycock et al., 2008).

The question of whether attention and working memory make an independent contribution to predicting intelligence was addressed in a study by Schweizer and Moosbrugger (2004), who conducted structural equation modeling on the responses of
120 adults on a test of intelligence (Raven’s Advanced Progressive Matrices), working memory (Exchange test, Swaps test) and sustained attention (The Frankfurth Adaptive Concentration-Performance test). Results of the study showed that the ability to sustain attention and the ability to maintain information in working memory each accounted for independent proportions of the variance.

Aims and overview of current Thesis

Current research on ID is based on the assumption that ID is not a unified concept and different etiologies of ID are associated with differing brain impairments and thus different cognitive impairments. We suggest that despite neurological differences between ID groups, what is common among them is impaired problem solving ability (or reasoning ability) as evidenced by poor performance on IQ measures such as the WISC-IV and the RCPM. Thus, this thesis begins to explore whether attention and working memory processes are primarily impaired in children with ID of different etiologies in comparison to TD children of the same non-verbal mental age on a measure of fluid intelligence (RCPM).

The general aim of this thesis was to develop a more extensive construct of ID. More specifically, the experimental studies primarily aimed to determine whether there is a similar cognitive phenotype that characterizes individuals with ID of known etiology (Down Syndrome) and unknown etiology (children with Idiopathic ID) or genetically non identified etiology (low functioning children with Autism), and whether this cognitive phenotype is characteristic of a delay or deviation from the cognitive developmental trajectory of typically developing (TD) children of similar non-verbal mental age (as measured by the RCPM)?

Refinement of the ID construct will provide greater insight for parents, practitioners and researchers into the cognitive capacity and limitations of children with ID. Such insight should also help facilitate the preparation of educational material and teaching approaches to ensure children with ID reach their highest potential, as well as provide parents and community services with more information and realistic expectation of the educational outcomes and potential ongoing needs for the child, including whether their child will ever develop speech, finish high school, be able to use their local ATM machine, earn a living etc. Furthermore, a better defined construct of ID will provide insight into the criterion by which to match ID children to TD children in research studies. A well defined construct of ID will also inform the construct of intelligence and intellectual development, ultimately expanding understanding of human
cognitive capacity in all individuals.

In particular, this thesis reports data of five experimental studies. The studies are based on the comparison of children with Down Syndrome (DS), low functioning children with Autism (LF Autism) and children with Idiopathic ID to TD children of similar non-verbal mental age (as measured by the RCPM). DS is the most common ID of known genetic etiology identified at birth, whereas the diagnosis of Autism is a behavioural classification often only being identified by preschool years and in a way more devastating for families. In addition, prevalence of Autism has been reported to be rising, but despite 70% of all individuals with Autism being diagnosed with ID, research on LF Autism remains rare. The RCPM was used to match the ID groups (already diagnosed using the WISC-III) to the TD group on non-verbal mental age in each experimental study of this thesis. The justification for this measure has been provided in Chapters 3 and 4 (Study 1 and 2). In each study, computer tasks measuring reaction time and accuracy of responses to stimuli were utilized. Non-parametric statistical analyses (with p< .05) were most often used in this thesis due to violations to Assumptions of Normality.

Chapters 2 – Part 1 and Part 2 of the thesis review the literature and provide an introduction to the concept of ID and attention impairment in children with DS, Idiopathic ID and children with LF Autism, as suggested up to 2008. The first study (presented in Chapter 3) aimed to test the validity of a newly created puzzle version of the RCPM against the standard book version of the RCPM in a group of TD children. The study also aimed to determine whether the puzzle form of the RCPM resulted in a performance advantage (i.e. total score correct and total number of items completed) in children with ID compared to the book form of the RCPM. The RCPM puzzle version has a visual motor component which we suggest should be useful with children with ID as visual motor requirements are a more general way to further engage their attention and reduce distractibility.

The second study (presented in Chapter 4) investigated whether children with ID are delayed or deviant in their cognitive development and whether the RCPM is a valid means of matching ID groups to TD groups on non-verbal mental age (as measured by the RCPM) and receptive language ability (as measured by Peabody Picture Vocabulary Test-Third Edition) (Dunn & Dunn, 1997). This aim was achieved by comparing groups on type of errors (as defined by Raven) made on the item types of the RCPM (as defined by (Corman & Budoff, 1974) and investigating correlations between RCPM
performance and cognitive processes associated with RCPM performance (total score correct and error types) in TD individuals (i.e. working memory, receptive language as well as chronological age).

The third study of this thesis (presented in Chapter 5) investigated reaction time and accuracy performance of children with DS on sustained and transient attention tasks (continuous performance tasks and visual search tasks, with and without a working memory component) compared to TD children of similar non-verbal mental age (as measured by the RCPM). In the fourth study (presented in Chapter 6), children with LF Autism were compared to children with Idiopathic ID and TD children of similar non-verbal mental age on visual and auditory discrimination tasks. The aim was to investigate whether children with LF Autism group detect visual changes (in a stimuli’s colour or identity) and discriminate between auditory stimuli according to the level expected of their non-verbal mental age and receptive language ability, or whether they would show the reported superior visual and/or auditory processing commonly reported for HF Autism children. The fifth study (presented in Chapter 7) compared multisensory integration of visual and auditory stimuli in children with LF Autism and non-verbal mental aged matched TD children and children with Idiopathic ID. Each chapter has outlined the experimental findings and implications of the study results. The final chapter of the thesis (Chapter 8) is the Discussion section, where findings of the thesis are reviewed in terms of their implications for the theoretical construct of ID, as well as the practical education of children with ID.
CHAPTER TWO: Literature Review – Part 1

Intellectual Disability: Beyond IQ scores

The literature reviews in Chapter 2 (Part 1 and Part 2) outline a summary of the ID literature. The primary argument made in the literature is that cognitive development in children with ID is deviant, supporting the ‘difference model’. The importance of investigating problem solving ability in children with ID is also highlighted.

Currently Intellectual Disability (ID) is classified as an Intelligence Quotient (IQ) below 70 on the Wechsler Intelligence Scale for Children - Fourth Edition (WISC-IV) and impairment in adaptive skills during the developmental period. We suggest that the non-verbal visual matching measure, Raven’s Coloured Progressive Matrices test (RCPM) is an acceptable alternative to the commonly used WISC-IV measure of intelligence, as a means of matching groups of ID with a verbal deficit to a typically developing (TD) group according to their mental age. We also present evidence that RCPM non-verbal mental age matched children with Low Functioning (LF) Autism, Down Syndrome (DS) and Idiopathic ID use different problem solving strategies than TD children, to achieve the same overall performance on the RCPM. This is presumably due to group differences in brain impairments as evidenced by brain imaging studies. Further, we present evidence from the literature that working memory is a major component of successful performance on an IQ test and that impairment in working memory in ID could affect problem solving abilities on the RCPM. The theoretical and educational implications of the discrepancy between similar overall performance level on an intelligence test, but different use of problem solving strategies are also explored.
Introduction

Intellectual Disability (ID) is commonly defined by three criteria: (1) a Wechsler Intelligence Scale for Children (WISC) Intelligence Quotient (IQ) of 2 SD below the norm of 100 (i.e. <70), (2) impairment in adaptive behaviour and (3) manifested developmental delay identified early in and persisting through childhood (Katz & Lazcano-Ponce, 2008; Leonard et al., 2003; Pratt & Greydanus, 2007; Salvador-Carulla & Bertelli, 2007; Shevell, 2008; World Health Organization, 1993). As well as informing the classification of an individual with ID, IQ test scores are used in research settings to co-vary intellectual ability and in clinical settings to help inform educational goals and evaluate therapeutic interventions (Dawson, Soulières, Gernsbacher, & Mottron, 2007).

We will briefly present the argument for mental age (MA) and chronological age (CA) matching from the developmentalist and difference theorists. We will then argue that when matching children with ID and Typically Developing (TD) children on MA, using the Raven’s Coloured Progressive Matrices (RCPM) (Raven, 1956b) should replace the more commonly used Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV) (Wechsler, 2003a), as the RCPM is a more valid measure of reasoning ability in children with an ID. We provide evidence that MA matched children with Low Functioning (LF) Autism, Down Syndrome (DS) and Idiopathic ID use different problem solving strategies compared to TD children when completing the RCPM, despite comparable overall performance. We argue that this is presumably due to different brain impairments in ID, as evidenced by brain imaging studies. We also present evidence from the literature that working memory is a major component of successful performance on an IQ test, as it presumably provides the opportunity for the use of higher order problem solving strategies. In order to enhance the education of children with ID, it is important to further explore the problem solving strategies utilised and implement understanding to drive personalized programs of education for each child. We also propose a revised position on the developmental/difference debate and further explore the educational implications of the discrepancy between similar overall performance level on an intelligence test, but use of different problem solving strategies.

What is Intellectual Disability?

Understanding the etiology and prevalence of the ID affecting individuals will inform the management, prognosis, educational and support resources available to assist each individual with ID in their day to day living (Soto-Ares, Joyes, Lemaître, Vallée, &
Pruvo, 2003). According to the American Association on Intellectual and Developmental Disabilities (AAIDD), more than 350 causes of ID were reported to exist in 1992 (King, State, Shah, Davanzo, & Dykens, 1997; Luckasson et al., 1992). However, in 30-50% of cases of ID, a genetic etiology has not yet been identified (Soto-Ares et al., 2003). ID of known etiology is classified as either genetic in origin or acquired (Katz & Lazcano-Ponce, 2008; Pratt & Greydanus, 2007). Research suggests that currently the most common hereditary form of ID is Down Syndrome (DS), which occurs in 15 of every 10,000 births due to an extra (partial or full) chromosome 21 or the translocation of chromosome 21 and 15. Other ID conditions that have a genetic origin include Fragile X syndrome, Prader-Willi Syndrome, Rett Syndrome and Neurofibromatosis (Katz & Lazcano-Ponce, 2008), to name just a few. In fact, according to Harris (1998) there are more than 500 different genetic causes of ID and Feldman (1996) suggests that at least 95 ID conditions have been linked to abnormalities of the X chromosome. This link with the X chromosome explains the prevalence ratio of 4:1 males to females with ID (Steyaert & De La Marche, 2008). In addition, there is a greater prevalence of mental illness in individuals with ID than those with TD (King et al., 1997).

Accurate estimates of prevalence rates of ID are important for the planning and provision of services, such as educational and family support services (Leonard et al., 2003). However, prevalence rates vary widely depending on the classifications of ID used, method of data collection and study location. Prevalence of ID in developed countries has been estimated at 1-3% in 1996 (Hodapp & Dykens, 1996; King et al., 1997).

The Australian Bureau of Statistics estimates that in 1997, 1% of the Australian population had an ID which required assistance in self-care, mobility and communication (Bower, Leonard, & Petterson, 2000). Prevalence studies carried out in Western Australia indicated a gradual rise in ID diagnoses in the past 20 years, which included an estimated 7.6 per 1,000 individuals between the ages of 6 and 16 years being categorized as having an ID between the years 1967-1976 alone (Bower et al., 2000; Leonard et al., 2003; Wellesley, Hockey, Montgomery, & Stanley, 1992). This rate had risen to 8.3 per 1,000 individuals approximately a decade later (Alessandri, Leonard, Blum, & Bower, 1996; Bower et al., 2000; Leonard et al., 2003). A further study in Western Australia reported the prevalence of ID in the period between 1983-1992 to be 14.3 per 1,000 individuals, with 10.6 per 1,000 of those individuals classified
as having ID of mild to moderate level of severity, 1.4 per 1,000 were classified as severe ID and the classification of the remaining 2.3 per 1,000 was unspecified. In addition, the prevalence of ID in Aboriginal mothers was 30.8 per 1,000 live births, which was double the prevalence rate of ID children for Caucasian mothers in the region (Leonard et al., 2003).

**Autism**

Autism is the most severe neurodevelopmental disorder on the Autism Spectrum and is characterized by impaired social and communication development and the presence of repetitive behaviours and fixed interests (American Psychiatric Association, 2000; World Health Organization, 1993). It affects males four times more often than females (Steyaert & De La Marche, 2008) suggesting an X-linked inheritance pattern. Approximately 50-70% of individuals with Autism Spectrum Disorder are also diagnosed with ID (Matson & Shoemaker, 2009). Autism has a strong genetic and biological component, however, it is diagnosed behaviourally as distinctive biological and genetic markers have yet to be established (Glessner et al., 2009; Happé, 1999). Research suggests that the prevalence of Autism is rising. Crewther et al. (2003) estimated 27 out of 10,000 children in Victoria, Australia, had severe Autism (as children diagnosed by age 6 years are predominantly those with extreme behavioural impairments). This increase in diagnosis is likely to be partially due to a broader interpretation of the diagnostic criteria (Steyaert & De La Marche, 2008). Most research is performed on Higher Functioning (HF) children with Autism (who do not qualify as ID) and very little research on children with Lower Functioning (LF) and severe Autism (Mottron, 2004). Therefore, our understanding of the nature of Autism currently remains limited and skewed.

**Down Syndrome and the classification of ID**

Down Syndrome (DS) is the most common cause of ID. In 95% of cases, DS is caused by an extra chromosome 21 (Pinter, Eliez, Schmitt, Capone, & Reiss, 2001). The replication of this chromosome results in specific facial features that are characteristic of those with DS. Though ID is a common feature of DS, its severity varies widely between individuals (Catalano, 1990; Fidler & Nadel, 2007; Sherman, Allen, Bean, & Freeman, 2007; Silverman, 2007). A recent study reported the prevalence of DS to be one in every 732 infants in the United States (Sherman et al., 2007) and its incidence as 1 in 800 live births (Pinter et al., 2001).

In order to accurately determine the causality and treatment options for ID, it is
vital for international classification bodies to agree upon a universal definition of ID, including a universal measure of IQ, in order to ensure consistency and comparability of results. This IQ test would have to be a valid and reliable measure of intelligence for children from the 0 to 100th percentile. At present, the appropriateness of the WISC-IV as a measure of intelligence in children with ID is questionable and the meaning of an IQ score in ID children has remained unexplored.

**Mental age Versus Chronological age Matching: the Developmental Origins of Intellectual Disability**

The developmental/difference debate surrounds the question of whether cognitive development is delayed (developmental perspective) or impaired (difference perspective) in ID. According to the developmental perspective, individuals with ID of a known etiology are developmentally deviant from the norm, as a result of neurological impairments, whereas individuals with ID of unknown etiology are only developmentally delayed and functioning on the lower end of the normal distribution of intelligence. These predictions are also known as the similar structure and similar sequence hypothesis (Zigler & Hodapp, 1986). The difference model on the other hand, which was initially proposed by Lewin (1935) and revised by Kounin (1941b) claims that individuals with ID (regardless of the etiology) develop differently to TD individuals because of their neurological deficiencies.

Although the relatively recent advent of understanding of the interacting genetic and neuroanatomical bases of many types of ID has largely made this debate anachronistic, the distinction between the developmental and difference theorists with regard to methods of matching of ID and TD groups on cognitive ability in research studies remains important. The developmentalists usually match groups on MA and the difference theorists match groups on CA. Indeed according to the developmentalists, MA provides an estimate of cognitive development and a means of testing whether individuals with ID are developmentally delayed or deviant, whereas the use of CA only confirms the differences in developmental level between ID and TD individuals. On the other hand, according to the difference theorists, ID and TD groups show qualitative and quantitative differences in cognition. Therefore, MA only reflects similarities in overall performance between ID and TD groups on a test of intelligence, and does not indicate differences in problem solving strategies used between groups (Bennett-Gates & Zigler, 1998). Difference theorists prefer to match on CA as this demonstrates how individuals with ID differ compared to individuals who have developed typically. This
debate is relevant and important both in the research and clinical settings. Matching strategies in research affect conclusions from research findings that are drawn, which in turn affects the conceptualization of ID and intelligence. In addition, understanding CA and MA differences between ID and TD groups informs how we educate children with ID individually and alongside TD children.

**WISC-IV Versus the Raven’s Coloured Progressive Matrices as a Valid Measure of Intelligence in Children with Intellectual Disability**

Tests of intelligence are often a measure of crystallized intelligence, fluid intelligence, or both (Kluever, 1995; Prabhakaran et al., 1997). Crystallized intelligence refers to long term knowledge, such as knowing the capital city or the population of a country, whereas fluid intelligence refers to the ability to solve a novel problem with the use of analytical reasoning (Prabhakaran et al., 1997). In many research studies, individuals with an ID are matched to other ID groups or to a TD group based on their performance on a fluid intelligence test. Thus, it is vital to base this matching on a valid measure of intelligence. In the low IQ range, inability to successfully complete items may be attributable to a number of causes, such as difficulty resulting in lack of motivation. What a test does though is shed light on which items were completed purposefully using a strategy of some sort and estimates the probability of how many answers to items were guesses. In order to obtain a valid estimate of an individual’s (with ID) IQ score, an intelligence test that reduces the probability of guessing is to be favoured.

The Wechsler Intelligence Scale for Children (WISC) is the “gold standard” for intelligence testing and the most commonly used test of intelligence in children (Hale, Fiorello, Kavanagh, Hoeppner, & Gaither, 2001; Kaufman et al., 2006; Keith, Fine, Taub, Reynolds, & Kranzler, 2006; Wilson & Reschly, 1996). The most recent edition is the Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV) (Wechsler, 2003a) which is a revision of the Wechsler Intelligence Scale for Children- Third Edition (WISC-III) (Wechsler, 1992). David Wechsler devised the first series of Wechsler tests known as the Wechsler-Bellevue Intelligence Scale in 1939 (Wechsler, 1939), which was followed by the development of Form II of the Wechsler-Bellevue test in 1946. In 1949, the Wechsler Intelligence Scale for Children was published (Wechsler, 1949) and revised three times in 1974, 1991 and 2003 (Wechsler, 1974, 1991b, 2003a), each applicable to a 6-16 year old age range. The current revision, WISC-IV gives 4 measures: Verbal Comprehension Index (VCI), Perceptual Reasoning
Index (PRI), Working Memory Index (WMI) and Processing Speed Index (PSI) which are considered measures of crystallized intelligence, visual processing, fluid reasoning, short-term memory and processing speed (Keith et al., 2006). WISC-IV has changed in some fundamental ways from the WISC-III. Firstly, it does not produce an overall Verbal IQ score and Performance IQ score and there is an increased emphasis on measuring fluid reasoning skills, with the addition of the Matrix Reasoning and Picture Concepts subsets. In addition, easier items have been included in order to improve the test for lower functioning children as well as chronologically young children (Keith et al., 2006).

Despite these changes, Wechsler scales are still likely to be inappropriate IQ measures for children with ID or suspected of an ID because they are lengthy to administer and require verbal comprehension and expression from a population typically characterized by low verbal skills and comprehension. The scales do not accommodate low functioning children’s deficit in attention and communication, and therefore do not motivate or sustain performance. Thus, performance on these scales could be more reflective of lack of motivation than level of mental maturation (Bello, Goharpey, Crewther, & Crewther, 2008). Indeed, David Wechsler views his scales as meant for people with average intelligence, not those of IQ above 130 or below 70. When told that most clinicians use his tests to identify the extreme populations, he stated “It’s not what I tell them to do, and it’s not what a good clinician ought to do. They should know better” (Kaufman, 1994). Bello et al. (2008) suggest that a more suitable measure of mental maturation in lower functioning children is the Ravens Coloured Progressive Matrices (RCPM) (Raven, 1965b) as it is an un-timed, non-verbal measure of reasoning ability (Carpenter, Just, & Shell, 1990; Cotton, Kiely, et al., 2005; Sattler, 2001), requires minimum language to explain the task, and requires no verbal response for completion. This increases the probability that attention and motivation will be sustained throughout the time of testing, and performance will be reflective of ability, rather than guessing coming from a lack of motivation.

The RCPM is one of three non-verbal measures of fluid reasoning ability devised by John Carlyle Raven in 1938 (JRaven, 1995). The Raven’s progressive matrices include the RCPM used for TD children aged between 5-12 years, the elderly and individuals with ID (Green & Kluever, 1991), the Raven’s Standard Progressive Matrices (RSPM) (Raven, 1956a) and the Raven’s Advanced Progressive Matrices (RAPM) (J.Raven, 1965a). The Ravens progressive matrices are widely used as culture
free measures of fluid intelligence that do not require any crystallized knowledge for successful completion (Prabhakaran et al., 1997). The RCPM has been utilized with children with severe ID, including those with Autism (Clark & Rutter, 1979b; Koegel, Koegel, & Smith, 1997) in research settings to control for non-verbal mentation (Barnard, Crewther, & Crewther, 1998; Cotton, Kiely, et al., 2005; Crewther, Lawson, Bello, & Crewther, 2007) and in educational settings to determine their level of functioning and treatment progress as part of a battery of tests (Anderson Jr, Kern, & Cook, 1968; Budoff & Corman, 1976).

The RCPM is made up of 36 coloured multiple choice matrices (although colour is irrelevant to the completion of the task), organized in three increasingly complex sets, Sets A, Ab and B (J. Raven, 1998; J. C. Raven et al., 1992). Each item consists of a matrix of geometric designs that is presented as the problem, with one design removed from the sequence. Beneath each pattern are six separate pieces, with one piece correctly completing the pattern. The goal is to deduce the theme of relations expressed among the designs and choose the missing figure from among the alternative set of six. Items can be solved using visuospatial analysis such as pattern matching or analytical or abstract reasoning. The RCPM is made up of more visuospatial items than analytical items in comparison to the RSPM and the RAPM (Prabhakaran et al., 1997; Villardita, 1985a).

The RCPM board form is another version of the RCPM standard form, designed for greater appeal to the lower functioning population, due to its movable pieces. It has a test retest reliability of 0.8, however evidence of its validity are limited (J. C. Raven et al., 1992). The board form is also limited in that it’s 36 separate wooden board pieces tend to become disorganized easily and the administration process can be time consuming (Raven et al., 1992). These limitations are potentially a problem for children with ID who often have difficulty sustaining their motivation and attention during testing. Therefore, in order to address the limitations of the RCPM board form, Bello et al. (2008) devised a velcro version (i.e. a tactile puzzle form) of the standard RCPM (i.e. RCPM puzzle form), particularly designed to sustain the motivation and attention of lower functioning children. Each response option was laminated and then velcroed in place. Items were completed by physically removing a response option and placing this velco compatible piece in the section of the item that was vacant. In their first study, Bello et al. tested the validity of the RCPM puzzle version by comparing TD children’s performance on the puzzle form to the standard book form of the RCPM test. Seventy
six TD aged between 5 and 11 years old (M= 8.57 years, SD= 2.06 years) were split into two groups. Half the children attempted the book form first, while the other half attempted the puzzle form. The two groups were comparable on CA and RCPM total score correct. The alternate form of the RCPM was administered after three weeks to each group, in order to minimize the impact of maturation in learning and memory or practice effects on performance. Results of the study showed a comparable performance between the RCPM puzzle and book forms in the TD school-aged children, regardless of order of completion and a strong correlation between first and second performance of the RCPM suggesting that RCPM puzzle and standard forms measure the same construct/s.

In their second study, Bello et al. (2008) administered either the RCPM puzzle form, or the standard form to 164 children with an ID, including 101 children with Autism, 20 with DS and 43 with Idiopathic ID, in order to determine which version of the RCPM would result in better performance and higher completion rate in children with ID. Results showed a significantly higher performance and completion rate for the puzzle form (76.2%) than for the standard form (40%), regardless of clinical group. Fifty-five per cent of children with Autism, 68% of children with DS, and 67% of children with Idiopathic ID were unable to complete the standard form but were able to complete the entire puzzle form. Bello et al. suggested that the puzzle form produced a performance and completion rate advantage in test takers with ID, possibly because the motor aspect of moving responses onto the item to complete the pattern served to engage test-takers’ attention and interest longer than the standard version. Findings of this study suggest that the RCPM puzzle form is a valid measure of reasoning ability in children with TD and ID and thus should replace the Wechsler scales as a measure of reasoning ability in children with ID. This ensures that test performance of children with ID is an accurate reflection of their reasoning ability, which enables researchers to better understand their capacity and clinicians to provide more suitable treatment options for them.

**Similar Mental age on the Raven’s Coloured Progressive Matrices Does Not Mean the Use of Similar Problem Solving Strategies**

Overall total correct performance score on tests of ability such as the RCPM is commonly used as a measure of MA. However, similar MA on an IQ test does not necessarily equate to similar problem solving strategies used to solve the items. Investigating how different groups of ID solve problems on the RCPM can provide an
insight into learning styles associated with different etiologies of ID, as well as highlight the abilities and skills that are commonly associated with intellectual functioning.

One attempt to explore the problem solving strategies used on the RCPM has been to assess the type of erroneous responses made on the RCPM. According to Raven et al. (1998), after completion of the test, incorrect responses can be categorized into one of four error categories which indicate different problem solving strategies and correlate with intellectual development. The error types include: a) Difference error, when the chosen piece has either no pattern of any kind or one of direct relevance to the target pattern; b) Figure Repetition error, when the chosen piece has either part of the pattern immediately above or beside the target gap in the pattern; c) Inadequate Individuation error, when the chosen piece is contaminated by irrelevancies, distortions or incomplete patterns; and d) Incomplete Correlate error, when the chosen piece correctly identifies part of the target pattern though the figure may be wrongly oriented or incomplete. Although Raven et al. were not clear as to what cognitive abilities are being used when certain errors are made, they did associate the errors with stages of cognitive development. For example, some errors such as Difference error were found to be made earlier in development before pattern differentiation matured, rather than later in development when abstract reasoning begins to appear.

Gunn and Jarrold (2004) explored the pattern of errors made on the RCPM task by children with DS matched on overall performance to children with moderate learning disability and TD. They found that DS and TD children were different in the proportion of error types made on the RCPM even when their overall total correct performance was comparable. They also found that overall RCPM performance showed a significant positive correlation with CA for both TD and DS groups, which suggests that individuals with DS perform better as they get older but continue to make the same types of errors. As the basis for understanding strategies of problem solving ability in ID, a study by Goharpey, Crewther and Crewther (under review) examined patterns of error types on the RCPM in children of similar MA (assessed on the RCPM), which included 38 children with LF Autism (M= 7.44 years, SD= 2.60 years), 17 with DS (M= 6.59 years, SD= 0.77 years), 32 with Idiopathic ID (M= 6.73 years, SD= 1.71 years) and 46 TD children (M= 7.76 years, SD= 2.21 years).

Similar to Gunn and Jarrold’s (2004) findings, Goharpey et al. (under review) found that all clinical groups showed a similar spread of error types, but the TD group showed a different proportion of error types made on the RCPM in comparison to the
clinical groups. Receptive language ability and working memory (the capacity to store and manipulate information for a brief length of time) has been consistently associated with successful performance on the Ravens matrices in TD individuals (Carpenter et al., 1990; Fry & Hale, 1996; Prabhakaran et al., 1997). Therefore, in attempting to explore possible strategies that may be associated with different error types, short-term and working memory capacity (as measured by visual and auditory forward digit span and backward digit span) and receptive language capacity (as measured by the Peabody Picture Vocabulary Test-Third Edition) (Dunn & Dunn, 1997), were correlated with error types and overall RCPM performance in each group. Performance of the ID and TD group on the RCPM was associated with an increase in receptive language and visual short-term memory. However the ID groups made more positional errors (i.e. selecting a response based on its position and not on its content) than the TD group, which suggests that some deviation exists in the problem solving strategy of children with LF Autism, DS and Idiopathic ID in comparison to TD children of similar non-verbal mental age.

The Role of Working Memory in IQ Performance of Individuals with Intellectual Disability

The activities of the fronto-parietal regions of the brain that have been consistently associated with working memory have also been shown to be associated with attention function (Cabeza & Nyberg, 2000; Kane & Engle, 2002; Naghavi & Nyberg, 2005; Pessoa, Kastner, & Ungerleider, 2003). Naghavi and Nyberg (2005) who reviewed studies using functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) found attention and memory functions have a common activation in the dorsolateral, prefrontal and parietal cortex. It is conceptually logical that areas of the brain involved in working memory are also involved in attention function, as attention cannot be sustained unless there is a memory of relevant previous information with which to compare incoming information.

Working memory has also been shown to be a major component of intelligence. Colm, Jung and Haier (2007) conducted a study in order to find the brain regions common to working memory and general intelligence (“g”). Vocabulary and block design performance of 48 adults on the Wechsler Adult Intelligence Scale (WAIS) were used to measure “g” and forward and backward digit span components of the WAIS were used to measure working memory. Correlation of Magnetic Resonance Imaging (MRI) with these performances showed Brodmann Area (BA) 10 (right superior gyrus
and left middle frontal gyrus) in the frontal lobe and BA 40 (right inferior parietal lobule) in the parietal lobe to be common regions associated with working memory and “g”.

A recent study by Alloway (2009) used a regression analysis to show that working memory (Pickering & Gathercole, 2001) and not IQ (Wechsler, 1992) was a significant predictor of learning outcomes, as measured by The Wechsler Objective Reading Dimensions (Wechsler, 1993) and The Wechsler Objective Numerical Dimensions (Wechsler, 1996) in a group of 64 children with mild to moderate learning disability aged 7 to 11 years (M=9.0 years, SD=1.2 years). However, in this study IQ was measured using the WISC-III, which includes only a small subset of tests that measure working memory, which is perhaps why IQ did not predict learning outcomes. If an IQ measure that was strongly associated with working memory (e.g. RSPM and RAPM) (Borella, Carretti, & Mammarella, 2006; Carpenter et al., 1990; R Colom, Flores-Mendoza, & Rebollo, 2003; Prabhakaran et al., 1997) had been used in the study, it may have in fact been a significant predictor of learning outcome.

Over the last decade, in an attempt to understand the nature of intelligence in the brain, Jung and Haier (2007) reviewed 37 studies that had imaged the brains of individuals using various techniques such as fMRI and PET as they completed items from measures of intelligence, such as the RSPM and the RAPM (Prabhakaran et al., 1997). They found a common overlap of individual differences in the activation of the frontal and parietal regions of the brain. Frontal lobe regions included BA 9, 46, 45 and 47 and parietal lobes regions included BA 40, 39 and 7. Some regions in the temporal (BAs 21, 22 and 37) and occipital lobes (BA 18 and 19) were also identified. Jung and Haier used the evidence to propose a model of the biology of intelligence, known as the Parietal-Frontal Integration Theory (P-FIT). The model suggests that intellectual ability is underpinned by the interaction between certain areas of the frontal and parietal brain regions when effectively linked by white matter structures. According to the P-FIT model, Wernicke’s area (BA 22) processes incoming auditory information and the extrastriate cortex (BA 18 and 19) and fusiform gyrus (BA 37) of the occipital lobe process incoming visual information. This information is then integrated by the parietal brain regions, predominately the supramarginal (BA 40), superior parietal (BA 7) and angular (BA 39) gyri. The problem is then evaluated by interaction of these parietal and frontal regions (BA 6, 9, 10, 45-47). The anterior cingulate (BA 32) then acts to select the best response and inhibit alternating choices. The white matter was considered to
ensure that information is reliably transferred from one brain region to another (Jung & Haier, 2007), but no consideration was given to the possibility that there could be white matter complications.

In an open peer commentary, Cohen, Walsh and Henik indicated that BA 10 in the frontal lobe and BA 39 and 40 in the parietal lobe, were the only regions in the P-FIT that were strongly supported by the structural data in the literature, providing little evidence to support the P-FIT model (Jung & Haier, 2007). In addition, Cohen et al. argued that parietal-frontal regions related to attention are only one component of intelligence and do not define intelligence as a whole construct. We suggest that one main reason for the inconsistent evidence in the literature in support of the P-FIT is that results from brain imaging studies are limited in that they do not provide information on whether or not participants completed items correctly during the imaging and what strategies they used to come up with their responses. These factors can result in different regions of the brain being activated during completion of an IQ measure.

Indeed, research shows that accuracy does make a difference in brain imaging results. In a series of studies, Haier and colleagues (1988) found an inverse correlation between regional glucose metabolic rate (GMR) and performance on the RAPM in 8 young males. Essentially, the brains of individuals who had high scores on the RAPM utilized less glucose when completing the task than those with low scores. It was not clear from the study how low and high performers were defined but nevertheless, this same pattern was also shown in a PET study of 16 individuals completing a high g-loaded verbal fluency test (Parks et al., 1988). Such observations support a model of neural efficiency (Kwan & Reiss, 2005). Interestingly, the opposite pattern was shown for individuals with an ID. Higher rate of glucose metabolism was found throughout the brain of adults with Autism (Rumsey et al., 1985), DS (Haier et al., 1995; Schwartz et al., 1983) and Idiopathic ID compared to TD individuals during task performance (Haier et al., 1995). This suggests that a more intelligent brain uses its glucose more efficiently than a less intelligent brain. It also suggests that different levels of accuracy on a test of intelligence in TD individuals can result in different activation patterns, making it difficult to separate the activation sites associated with high performers and those associated with low performers.

Evidence also suggests that the use of different strategies to complete the same items on the RCPM results in activation of different regions of the brain. In a study by Prabhakaran and colleagues (1997), young adults (M= 26 years) attempted three
different types of problems on the RSPM and the RAPM, whilst their brain activation was being measured by fMRI. The three problems involved (1) figural or visuospatial reasoning, (2) analytical reasoning; or (3) simple pattern matching which served as a control for the motor and perceptual activation involved in completing each item. Results showed that different regions of the brain associated with working memory were activated when each question type was attempted. Bilateral frontal and left parietal, occipital and temporal regions were activated more by analytical problems than pattern matching problems. Thus, if test takers use other strategies such as verbal abilities to problem solve or simply guessing, different regions of the brain would be expected to be activated as a result.

According to the literature, working memory is a major component of intelligence and we speculate that this may be because working memory capacity allows information to be available for inspection and manipulation longer and therefore provides an opportunity for information to be manipulated using higher order problem strategies, such as reasoning by analogy. Thus, an individual with ID who has a lower working memory capacity may not be able to retain information long enough to apply principles of analogy to successfully solve more difficult problems. Therefore, they may have to rely on using lower level abilities such as pattern matching or guessing, as a strategy to solve problems that require reasoning by analogy for successful completion.

This explanation is supported by research which shows that individuals with an ID generally have deficits in working memory and attention. For example, individuals with Autism have been consistently shown to have difficulties with executive functions associated with a fronto-parietal connectivity deficit (Just, Cherkassky, Keller, Kana, & Minshew, 2007; Kana, Keller, Minshew, & Just, 2007; Solomon et al., 2009). In a recent study by Solomon and colleagues (2009), 22 adolescents with HF Autism and 23 age, gender and IQ matched TD adolescents performed a visual response task that had previously been shown to activate fronto-parietal regions associated with executive functions, such as dorsolateral prefrontal cortex (DLPC; BA 9), anterior frontal (BA 10), parietal cortex (BA 7 and 40) and anterior cingulate cortex (ACC; BA 32). Results showed less activation in these regions in the HF Autism group compared to the TD group. Future research will need to conduct brain imaging studies using both HF and LF children with Autism, in order to determine whether a deficit in frontal-parietal regions of the brain are associated with the Autism diagnosis, or only children with HF Autism who do not have an ID. Such future studies should use brain imaging equipment such as
EEG or magnetoencephalography (MEG), where the testing environment is less noisy and potentially less distressing for children (particularly those with ID) than the fMRI testing environment. Unlike individuals with HF Autism, research shows a preservation of the parietal lobe in individuals with DS, despite impaired language ability including verbal working memory (Pinter et al., 2001). Using an fMRI procedure, Pinter and colleagues (2001) showed that consistent with behavioural evidence of typical parietal functioning in DS, there was also preservation of prefrontal lobe grey matter in the sample of 16 individuals with DS (M = 11.3 years). Preservation in the prefrontal lobe in individuals with DS was also shown in a study by Jernigan, Bellugi, Sowell, Doherty and Hesselink (1993) who found typical parietal and occipital gray matter in an fMRI study on 6 children with DS. Findings suggest that areas of working memory may be affected differently depending on the etiology of the ID.

Impairments in other brain regions in individuals with ID may also be associated with differences in problem solving strategies used to complete tests of intelligence, such as the RCPM (Goharpey et al., under review). In their review, Lawrence, Lott and Haier (2005) identified six aspects of brain structure and/or function that were commonly affected in Autism, DS and Idiopathic ID, but not always in the same way. These included the cerebellum volume, brain stem volume, hippocampus volume, dendritic development, whole brain volume and whole brain metabolism. Studies have consistently shown a smaller cerebellum, brain stem and hippocampal volume as well as abnormal dendrites in Autism, DS and Idiopathic ID groups in comparison to TD individuals. In addition, a larger brain size has been related to increased intelligence in Autism. Individuals with DS and Idiopathic ID also show a smaller brain size in comparison to TD individuals and a higher brain metabolism in resting state, which suggests that a less intelligent brain needs to work harder (Lawrence et al., 2005).

Working memory and attention are a significant component of intelligence. However, the use of other cognitive abilities to solve problems on measures of intelligence in children with ID needs to be further explored in future studies. This will highlight cognitive abilities associated with intelligence, as well as inform educational interventions for children with ID.

**Implications for Working with Children with Intellectual Disability**

**Theoretical Implications: the Developmental/Difference Debate Revised**

The main issue in the developmental/difference debate centering on whether there is any neurological impairment in individuals with Idiopathic ID that correlates
with their cognitive ability is now considered less relevant. Indeed if brain imaging studies identified clear brain areas that were anatomically different in children with Idiopathic ID compared to TD children, then the debate will cease to be an issue. Though more research is required, we believe that the evidence in the literature on the pathological impairments in individuals with Idiopathic ID is sufficient to demonstrate that it involves neurological impairments that result in developmental deviance and not just developmental delay per se (Lawrence et al., 2005; Soto-Ares et al., 2003). In a study by Soto-Ares and colleagues, thirty children with ID of unknown etiology (M=5.2 years) underwent an MRI in order to determine the neuroanatomical abnormalities associated with ID. The study found subtle brain abnormalities of the cerebral cortex or ventricles, midline structures (corpus callosum and septum pellucidum) and the posterior fossa (cerebellar hemisphere or vermis) in the brains of participants. However, more research is required to understand the origins and implications of these brain abnormalities and their relationship to behavioural phenotypes in children with ID of unknown etiology.

Although we agree with the difference theorists that ID of unknown etiology involves brain impairments that, like other forms of ID, result in deviant development of cognitive ability, we do not agree with them in using CA as a means of matching ID and TD children in research studies. We hold the position that MA is a more meaningful method of matching children with an ID and TD, as it allows us to explore the developmental profile of different groups of ID in comparison to one another and to a TD group without introducing additional variance between groups such as learning opportunity and life experience, that would occur with CA matching.

**Educational Implications: how do we teach Children with Intellectual Disability?**

The evidence in the literature suggests that there is no single profile of ID. Different groups of ID show different brain impairments that vary due to the severity of ID and etiology. However, when educating children with ID of varying etiologies, it is important to note that even though their performance on certain tasks may be comparable, problem solving strategies used to achieve that performance may not be. This is presumably due to differences in brain structure and function in different groups of ID. The type of problem solving strategies used by children with ID, whether it be visual, auditory or audiovisual in nature needs to be further investigated. Educational tasks and curricula need to be designed so that they engage visual, auditory and motor as well as audiovisual abilities of children with ID. Educational approaches should be
selected based on what a child with ID finds motivating and engaging. Thus, strategies that engage and try to maintain a child’s attention are likely to provide the best opportunity for learning, and, as few would dispute, a child cannot begin to learn or solve a problem unless their attention and working memory are activated. The next step is to discover through research, how the child is engaging with this information so that we can then understand how to facilitate this engagement and begin to increase educational outcomes for children with ID.
CHAPTER TWO: Literature Review – Part 2

Does Disregard of Transient Changes in the Environment Differentiate Behaviour of Children with Autism from Typically Developing Children and those with Down Syndrome and Idiopathic Intellectual Disability?

In the research literature, Intellectual Disability (ID) is conceptualised as a set of unique cognitive deficits associated with particular genetic causes rather than simply low IQ. We add to this literature by exploring social/communication features that differentiate ID of three different etiologies: Autism, Down Syndrome (DS) and Idiopathic ID. A body of research suggests that slow shifting and/or disengaging visual attention in children with Autism is likely to be a major contributing factor to the impaired social and cognitive development characterizing this condition. We propose that slow visual orienting ability in Autism is due to impairment in magnocellular processing of the visual system, as evidenced by the apparent disregard for rapid transient stimuli in the environment. By comparison, individuals with DS and Idiopathic ID show the opposite pattern, in that they appear to be unable to maintain attention to a task, being easily distracted by transient moving stimuli in their environment. The implications of this visual orienting deficit are discussed in terms of conceptualisation of Autism, visual orienting research in Autism and evidence based educational practice for children with Autism, DS and Idiopathic ID.
Introduction

Intellectual Disability (ID) is defined as an IQ score below 70 on the Wechsler Intelligence Scale for Children- Fourth Edition (Wechsler, 2003a) and an inability to adapt to the local environment during the developmental period (Katz & Lazcano-Ponce, 2008; Luckasson et al., 1992; World Health Organization, 1993). Currently in the research literature, cognitive impairments among individuals with ID of different etiologies, such as Autism and Down Syndrome (DS) have often been attributed to brain abnormalities characteristic of the particular etiology rather than ID per se (Vicari, 2004). This approach has supported the theoretical position that ID is not equivalent to low intelligence (Goharpey et al., under review), but a set of cognitive profiles associated with distinct brain pathology. Greater understanding of the cognitive profiles of different groups of ID may reveal common cognitive and neurological impairments in all individuals with ID regardless of genetic cause.

Autism is one of a number of neurodevelopmental disorders on the Autism Spectrum, characterised by abnormal social and communication development and the presence of repetitive behaviour (American Psychiatric Association, 2000), and is diagnosed four times more in males than females (Christian et al., 2008). According to prevalence studies in the past 20 years, there has been a rise in cases of Autism (Barbaresi, Katusic, & Voigt, 2006). According to Crewther et al. (2003), an estimated 27 in every 10,000 children in Victoria, Australia are diagnosed with severe Autism. Fifty to 70% of all children with Autism Spectrum Disorder also have an ID (Matson & Shoemaker, 2009) and it has been suggested that etiology of Autism may vary with IQ (Szatmari & Jones, 1991). Despite this, the cognitive profile of Low Functioning (LF) children with Autism is rarely investigated.

In this chapter, we will investigate how individuals with LF Autism and High Functioning (HF) Autism (i.e. who do not qualify as ID) compare to individuals with DS and Idiopathic ID in terms of one important aspect of the attentional system: ability to shift and/or disengage visual attention from stimuli in the environment. We will argue that shifting and/or disengaging visual attention is delayed in individuals with Autism in comparison to DS, Idiopathic ID and Typically Developing (TD) individuals matched for mental age (MA) and/or chronological age (CA). We will report research that suggests that this deficit in ability to rapidly shift visual attention could contribute to the impaired social development in Autism. We propose that this visual orienting deficit in Autism may be due to impaired processing and activation of attention by the
magnocellular pathway of the visual system. The magnocellular system dominates the
dorsal visual pathway, and is reported to contribute to attentional processing (Laycock
et al., 2007; Pammer, Hansen, Holliday, & Cornelissen, 2006; Vidyasagar, 1999). Thus,
individuals with Autism could be delayed in shifting and/or disengaging visual attention
because they fail to activate to transient stimuli in their environment and therefore are
unlikely to shift their visual attention to new stimuli, especially socially relevant activity
such as changes in facial expression, like TD individuals of the same MA. We explore
this theory in greater detail and briefly explain the theoretical and practical implication
of this theory in our understanding of ID and its implication for the methods by which
children with Autism, DS and Idiopathic ID are educated.

Impaired Shifting and/or Disengaging of Attention in High Functioning Autism

What essentially characterises and differentiates Autism from Idiopathic ID and
DS as well as TD individuals is a marked deficit in social development. Interestingly, it
has been suggested in the literature that this might be due to a delay in rapidly shifting
visual attention (orienting attention to a different location in space) and/or disengaging
attention (termination of the visual information processing at a certain location in space)
as this hinders an infant’s ability to engage in joint attention early in life and as a result,
leads to impaired social understanding, communication, imitation, turn-taking, symbolic
play and the ability to exchange experiences and emotions with others (Courchesne et
al., 1994; Landry & Bryson, 2004; Tronick, 1982). Tronick (1982) suggested that a slow
orienting of visual attention to stimuli in the environment may derail the infant with
Autism from the typical developmental trajectory and presumably lead to social and
cognitive developmental abnormalities. Thus, an infant with Autism who is unable to
rapidly shift his/her visual attention from one stimulus to another, is unlikely to be able
to keep up with the rapidly changing social responses in the environment and, as a result,
the social world of that child may only be made up of fragments of information that lack
context and temporal continuity (Courchesne et al., 1994).

Research shows that voluntary (endogenous) shifts of visual attention are
influenced by cognitive factors (e.g. one’s current goals, knowledge and expectations)
and involuntary (exogenous) shifts of visual attention are influenced by sensory
properties of stimuli in the environment (Corbetta & Shulman, 2002). It is the
interaction of these cognitive and sensory factors at any one time that is central to
determining how, where and to what object in the environment visual attention is
oriented. Neurophysiological studies indicate that exogenous and endogenous visual
attention is controlled by two partially segregated neuronal pathways. Corbetta and Shulman (2002) have argued that endogenous or top-down attentional modulation is controlled by a dorsal frontoparietal network (not to be confused with the dorsal visual stream), a system that appears to be bilateral. This system interacts with a more ventral frontoparietal network which is reported to be largely lateralized to the right hemisphere and is exogenously driven by externally relevant stimuli. In particular this ventro-frontoparietal network may be recruited to redirect visual attention to unexpected or salient visual events.

Endogenous and exogenous orienting in Autism have been widely studied using Posner’s visual orienting task (Burack, 1994; Casey, Gordon, Mannheim, & Rumsey, 1993; Courchesne et al., 1994; Posner, Walker, Friedrich, & Rafal, 1987; Posner, Walker, Friedrich, & Rafal, 1984; Townsend, Harris, & Courchesne, 1996; Wainwright-Sharp & Bryson, 1993), which is usually presented as a series of three boxes located in the centre, right and left side of a computer screen. A visual cue is presented in one of the boxes, followed by a visual target that is presented either at the same location or at a different location as the cue. Cues that validly direct attention to the target location are used as a measure of ability to engage attention on the target location, whereas cues that invalidly direct attention serve as a measure of ability to disengage attention from the cued location, then shift attention from the cued location to the target location and engage attention at the target location (Posner, 1988; Posner & Dehaene, 1994). Reaction times to targets vary depending on the nature of the cues. Cues that provide information regarding a target’s location (e.g. an arrow) elicit endogenous shifts of attention which result in faster reaction times at valid cued locations, rather than invalid cued locations. Cues which are characterised by a sudden change in luminance or movement in the periphery elicit exogenous shifts of attention that result in faster reaction times to targets within 150 ms following a valid cue rather than an invalid cue. Reaction times are slower to targets presented 300 ms after a valid cue, rather than after an invalid cue (Rosen et al., 1999).

It has been widely reported in the literature that children and adults with HF Autism are slower to disengage and/or shift exogenous and endogenous visual attention, compared to TD individuals matched for CA and/or MA (Casey et al., 1993; Courchesne, Akshoomoff, & Townsend, 1990; Courchesne et al., 1994; Landry & Bryson, 2004; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001; Townsend, Courchesne, & Egaas, 1996; Townsend, Harris, et al., 1996; Wainwright-Sharp &
Bryson, 1993; Wainwright & Bryson, 1996). Similar findings have also been shown for individuals with Asperger’s disorder, which diagnostically shares similarities with HF Autism except that Asperger’s disorder is characterized by typical development of expressive language rather than a delay before 36 mths of age, which is characteristic of HF Autism (Howlin, 2003; Lotspeich et al., 2004). For example, a study by Wainwright-Sharp and Bryson (1993) found that adults with HF Autism or Asperger’s disorder were delayed in shifting and/or disengaging attention to the target location on a visual orientation task, compared to TD individuals of the same CA and handedness. TD adults were faster to detect the target at valid endogenously cued locations, rather than invalid endogenously cued locations regardless of the cue to target delay. However, adults with HF Autism or Asperger’s disorder showed no cue effect for 100 ms cue to target delay, but a faster reaction time to targets at 800 ms cue delay to valid cues rather than invalid cues.

The findings are consistent with past research which suggests that individuals with HF Autism are delayed in shifting and/or disengaging their visual attention compared to TD individuals of the same MA and/or CA (Casey et al., 1993; Courchesne et al., 1994; Landry & Bryson, 2004; Rinehart et al., 2001; Townsend, Courchesne, et al., 1996; Townsend, Harris, et al., 1996; Wainwright-Sharp & Bryson, 1993; Wainwright & Bryson, 1996). Wainwright-Sharp and Bryson (1993) suggested that the HF Autism and Asperger’s disorder group may not have shown the reaction time advantage to valid cues in the 100ms cue to target delay because they did not have sufficient time to process the centrally (arrow) presented cue, which indicated the targets’ location symbolically. However, a study by Townsend, Courchesne and Egaas (1996) employed a visual orientation task in which the exogenous cue (brightening of one of the boxes) was presented for 50 ms and then covered by a visual mask, before the target appeared in either the central or peripheral locations. They found that adults with HF Autism were still less accurate and slower to detect targets at the 100 ms cue to target delay, than the 800 ms cue to target delay, compared to CA matched TD adults, whose performance did not differ between the two conditions. In this study, the authors concluded that individuals with HF Autism failed to orient to 100 ms cue to target delay because they were slow to orient to new stimuli and not because they did not process the cue. All the participants with HF Autism in their study previously had Magnetic Resonance Imaging (MRI) which confirmed the presence of bilateral cerebellar abnormalities. Thus, the authors attributed slow visual orienting deficit in the HF
Autism group to cerebellar abnormality. The cerebellum is the most consistently reported neurological abnormality in Autism and this is consistent with evidence suggesting that the cerebellum is involved in the modulation of attention (Courchesne et al., 1994; Townsend, Harris, et al., 1996).

A study by Courchesne and colleagues (1994), found that like patients with acquired cerebellar damage, individuals with HF Autism were impaired in their ability to rapidly shift attention (within 2.5 seconds or less) between visual and auditory stimulus modalities. However, when the time between stimuli presentation was increased, HF Autistic and cerebellar patients were comparable to TD individuals in their speed and accuracy of target detection. Therefore, Courchesne et al. suggested that the cerebellum may act to optimize the neural signal-to-noise conditions in the systems involved in processing up-coming stimuli. Thus, acquired damage to the cerebellum may not inhibit shifts of attention entirely but merely make attentional shifts slow and inaccurate. In addition to cerebellar abnormalities, parietal lobe abnormalities have also been implicated in visual orienting deficits in individuals with HF Autism. One study (Bryson, Wainwright-Sharp, & Smith, 1990) found that individuals with HF Autism showed difficulty disengaging and shifting visual attention from the right to the left side of space, a pattern that is also seen in patients with hemi-spatial neglect, which is typically associated with damage to the right parietal cortex. Using MRI, Townsend, Courchesne and Egaas (1996) noted that cerebellar abnormalities alone were associated with deficits in shifting attention, whereas cerebellar plus parietal abnormalities were associated with deficits in both shifting and disengaging visual attention in HF Autism.

Furthermore, many studies have combined individuals with HF Autism with those with Asperger’s disorder in the same clinical group, and concluded that they are comparable in their deficit in shifting and/or disengaging attention without any direct comparison between groups in performance. For example, Wainwright and Bryson (1996) compared exogenously driven visual orienting performance of 4 individuals with HF Autism and 7 individuals with Asperger’s disorder, matched to one sample of TD individuals on CA (M= 20:6) and to another sample of TD individuals on handedness and receptive language ability, as measured by the Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981). In the study, participants were required to press the space bar whenever they detected a target that appeared either centrally (at the location of the fixation cross) or on the left or right side of the fixation cross. Results showed that adults with HF Autism or Asperger’s disorder responded faster to centrally located
targets than lateralised targets, compared to TD individuals matched either on CA or receptive language ability and handedness. Despite their small sample size, Wainwright and Bryson concluded based on observation of the data, that adults with HF Autism and those with Asperger’s disorder both show a deficit in shifting and/or disengaging attention. However, findings in a more recent study (Rinehart et al., 2001) found that children with HF Autism were delayed in their ability to shift attention compared to TD children matched on sex, CA and MA, whereas a group of children with Asperger’s disorder who were matched to another TD control group on sex, CA and MA did not show this same visual orienting deficit. The authors of this study suggested that individuals with HF Autism but not Asperger’s disorder exhibit a delay in shifting attention. Regardless of the inconsistent findings, research overall suggests that impaired shifting and/or disengaging visual attention may be related to the Autism diagnosis.

**Impaired Shifting/ and or Disengaging of Visual Attention Could Differentiate Low Functioning Autism from Down Syndrome, Idiopathic Intellectual Disability and Typical Development**

Difficulties shifting and/or disengaging visual attention in Autism are consistent with claims that attention in these individuals is overly focused on local rather than global scenarios (Lovaas, Schreibman, Koegel, & Rehm, 1971; Rincover & Ducharme, 1987; Wainwright-Sharp & Bryson, 1993). Individuals with Autism typically focus on one aspect of their environment and are not easily distracted. Interestingly, Landry and Bryson (2004) found the opposite pattern in children with DS. Very little research on visual orientation has been conducted on children with LF Autism. However, in this one study (Landry & Bryson, 2004) visual orienting was compared in 15 children with LF Autism or pervasive developmental disorder (PDD), 13 with DS and 13 with TD matched on non-verbal and verbal MA, as measured by the Leiter International Performance Scale (Leiter, 1948) and the Test of Auditory Comprehension of Language- Revised (Carrow-Woolfolk, 1985). Two conditions on the task provided independent measures of disengaging and shifting visual attention exogenously. All groups were faster to shift than disengage attention, except for the DS group who showed no reaction time difference between these two conditions. The LF Autism group displayed a subtle impairment in executing rapid shifts of attention and was slower to disengage their visual attention compared to the other groups. The DS group however, was faster to disengage their visual attention than the other groups. The findings
indicated that visual attention is more randomly distributed in space in children with DS and overly focused in space in children with LF Autism. Therefore, children with LF Autism and DS are both presenting with impairments in visual orientation but at opposite poles from one another. It is also important to note that the ability to disengage attention was not related to verbal or non-verbal intelligence, which has been consistently shown in previous studies (Landry & Bryson; Rinehart et al., 2001; Wainwright & Bryson, 1996).

Individuals with Idiopathic ID show a similar pattern of visual orientation to those with DS. Previous studies have shown that individuals with Idiopathic ID have difficulty focusing on relevant information and their learning and memory formation are disrupted more by irrelevant information compared to TD individuals (Hagen & Huntsman, 1971). Merrill and O’Dekirk (1994) tested 16 individuals with ID (8 with DS and 8 with Idiopathic ID) and 16 TD individuals on a target detection task, where targets were flanked by one distracter either from the same category or a different category as the target. The spatial degree of separation between targets and distracters was also varied. Results showed that both individuals with DS and Idiopathic ID experienced a larger degree of interference for lower target-distracter separation than TD individuals, and unlike the TD group, those with DS did not show more interference for same-category distracters than different-category distracters. These findings suggest that both individuals with DS and those with Idiopathic ID are more distractible than the TD group. This suggests that DS and Idiopathic ID may be impaired in their ability to sustain attention. Despite these findings, other studies have found that sustained attention in individuals with Idiopathic ID may be delayed in childhood (Kirby, Nettelbeck, & Thomas, 1979; Semmel, 1965) but then become comparable to TD individuals in adolescence and adulthood (Kirby et al., 1979; Ware, Baker, & Sipowicz, 1962; Warm & Berch, 1985).

Tomporowski and Allison (1988) suggested that comparable findings between TD individuals and those with Idiopathic ID, on sustained attention in the literature, may have been due to ceiling effects because the tasks were not sufficiently demanding on participants’ attention and/or cognition. Therefore, in their study (Tomporowski, Hayden, & Applegate, 1990) they increased the working memory load on a sustained attention task and found that individuals with Idiopathic ID performed worse than TD individuals. Their impaired performance was attributed to impaired working memory and not necessarily an impaired ability to sustain attention. However, many
neuroscientists researching memory consider that the laying down of memory traces is not possible without learning and that learning first requires attention to the task information (Bear, Connors, & Paradiso, 2006). Thus, this study further supports the findings that individuals with Idiopathic ID and DS have difficulty sustaining visual attention, compared to TD individuals. This finding further suggests that individuals with Autism may be differentiated from Idiopathic ID and those with DS by an over-focused sustained attention, which has been associated with delayed shifting and/or disengaging attention in the literature (Lovas et al., 1971; Rincover & Ducharme, 1987; Wainwright-Sharp & Bryson, 1993).

New Biological Explanations for Impaired Shifting and/or Disengaging Attention in Autism

Psychophysiological studies have demonstrated repeatedly that children and adults with Autism show a deficit in shifting and/or disengaging visual attention, which is thought to behaviourally manifest as an over-focused and narrow “spotlight” of attention (Lovas et al., 1971; Rincover & Ducharme, 1987; Wainwright-Sharp & Bryson, 1993). Studies have also shown that this is the opposite for children with Idiopathic ID and DS who are very easily distracted and do not sustain attention readily (Hagen & Huntsman, 1971; Landry & Bryson, 2004; Merrill & O'Dekirk, 1994; Tomporowski & Allison, 1988). It has consistently been shown that this pattern of findings is not related to MA (Landry & Bryson, 2004) and therefore may distinguish Autism from Idiopathic ID and DS. We suggest a new biological explanation for this pattern of findings. As the magnocellular stream of the visual cortex is associated with activation of visual perception to transient stimuli, we suggest that activation of this magnocellular pathway may be impaired in individuals with Autism, thus leading to impaired shifting and/or disengaging of visual attention. Thus, we suggest that individuals with Autism have difficulty shifting attention because they apparently show a disregard for transient visual stimuli in the environment. Thus, individuals with Autism are unlikely to shift their attention to transient stimuli as readily as TD individuals, making it difficult to distract them from the current focus of their attention. We suggest that the opposite is true for individuals with Idiopathic ID and DS, who respond very readily to transient stimuli in their environment, and cannot sufficiently sustain their attention in comparison to individuals with TD and individuals with Autism. Thus, individual with Idiopathic ID or DS are very easily distractible.
What is The Magnocellular Advantage?

The Magnocellular and Parvocellular streams are the two major subcortical visual projections that convey information from the retina to the primary visual cortex (V1). Magnocellular neurons have been shown to be sensitive to motion and luminance contrast at higher temporal and lower spatial frequencies, together with the provision of rapid signal transmission. In comparison, parvocellular neurons code for colour and have greater spatial sensitivity at lower temporal frequencies and do not saturate with higher contrast (Callaway, 2005; Kaplan & Shapley, 1982; Merigan, Byrne, & Maunsell, 1991; Merigan & Maunsell, 1993; Schiller & Logothetis, 1990). The magnocellular pathway provides the major visual input to the dorsal cortical stream through to primate parietal cortex (Maunsell, Nealey, & DePriest, 1990; Merigan et al., 1991). Magnocellular processing has consistently been associated with visual search and particularly transient attentional processing (Li, Sampson, & Vidyasagar, 2007; Steinman, Steinman, & Lehmkuhle, 1997; Wijers, Lange, Mulder, & Mulder, 1997). In addition, the dorsal cortical stream leading to the parietal cortex is also responsible for visuo-motor control, while perception and object recognition is contingent on the ventral stream (Goodale & Milner, 1992). Both magnocellular and parvocellular signals contribute to the ventral stream projecting through to the inferotemporal cortex (Merigan & Maunsell, 1993). Essentially, the inferotemporal cortex, and in particular regions within the lateral occipital complex in the extrastriate cortex, provides a neural centre of object representation (Malach et al., 1995), whereas the parietal cortex and its dorsal cortical projections are more commonly associated with the spatial representation of objects (Livingstone & Hubel, 1987) or with visuo-motor action (Goodale, 2008).

Traditional feed-forward neurobiological models of the visual system describe the hierarchical passage of visual information from lower to higher visual areas via two visual streams: the dorsal and ventral visual streams. Specifically, signals travel from the retina to the lateral geniculate nucleus (LGN) and then pass on to areas V1/V2. From there processing proceeds dorsally through regions including V3, the middle temporal area (MT), V6 and through to parietal cortical regions before continuing on to frontal regions such as the Frontal Eye Fields and dorsolateral prefrontal cortex (DLPFC). On the other hand a ventral stream signal proceeds from primary visual cortical areas to V4, lateral occipital cortex (LOC) and through to inferotemporal cortex and onto the ventrolateral prefrontal cortex (VLPFC).

However, it is now more commonly understood that many feedforward
connections are reciprocated by feedback connections from higher to lower order areas. According to Bullier’s (2001) visual processing model, visual information is rapidly transmitted by feed-forward and feed-back cortical projections of the magnocellular dominated dorsal pathway to V1 to provide for global processing and figure-ground segregation which could not otherwise be handled by horizontal connections within V1/V2. The feedforward-feedback loop is completed prior to parvocellular inputs to V1 which is used as an active ‘blackboard’ to continue more fine-tuned detailed processing. This type of model has been elaborated more recently (Laycock et al., 2008; Laycock et al., 2007), such that magnocellular inputs arrive in V1 up to 20 milliseconds prior to the parvocellular signals. This timing advantage of the magnocellular system allows rapid activation of exogenously driven attention mechanisms in parietal cortex to influence detailed processing in V1 and object recognition through the ventral stream. In this way, even processing normally associated with the ventral stream is assisted by a rapid activation of exogenously driven attention through the dorsal stream. Impairment in the subcortical magnocellular system or in the cortical dorsal stream feedforward/feedback loop (though not synonymous with the magnocellular pathway, which is largely driven by such inputs) could thus affect one’s ability to engage and disengage visual attention to new salient events.

Implications for Understanding Visual Orienting in Autism, Down Syndrome and Idiopathic Intellectual Disability

Inhibition of Return Research in Autism

Posner and Cohen (1984) first noticed that visually presented targets that appeared 150 ms before the cue were detected faster at cued than un-cued locations (facilitation of return). However, targets that appeared 200 ms or more after the cue were detected faster at invalid than valid cued locations. They termed this detection pattern Inhibition of Return (IOR) and suggested that it reflects an attentional orienting mechanism that facilitates search behaviour by inhibiting attention from returning to previously inspected locations (Klein, 2000). However, according to the perceptual theory of IOR, search is facilitated because attention is drawn to processing novel stimuli, rather than being inhibited from returning to previously inspected locations and objects (Lupiáñez et al., 2004). Lupiáñez et al. (2004) suggested that when a target is presented shortly after a cue, these two events may be encoded as the same perceptual event, which explains facilitation of return effect. However, when the target is presented following a long delay (i.e. 200 ms +) after the cue, it is perceived as a new and separate
event from the cue. Assuming novelty biases attention; attention is then drawn faster to the target at the un-cued location than at the cued location, because it is “novel”. This explains the IOR effect, whilst making the distinction from the attentional hypothesis, that IOR does not occur from an inhibition at the cued location. This is supported by Lupiáñez and colleagues who examined the pattern of reaction times for targets that proceeded non-informative cued locations (50% of trials were valid cued locations) compared to reaction times for targets that appeared in informative cue trials (80% of trials were valid cued locations). The authors found that for TD individuals, the IOR effect occurred for both non-informative and informative cue trials, where targets were expected to appear in cued locations most of the time and hence attention was not usually orientated away from the cued location. This finding suggests that IOR can occur even when attention is not removed from the cued location.

It has been widely reported in the literature that children and adults with HF Autism show superior visual search ability as evidenced by faster target detection rates on feature and conjunctive visual search tasks, compared to TD individuals of comparable MA and/or CA (Brenner, Turner, & Müller, 2007; M O’Riordan, 2000, 2004; M O’Riordan & Plaisted, 2001; M O’Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O’Riordan, & Baron-Cohen, 1998a). In feature visual search tasks the target differs on all properties from the surrounding distracters (e.g. a red R target among yellow T distracters), whereas it shares at least one property from each distracter in a conjunctive search task (e.g. a red R target among yellow R and red T distracters). Therefore, the target is thought to “pop out” in feature search tasks, whereas each distracter must be serially attended to in conjunctive search tasks until the target is located (M O’Riordan & Plaisted, 2001). Individuals with HF Autism have also shown a faster target detection rate in the embedded figures task (Jarrold, Gilchrist, & Bender, 2005; Jolliffe & Baron-Cohen, 1997; Keehn et al., 2009; Shah & Frith, 1993), which requires the participants to search and find a hidden figure that is embedded in a larger figure, as well as faster performance on the block design task of the Wechsler scales (Shah & Frith; Tymchuk, Simmons, & Neafsey, 1977).

It has been suggested in the literature that if the role of IOR is to facilitate search, superior visual search in HF Autism may be due to a larger IOR effect (Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2008). However, neurological investigations of IOR have implicated the superior colliculus as a neural structure that is especially important in IOR effect (Posner, Rafal, Choate, & Vaughan, 1985; Rafal, Posner,
The superior colliculus has projections to the Left Frontal Eye Fields and V5 within the dorsal visual stream. Thus, we suggest that if visual orienting is delayed in Autism due to a deficit in the magnocellular projections’ ability to activate attention mechanisms, then we would expect a delayed onset of IOR in Autism compared to TD individuals of the same MA.

Surprisingly, very little research has been conducted on IOR in individuals with Autism and thus far the findings have been mixed. A study by McConnell (2004) found excessive facilitation of return and delayed IOR in adolescents and adults with HF Autism compared to TD individuals matched on CA. However, a study by Brian (2001) found excessive IOR in a mixed sample of adults with HF Autism and Asperger’s disorder in comparison to CA matched TD individuals, which supported the predication that the IOR mechanism may account for superior visual search in Autism. These findings were only partially supported in a more recent study by Rinehart and colleagues (2008) who found a borderline significant trend towards a greater IOR effect in a group of children with Asperger’s disorder, than a group of children with HF Autism or TD, matched on sex, CA and full-scale IQ. However, the group of children with Asperger’s disorder did have a borderline significant trend towards showing greater IOR effect than the HF Autism group and TD participants. It is difficult to compare findings across studies, due to methodological differences, such as differences in tasks used, as well as the diagnoses and MA of participants. Thus, in order to test the magnocellular impairment hypothesis in Autism and its effect on IOR, future research will need to compare IOR as well as visual search performance in individuals with HF and LF Autism.

**Theoretical and Educational Implications**

If a deficient magnocellular advantage was the biological mechanism behind impaired shifting and/or disengaging visual attention in Autism, it would have serious implications for the way we conceptualise ID, as well as the way we educate children with Autism, DS and Idiopathic ID. Learning cannot occur without attention, therefore from a practical perspective, educational material will need to be presented differently to children with Autism compared to children with DS and Idiopathic ID. Given that children with Autism are slow to orient their attention and are not easily distracted, we suggest the use of therapies which follow the child’s line of attention rather than attempting to constantly shift the child’s attention onto a pre-selected stimulus. If begun
very early, infants with Autism may come back onto the typical social developmental trajectory and prevent the social and cognitive developmental deficits occurring later on. On the other hand, given that children with DS and Idiopathic ID have difficulty sustaining attention and are easily distracted, we suggest the need to minimize distractions (particularly of a transient nature) in the teaching environment. In addition, teaching should occur over short periods of time and with the use of new and variable objects in an attempt to sustain the attention and motivation of such children. Furthermore, as already described, a major implication of a deficient magnocellular system is a delayed IOR effect, which is likely to disrupt the normal pattern of eye movements needed for reading (Spalek & Hammad, 2005). Indeed, a delayed IOR may contribute to some of the reading deficits reported by individuals with Autism. Future research is needed to investigate this possibility.

On a theoretical level, impairments in magnocellular driven attention in all individuals with ID whether it be slow shifting of attention in individuals with Autism and over activated shifting of attention in those with Idiopathic ID and DS would contribute to their respective deficiencies in sustained attention, and is essentially closely associated with the etiology of their ID. More specifically, it suggests that sustained attention may be a common impairment in ID regardless of genetic etiology, as either way, the necessity of sustained attention for learning is going to be impaired. This collection of research adds to the differentiation of the cognitive profile of Autism compared to DS and Idiopathic ID. This further contributes to the growing conceptualisation of ID as having different sets of problem solving strategies and information processing abilities associated with different brain pathologies rather than simply low IQ. The finding of visual orienting differences between Autism compared to DS and Idiopathic ID, brings us a step closer to understanding which features are different and which features are common in these three forms of ID.
CHAPTER THREE: STUDY 1 - The effect of visuo-motor response to problem solving ability in children with Intellectual Disability compared to Typically Developing children of similar non-verbal mental age

Incomplete task completion in children with Intellectual Disability (ID) in comparison to typically developing (TD) children is one variable that may contribute to the measured impairment in problem solving ability. Indeed, the research literature shows that task incompletion in children with ID is often attributed to a lack of motivation and ability to sustain attention on the task. An incomplete IQ test can significantly underestimate a child’s cognitive ability, which has implications for matching of ID and TD groups in research studies and the education of children with ID.

In order to begin to understand problem solving differences in children with ID, task completion needs to be encouraged. Therefore, in the first study of this thesis, we trialed a visuo-motor version of the Raven’s Coloured Progressive Matrices test (RCPM), which we devised ourselves, with the aim of sustaining attention on the task and reducing the probability of distractions in children with ID, in order to increase the validity and accuracy of their performance on the RCPM. This study investigated the validity of what we named the puzzle version of the RCPM in a group of TD children. We also investigated whether more children with ID of different etiologies (i.e. lower functioning Autism, Idiopathic ID and Down Syndrome) completed the RCPM puzzle form compared to the RCPM standard book form.
Introduction

Intellectual Disability (ID) affects 1.25% of the Australian population (White, Chant, Edwards, Townsend, & Wagborn, 2005) and is defined according to the ICD-10 criteria as ongoing difficulties in age appropriate functioning and below age average cognitive performance, as demonstrated by a score of two standard deviations below the mean on standardized intelligence tests. However, standardized intelligence tests such as the Wechsler Intelligence Scale for Children- Fourth Edition (Wechsler, 2003a), is often limited in its assessment of children with ID who are often unable to stay on task for the lengthy administration of the test, or handle its heavy reliance on language skills (Borthwick-Duffy, 1994; Sattler, 2001; Walsh et al., 2007) and lack of ability to motivate (Koegel et al., 1997). Thus, to produce a valid measure of cognitive ability for children with ID, testing procedures must accommodate their profound deficits in communication, attention and social skills (Brown et al., 2003; Chapman, 1998; Rapin & Dunn, 1997; Wing, 1981; Ypsilanti & Grouios, 2008). Such procedures are necessary and important to facilitate the most appropriate educational placement, to enhance their education and learning potential.

We suggest that the Raven’s Coloured Progressive Matrices test (RCPM) (J. Raven, Raven, & Court, 1998) is a potentially more suitable alternative to tests such as the WISC-IV, as it is an untimed non-verbal measure of reasoning ability (Carpenter et al., 1990; Cotton, Kiely, et al., 2005; Sattler, 2001). This is supported by a recent study by Dawson, Soulhières, Gernsbacher and Mottron (2007), which showed that the Wechsler Intelligence Scale for Children- Third Edition (Wechsler, 1992) underestimates intelligence in high functioning children with Autism (HF Autism; those who do not qualify as ID). They found that scores of 38 children with HF Autism were on average 30 percentile points higher on the Raven’s Progressive Matrices (RPM) than their scores on the WISC-III, whereas no such difference was found for Typically Developing (TD) children.

The RCPM consists of 36 coloured multiple choice matrices (although colour is irrelevant to the completion of the task), organized in three increasingly complex sets (Raven et al., 1998; Raven et al., 1992; Wright, Taylor, & Ruggiero, 1996). It is being utilized increasingly with children with ID, including low functioning children with Autism (Clark & Rutter, 1979b; Koegel et al., 1997) in research settings to control for non-verbal mentation (Barnard et al., 1998; Cotton, Crewther, & Crewther, 2005; Crewther et al., 2007) and in educational settings to determine the level of functioning...
and treatment progress as part of a battery of tests (Anderson Jr et al., 1968; Budoff & Corman, 1976).

Despite it being a better indicator of non-verbal cognitive ability than the WISC-IV, many children with ID have still shown difficulties in completing the RCPM. Clark and Rutter (1979b) found that motivation and associated disruptive behaviours such as task avoidance, self-stimulation and escape behaviours in children with LF Autism, hindered test performance on the RCPM. Techniques adopted to maintain motivation (e.g. lowering task difficulty to increase success rate in low scoring children) led to better performance, which suggests that the task itself is not sufficiently engaging of attention for children with impaired intellectual functioning. The standard book form of the RCPM also requires the child to point to their chosen pattern, which is a problem as pointing is one of several delayed social communication skills observed in many children with ID, particularly LF Autism (Camaioni, Perucchini, Muratori, Parrini, & Cesari, 2003).

To enhance compliance in cognitively less able clinical groups, Raven produced a board form of the RCPM (J. C. Raven et al., 1992) where each item, presented on a wooden board, can be completed with the correct placement of movable pieces. Raven et al. (1992) claim that the board form is a consistent, reliable and psychologically valid estimate of reasoning ability, with a test retest reliability of approximately $r = 0.80$. However, although past studies (Carlson & Wiedl, 1976, 1978; Clark & Rutter, 1979b; Wright et al., 1996) have utilized the board form, the study details are not available and evidence of its validity is limited. Furthermore, its heavy inflexible wooden design is often unsuitable for use for children with ID. Carlson and Wiedl (1976) used a test-retest design to show that the board form produced better performance than the book form in TD children (Carlson & Wiedl, 1976) and children with ID (Carlson & Wiedl, 1978). However, because they allowed for trial and error in the completion of the board form, it is unclear whether the better performance on the board form was due to increased opportunity for self-correction or the nature of the board form itself. The board form is also limited as the moveable pieces are easily disarranged when in use and administration of 36 separate board pieces is quite time consuming (Raven et al., 1992). Such task characteristics do not encourage sustained attention and motivation in children with ID.

In line with the merits of the board form and considering its administrative inflexibility we have designed a puzzle version as an alternate form of the RCPM,
specifically designed to encourage greater sensory attention and motivation, increase task comprehension and consequently limit other disruptive behaviours, in order to obtain a more valid measure of reasoning ability in children with ID. This new form resembles a jigsaw puzzle and therefore minimizes verbal task instructions for children with ID (Quill, 1997). It is also conceptually like the board form in that participants must physically remove pieces, however, our puzzle form utilizes a cardboard and Velcro™ system to allow the children to simply grasp and easily remove their chosen piece and place it in the gap of the larger pattern. Unlike the board form, the puzzle form is presented in a folder with each item displayed individually on one page and each piece secured with Velcro to minimize weight, distractions and ease and time of administration.

Another advantage of the puzzle form is that grasping the pieces maintains attention better than the requirement of pointing, as in the book form. This is consistent with the idea that grasping requires more brain activation than visual recognition alone (Culham et al., 2003). Grasping requires processing of spatial location, in addition to form, orientation and size (Goodale, Milner, Jakobson, & Carey, 1991) and serves to draw attention to the object, which maintains attention on the task. Motor engagement with the pieces and placement in the appropriate area provides immediate feedback and requires more attentional resources. Kaplan, Clopton, Kaplan, Messbauer and McPherson (2006) showed that people with ID receiving sensory input from different pieces of equipment, showed less aggression and self-stimulatory behaviour and more task completion. This effect was also generalized to subsequent tasks, which supports the effect of tactile stimulation in increasing task engagement in people with ID. Motor engagement is particularly important in children with ID and children with LF Autism, who are less motivated by social reinforcement (Allen & Courchesne, 2001) perhaps due to their failure to orient to and engage with the affective expressions of others (H. Kaplan et al., 2006; Lee & Hobson, 1998; Wimpory, Hobson, & Nash, 2007). Doussard-Roosevelt, Joe, Bazhenova and Porges (2003) found that children with HF Autism were more engaged when their mothers physically and non-verbally demonstrated an object to them than when they verbally described the object to them.

Overall, the aims of these studies were to test the validity of performance of TD children on the puzzle form of the RCPM by comparing it to the standard book form (Experiment 1); and to examine overall performance and completion rate of the puzzle and book form in children with Idiopathic ID, Down Syndrome (DS) or LF Autism, to
establish the potential applicability of this alternative puzzle form to children with ID (Experiment 2). We hypothesized that, in Experiment 1, TD children would show comparable performance in the book and puzzle form of the RCPM, irrespective of which form was completed first on a counterbalanced cross over design over a three week period. We also hypothesized that, in Experiment 2, children with ID, whether idiopathic ID, DS or LF Autism, who completed the puzzle form, would show a higher performance rate than children who completed the book form, irrespective of clinical group.

**Method**

**Participants**

In Experiment 1, participants included seventy-six TD children attending a mainstream primary school within the Catholic education system in the north eastern suburbs of Melbourne, Australia. Participants were aged between 5 and 11 years ($M = 8.57$, $SD = 2.06$), 40 of whom were male, and 36 were female. Participants were required to speak English as a primary language and fall within the middle range for socio-economic status backgrounds. Participants had no known neurological intellectual disabilities, normal hearing and normal or corrected to normal vision. Participants were randomly assigned to a group who complete the book form first or another group who completed the puzzle form first.

In Experiment 2, participants included one hundred and eighty-nine children with LF Autism, DS or Idiopathic ID, recruited from specialist schools in metropolitan Melbourne, Australia. As a condition of entry into specialist schools, ID groups had all been previously diagnosed with a neurodevelopmental disorder according to the DSM-IV criteria (American Psychiatric Association, 2000) by a psychologist. ID was diagnosed as an Intelligence Quotient of below 70 on the Wechsler Intelligence Scale-Third Edition (Wechsler, 1992). Participants had normal hearing and normal or corrected to normal vision. Participants were randomly assigned to be administered either the book form or puzzle form.

Ethics approval for Experiments 1 and 2 was obtained from the Swinburne University of Technology Ethics Committees. Permission to conduct testing in the school was obtained from the Catholic Education Office in Victoria, and the Principal of the School. Individual parental or guardian consent for each child was required prior to testing and all children were free to withdraw from testing at any time.
Materials

The RCPM is comprised of 36 items divided into three subsets of 12 items (sets A, Ab, and B). Each item consists of a different coloured pattern with six possible pieces available to fill the “missing” location required to complete the pattern. The participant’s task was to deduce the theme of relations expressed among the designs and choose the missing figure from among the alternative set of six. The original book form displayed each item on a page in a booklet. The alternative puzzle version was the same size and colour as the book form, but differed in that each of the alternative patterns could be removed and physically attached to the missing place on the matrix through the use of a Velcro system.

Procedure

The standard administration procedure as prescribed by Raven et al. (1998), was used for the original book form, with trained clinicians administering both book and puzzle forms individually to each child (Raven et al., 1998; Raven et al., 1992), within the school setting. As suggested by Raven et al. (1998) no time limit was assigned for either task. Participants were required to select a piece from six alternatives that completed the pattern for each item by either pointing to their chosen response in the book form or by removing their chosen response and placing it in the missing section of the matrix in the puzzle form. Participants were asked to do this using the verbal instruction “find missing”. This very simple, clear and short verbal instruction was chosen to ensure that it could be successfully used with children with ID who have limited receptive language. Item one of the standard and puzzle versions served as a practice trial, where incorrect responses were corrected and no further assistance or verbal reward was given during performance and completion of the task. Performance on the RCPM was calculated according to the number of items correct, and unattempted items were classified as incorrect. Inclusion criteria required children to attempt at least one full set of 12 items. Children attempting less than this, were excluded from further analysis.

In Experiment 1, the TD children were randomly assigned to two groups, where one group attempted the book form first, whilst the other half attempted the puzzle form. The alternate form of the RCPM was again administered after three weeks. To minimize the impact of maturation in learning and memory or practice effects on performance a three-week interval between the puzzle and book form was used (Cotton, Kiely, et al., 2005; Portney & Watkins, 2000). In Experiment 2, participants were administered
either the book or puzzle form, but 25 participants were unable to complete the minimum of 12 items and were therefore excluded from further analyses.

**Data Analyses**

In Experiment 1, in order to validate the puzzle form, the performance of children who completed the standard book form first was compared to the performance of children who completed the puzzle form first using an independent samples t-test. A comparison of the two versions using a cross-over design was then used to examine the puzzle version performance over time, and to show that it matters little to overall performance of TD children, which form of the test was performed first. Previous test-retest studies using only the book form of the RCPM were conducted three weeks apart and reported correlations of Pearson’s $r = 0.80$ (Cotton, Crewther, et al., 2005; Jaworska & Szustrowa, 1993; Rao & Reddy, 1968). As an alternative measure to Pearson’s $r$, interclass correlation coefficient (ICC) (Wimpory et al., 2007) and coefficient of variation of measurement error (CVME) (Wimpory et al., 2007) were also calculated for an indication of degree of relatedness and percentage of variation respectively, between scores from the first and second test occasions.

**Results**

Data were initially screened for outliers and any violations of the assumptions of normality, homogeneity of variance, and sphericity. No outliers or violations of assumptions in the data were detected.

**Experiment 1: Comparison of the standard and puzzle forms for the validation of the puzzle form of the RCPM**

**Between-group comparison of chronological age**

In order to ensure that any difference observed in RCPM total correct score between groups was not due to differences in the groups’ chronological age, groups were matched on chronological age. Table 1 shows the chronological age and RCPM score of each group. As can be seen, the groups were closely matched and were not significantly different for age, $t(74) = 0.45$, $p > .05$. 

Table 1

Means (M) and standard deviations (SD) of chronological age (CA; years) and RCPM total correct score for typically developing children who completed the standard book form first or the puzzle form first

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>CA</th>
<th>CA SD</th>
<th>RCPM score</th>
<th>RCPM SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>76</td>
<td>8.6</td>
<td>2.1</td>
<td>25.6</td>
<td>6.1</td>
</tr>
<tr>
<td>Book form</td>
<td>38</td>
<td>8.7</td>
<td>2.1</td>
<td>25.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Puzzle form</td>
<td>38</td>
<td>8.4</td>
<td>2.1</td>
<td>25.8</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Between-group comparison of RCPM total score correct on the standard and puzzle forms

Table 1 shows the mean and standard deviation of RCPM score for the TD participants who completed the original book form and the group who completed the puzzle version. It can be observed from Table 1, that the mean score for each group was similar and an independent samples t-test showed no significant difference in RCPM score between children who completed the original book form and children who completed the novel puzzle form, $t(74) = -0.22, p > .05$.

Cross-over design

As displayed in Figure 1, the mean raw performance score on the RCPM for the first attempt was lower than for the second attempt, irrespective of which version was completed first. A repeated measures ANOVA found this to be a significant effect, $F(1, 74) = 8.62, p < .05$. No significant interaction effect $F(1, 74) = 0.14, p > .05$ was found.
Figure 1. Mean and standard error of RCPM score for typically developing participants who completed the original book form first and those who completed the puzzle version first.

As presented in Table 2, a high correlation, $r = 0.85$, $p < .01$, was found between first and second attempt regardless of the form. The correlation between the first and second attempt for participants who completed the puzzle form first was higher, $r = 0.93$, $p < .01$, than for participants who completed the standard form first, $r = 0.76$, $p < .01$. This pattern was also observed with the ICC and CVME measures in that respectively, the degree of relatedness between first and second test occasions was greater for those who completed the puzzle form first compared to those who completed the book form first; and the percentage of variation between scores from the first and second test occasions was less in those who completed the puzzle form first compared to those who completed the standard form first.

Table 2

<table>
<thead>
<tr>
<th>Number (N) of typically developing children who for children who completed the book first and children who completed the puzzle first and their correlation coefficients Pearson’s r (R), interclass correlation coefficient (ICC), and coefficient of variation of measurement error (CVME) values for RCPM score for their first and second attempt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Book first</td>
</tr>
<tr>
<td>Puzzle first</td>
</tr>
</tbody>
</table>
A large test-retest reliability score ($r = 0.85, p < .01$) was found between the standard book form and the puzzle version in TD children. This correlation is comparable to past studies solely examining the RCPM book form using a similar time frame of three weeks (Doussard-Roosevelt et al., 2003; Jaworska & Szustrowa, 1993). The findings suggest that the puzzle form is as useful as the standard book form of the RCPM in measuring non-verbal mentation in TD children.

In summary, the findings of Experiment 1 support the hypothesis that the book and the puzzle forms are measuring similar constructs in TD children. This suggests that the puzzle form can be used with children with ID and potentially enhance performance and completion rate, whilst still measuring the same constructs as the book form. Experiment 2 was conducted to examine the use of the puzzle form of the RCPM to measure non-verbal mentation in children with ID, to evaluate the hypothesis that the puzzle form maintains attention in such children.

**Experiment 2: The puzzle form of the RCPM to measure non-verbal mentation in children with Intellectual Disability**

Given that the data from this study were not normally distributed, non-parametric testing was used for all analyses.

**Between-group comparison of chronological age**

There was a significant difference in chronological age between the three clinical groups $F(2, 161) = 13.20, p < .05$ (refer to Table 3). The LF Autism group was significantly younger than the DS and Idiopathic ID groups. However, the age difference between the clinical groups administered the puzzle and book form was not significantly different (LF Autism $t (99) = -1.20, p > .05$; DS $t (18) = -0.78 , p > .05$; Idiopathic ID $t (41) = 0.44 , p > .05$). Thus, difference observed in RCPM total correct score between groups cannot be attributed to differences in the groups’ chronological age.
Table 3

Number of participants (N), means (M) and standard deviations (SD) for chronological age (CA; years) for each group of children with Autism Spectrum Disorder (ASD), Down Syndrome (DS), and Idiopathic Intellectual Disability (IID)

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>CA</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>101</td>
<td>9.7</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>DS</td>
<td>20</td>
<td>11.8</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>IID</td>
<td>43</td>
<td>10.6</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>164</td>
<td>10.7</td>
<td>3.9</td>
<td></td>
</tr>
</tbody>
</table>

Between-group comparison of RCPM total score correct on the standard and puzzle forms

The inter-group RCPM performance (and hence, non-verbal mental age) was not significantly different between-groups. Mean and standard error of RCPM score for each clinical group administered the book and puzzle forms are shown in Figure 2. A Kruskal-Wallis test showed no significant differences in RCPM score between the clinical groups, $H(2) = 2.89, p > .05$. A Mann-Whitney test showed a significant difference in RCPM score between performance on the book and puzzle form regardless of clinical group, $Z = -3.02, p < .05$. When each clinical group is examined separately, the LF Autism group participants who were administered the puzzle form, performed significantly better than those who were administered the book form ($Z = -3.99, p < .05$) and the Idiopathic ID group ($Z = -3.31, p < .05$), but not the DS group ($Z = 1.60, p < .05$).
Figure 2. Mean and standard error of RCPM score for children with low functioning Autism (LFA; n=101), Down Syndrome (DS; n=20), and Idiopathic intellectual disability (IID; n=43) who completed the standard form or the puzzle form of the RCPM.

**Between-group comparison of completion rate of RCPM standard and puzzle forms**

As displayed in Figure 3, completion rate for the puzzle form (76.2%) was greater than for the book form (40%), regardless of clinical group. A Mann-Whitney test showed a significant difference in RCPM score between children who were able to complete the RCPM test and children who attempted at least 12 items but were unable to complete the task, regardless of which form they were administered, $Z = -10.55, p < .05$. Of those children who were unable to complete the book form, 55% of children with LF Autism, 68% of children with DS, and 67% of children with Idiopathic ID were able to complete the puzzle form. The results suggest that the use of the puzzle form as compared to the book form of the RCPM has resulted in better task performance and completion rate for all clinical groups.
Figure 3. Percentage of children with low functioning Autism (LFA), Down Syndrome (DS), and Idiopathic intellectual disability (IID) who completed the standard or the puzzle form of the RCPM.

Figure 4. Mean RCPM score of children with low functioning Autism (LFA), Down Syndrome (DS), and Idiopathic intellectual disability (IID) who were able to complete the standard or the puzzle form of the RCPM.

To deal with the potential confound of completion rate, further analyses were performed only on participants who completed the puzzle or book form. A Mann-Whitney test showed that the participants who completed the puzzle form achieved significantly more correct responses than those who completed the book form, $Z = -2.89$, $p < .05$. From Figure 4, it can be seen that in each clinical group, those who completed the puzzle form achieved more correct responses than those who completed the book form.
form, but only the LF Autism group showed this difference to be statistically significant \((Z = 2.52, p < .05)\), but not the DS \((Z = -0.19, p < .05)\) and Idiopathic ID \((Z = -1.61, p < .05)\) groups.

**Discussion**

The finding from Experiment 1 of no difference between the total correct performance of TD children in the RCPM book and puzzle forms, combined with the finding of a strong correlation between first and second performance of the RCPM regardless of the order in which the forms were completed, shows that the alternative puzzle version is comparable to the book form in measuring reasoning ability. Past studies have reported that three factors delineate performance on the RCPM: continuous and discrete pattern completion, pattern completion through closure, and concrete abstract reasoning (Carlson & Jensen, 1981; Carlson & Wiedl, 1978; Cotton, Kiely, et al., 2005). The high correlation between the book and puzzle forms found in the current study suggests that these constructs are maintained in the puzzle version.

Experiment 2 demonstrated that children with ID (DS, LF Autism and Idiopathic ID) who were administered the puzzle form showed a performance advantage, as compared to those who were administered the book form. The findings suggest that the puzzle form provides a better indicator of learning potential than the book form in children with ID. We suggest that the performance advantage observed for the puzzle form is due to its unique features designed specifically to maintain attention and increase completion rate, though we have not tested this suggestion directly. This is consistent with previous studies that have shown that added motivational techniques increased total correct performance (Crewther et al., 2007; Koegel et al., 1997). However, the current study does provide evidence that attention can be engaged while maintaining the underlying constructs being measured. Thus, it is likely that the puzzle form does not demand additional cognitive processing on children with ID, but increases sustained attention on the task in comparison to the book form. If this were the case, it would suggest that the puzzle form effectively engages cognitive ability of children with ID through the integration of motor and sensory based learning, but only when the child directs their own responses. This is advantageous and potentially useful as it puts the emphasis on the test to be able to engage children with ID, rather than requiring the administrator to promote engagement in the child during the testing. For example, a study found that certain adult styles of interaction, such as following a child’s line of action instead of trying to re-direct it enhances social engagement in
children with LF Autism (Dawson et al., 2007).

Alternatively, the performance advantage of the puzzle form may be due to the greater completion rate for children who were administered the puzzle form, compared to the book form. It can be argued that the puzzle form produces a performance advantage because the physical placement of response pieces reduces the mental function of abstractly visualizing the chosen piece in the missing area (Carlson & Wiedl, 1978). Unlike the results of the study by Carlson and Wiedl (1978), a trial and error approach was not permitted and hence this cannot be the source of increased performance when using the puzzle form. In addition, the performance advantage in the puzzle form was only demonstrated by the children of the same non-verbal mental age, some with ID and some developing normally, which could suggest that the puzzle form maintained attention and motivation in those with severely limited attentional resources.

Given that more ID children were able to complete the puzzle form than the book form, it is possible that the performance advantage of the puzzle form was partially associated with an increase opportunity to select responses, as opposed to increased task engagement. As the RCPM is a multiple choice task, the more items an individual completes, even at random, the greater the possibility of obtaining a higher overall score. However, this is unlikely as additional analyses showed that the performance advantage of the puzzle form was maintained even when only those children who completed either RCPM form were included. However, this performance advantage was not observed in the DS and Idiopathic ID groups (also in the DS group when all participants were included regardless of whether they completed the RCPM or not). These non-significant findings are likely to reflect a Type II error and may be due to the small number of participants in the DS and Idiopathic ID groups. Future studies should examine more closely the effect of responses due to chance when completing the RCPM, specifically error-type analysis reflecting problem solving strategies in children with ID (Gunn & Jarrold, 2004).

Profound deficits often make the assessment of children with ID very difficult, and the characteristics of standardized intelligence tests do not take into consideration such deficits. The current study indicates that children with ID perform better on the puzzle form of the RCPM and suggests that it is a better indication or problem solving in children with ID that the book form. The puzzle form has proven to give a useful measure of RCPM in children with ID as it considers the degree of intellectual disability and severity of the language deficit, as well as engaging attention and motivation while
limiting distractions. Hence, this study supports the use of the puzzle form of the RCPM in clinical and educational research settings in place of the book form, as a better measure of reasoning ability in children with ID and in clinical settings for monitoring treatment progress, as a component of a battery of tests.
CHAPTER FOUR: STUDY 2 - Non-verbal mental age as a valid criterion for comparing children with Intellectual Disability and Typically Developing children

One of the implications of understanding the developmental trajectory of fluid intelligence in children with Intellectual Disability (ID) is that it will inform the debate on the best method to match children with ID to typically developing (TD) children for research studies. After all, determining the cognitive characteristics that are associated with ID, is dependent on how ID and TD groups are matched, to which control groups they are matched and with which matching instrument (if any) they are matched on.

Thus, the aim of this study was to determine whether the cognitive trajectory of children with intellectual disability (ID) is delayed or deviant and to assess the validity of the Raven’s Coloured Progressive Matrices test (RCPM), as a means of matching children with intellectual disability (ID) and typically developing (TD) children on non-verbal mental age (NVMA). This aim was achieved through an error type analysis and by investigating the relationships between NVMA and error type performance with chronological age, short-term/working memory (as measured by visual and auditory forward and backward digit span) and receptive language (as measured by Peabody Picture Vocabulary Test – Third Edition) in all groups. Children with ID and TD of the same NVMA (as measured by RCPM) and receptive language ability showed similar patterns of correct responses and error type distribution but differed in frequency of positional errors, suggesting that children with ID are developmentally delayed but also demonstrate deviant problem solving strategies. NVMA was positively related to receptive language ability and visual short-term memory, but not to visual working memory performance in all groups, suggesting that NVMA is a valid criterion upon with which to match TD and ID children on cognitive ability.

This is an original study. It is the first study in the research literature to investigate RCPM error type analysis in children with Autism and the first study to investigate frequency of positional errors and the relationship between working memory or receptive language and RCPM performance (overall correct and error types) in children with TD and children with ID of similar non-verbal mental age and receptive language.
Introduction

Development of a construct of intellectual disability (ID) requires identification of the characteristics unique to individuals with ID. In research studies this is usually achieved by comparing the performance of individuals with ID on a battery of cognitive tests to a control group (i.e. usually a group of typically developing, TD, individuals) (Mottron, 2004). However, the question of which matching procedure, chronological age or mental age, is the more valid means of equating for cognitive development has been the basis of considerable controversy in the literature (Jarrold & Brock, 2004; Mervis & Klein-Tasman, 2004; Weiss, Weisz, & Bromfield, 1986) and thus, this paper aims to explore the theoretical basis of matching.

Matching criteria and exactly what cognitive characteristics are important have largely been driven by the Developmental versus Difference cognition debate. Over the decades, Difference theorists have argued that all individuals with ID (regardless of etiology), are developmentally deviant due to profound cognitive deficiencies and therefore, considered to be qualitatively different to TD individuals in their cognitive abilities, even when matched on mental age on standardized IQ tests (Bennett-Gates & Zigler, 1998; Kounin, 1941a, 1941b; Lewin, 1935; Zigler & Hodapp, 1986). Thus, Difference theorists chose to match groups on chronological age. The Developmental theorists, however, accept that individuals with ID of known genetic etiology are developmentally deviant, but still can be more effectively considered as primarily developmentally delayed (Bennett-Gates & Zigler, 1998; Zigler & Hodapp, 1986), and thus, capable of reaching typical developmental milestones but over a longer time than TD individuals of the same chronological age. Therefore, when matched on mental age, children with ID of unknown (or genetically non identified) etiology and TD children would be expected to be at the same cognitive stage, with similar understanding of language (receptive language score) and similar memory characteristics (digit span forward and backward score).

Recently the major differences in the Developmental versus Difference debate have been bridged by Anderson’s theory of the Minimal Cognitive Architecture (1992, 2001), which suggests that children with ID (regardless of etiology) are all developmentally delayed, and also developmentally deviant due to relatively slow information processing speed. What remains to be determined is whether children with ID who achieve the same total correct score on a standardized test of reasoning ability
as TD children, are also qualitatively similar, i.e., in making similar patterns of correct and incorrect responses and requiring similar levels of cognitive abilities to solve items.

Thus, we set out to investigate problem solving ability in TD and ID children (of many etiologies) achieving the same score (equivalent to non-verbal mental age) on the non-verbal Raven’s Coloured Progressive Matrices (RCPM) (Cotton et al., 2005; Raven et al., 1995). We chose to use the RCPM, as most children with ID have significant verbal limitations, making the verbally based Wechsler Intelligence Scale for Children (Wechsler, 1991a) (WISC) a potentially less valid measure of mental age for children with ID. The WISC is also lengthy to administer (Whitaker, 2005, 2008; Whitaker & Wood, 2008) and more specifically, has been shown to “underestimate” the intelligence of children with Autism (Dawson et al., 2007). Indeed, better non-verbal mental age scores have been achieved on the RCPM, where reduced need for verbal comprehension and lack of time constraints have been shown to facilitate increased engagement in test performance in young children with ID (Bello et al., 2008).

The RCPM was first designed and developed by John Carlyle Raven (i.e. Raven) in 1938 (and later revised in 1947 and 1956) (Raven et al., 1995), as a measure of fluid intelligence for use with TD children between the ages of 5 and 11 years, the elderly, people with ID and/or physical disabilities, deafness, mental deterioration or those who cannot speak or understand spoken language. The Raven matrices (i.e. including the Raven’s Standard and Advanced Progressive Matrices) have all been shown to measure Spearman’s g, usually known as fluid intelligence (Carpenter et al., 1990) defined as the ability to solve novel problems without relying on previous knowledge or experience (Cattell, 1963). As a concept, g is usually defined in terms of factor/s underlying shared variance between tests of intellectual ability (Carpenter et al., 1990).

Raven initially designed the items of the RCPM into seven categories or types that would reflect the qualitative levels that are reached with increasing intellectual capacity during childhood. Item types were differentiated on the basis of strategy required for successful completion (Raven et al., 1995). In 1974 a principle component analysis by Corman and Budoff found that the performance of both ID and TD groups on the RCPM test loaded well on four factors. Corman and Budoff classified these four factors as item types of increasing difficulty, which included: Factor 1: Simple Continuous Pattern Completion (Items A1-A6); Factor 2: Discrete Pattern Completion (Items Ab1-Ab3, B1-B2); Factor 3: Continuity and Reconstruction of Simple and
Complex Structures (Items A7-A12, Ab4-Ab11, B3-B7); and Factor 4: Reasoning by
Analogy (Items Ab12, B8-B12).

In 1984 Sigmon (1984) interpreted Corman and Budoff’s four factors to be representative of Piaget’s (1976) four stages of cognitive development in TD children. Piaget’s stages of cognitive development generally represent increasing sophistication of thought and included: (1) Intuitive preoperational (4-7 years); (2) Low-concrete operations-for solutions (7-8 to 11-12 years); (3) High-concrete operations-for solutions (7-8 to 11-12 years); and (4) Formal operations-for solutions (11-12 years) (Piaget, 1976; Sigmon, 1984). However, research on the relationship between the RCPM and Piaget’s cognitive stages still remains to be verified.

In addition to the original classification of item types in terms of strategy, Raven also categorized erroneous responses for each of the RCPM items as belonging to a particular error category or type (Raven et al., 1995). The error types identified by Raven varied in sophistication, for instance the first error type is based on how many aspects of visual similarities are shared with the correct answer. Hence, each type of error can be viewed as an indication of how close the test taker’s response is to the correct answer. The four error types (from least to most sophisticated) were: 1) Difference error, when the chosen piece has either no pattern of any kind or one of direct relevance to the target pattern; 2) Figure Repetition error, when the chosen piece has either part of the pattern immediately above or beside the target gap in the pattern; 3) Inadequate Individuation error, when the chosen piece is contaminated by irrelevancies, distortions or incomplete patterns; and 4) Incomplete Correlate error, when the chosen piece correctly identifies part of the target pattern though the figure may be wrongly oriented or incomplete. In regard to deviant error responses, Raven also noticed that position 2 was chosen more often by TD children in comparison to other response positions and attributed this to position 2 being the closest to the center of the page (Raven et al., 1995). Raven attempted to control for this by evenly distributing the correct responses (in the 1938 RCPM edition) and the error types (in the 1958 RCPM edition) across the six response positions throughout the test and hence, did not nominate it as a particular type of error. Thus, it remains to be seen whether ID children utilize a positional strategy more frequently on the RCPM test than TD children of similar mental age.

Research by Gunn and Jarrold (2004) has previously compared the RCPM error type performance between TD and ID children. They found that although children with
Down Syndrome (DS) made most Figure Repetition errors (Raven’s type 2 error) when compared to TD children with similar number of items correct (i.e. similar non-verbal mental age). Children with DS also made more Difference errors (Raven’s type 1 error) and Inadequate Individuation errors (Raven’s type 3 error) than TD children or children with moderate learning disability. Chronological age was also found to be associated with a different pattern of error types for TD children, but not for children with DS. Gunn and Jarrold (2004) suggested on the basis of their findings, that the DS and TD groups use different problem solving approaches on the RCPM, that is, when considering proportion of opportunity for errors rather than the frequency of error types. Interestingly, these findings have been contradicted in more recent studies comparing children with TD and ID (of different etiologies) on item difficulty and proportion of error types made on the RCPM.

Facon and Nuchadee (2010) demonstrated using a transformed item difficulty statistical method (also known as the “delta-plots”) (Angoff, 1982) that item difficulty on the RCPM is similar for children with DS, Idiopathic ID or TD children matched on RCPM total score correct. This conclusion was also supported by the study of Van Herwegen, Farra and Annaz (2010) which showed using the same item differentiation method as Facon and Nuchadee (2010), that individual items on the RCPM are similar in difficulty for children with Williams Syndrome and TD children matched on RCPM total score correct. Furthermore, children with Williams Syndrome made the same proportion of error types as TD children. Total correct performance for both groups increased with chronological age, but the relationship was weaker for children with Williams Syndrome (chronological age accounted for 18% of total variance of RCPM score) than TD children (42% of variance of total RCPM score was accounted for by chronological age), indicating that children with Williams Syndrome are developmentally delayed (Van Herwegen et al., 2010). However, what remains to be explored in greater detail is whether similar scores for non-verbal mental age reflect not only similar levels of intellectual capacity but also similar cognitive processing, as would be expected if children with ID (regardless of etiology) are primarily developmentally delayed per se.

Raven did not attempt to identify the cognitive nor neural processes underlying each item type or error type (J. C. Raven et al., 1995), but a more recent brain imaging study using fMRI in adults performing “Figural” items from the Raven’s Standard Progressive Matrices (RSPM) test (i.e. problems that are solved mostly using
visuospatial analysis according to Carpenter, Just and Shell, 1990) has shown predominant activation of right-hemisphere areas (Prabhakaran et al., 1997) often associated with visual working memory tasks involving spatial location, object identity and mental rotation (Jonides et al., 1993; McCarthy et al., 1996; Smith, Jonides, & Koepepe, 1996). More recently, these same areas have been shown by Corbetta and colleagues (Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005; Corbetta & Shulman, 2002; Fox, Corbetta, Snyder, Vincent, & Raichle, 2006) to be representative of primate attention networks. Prabhakaran and colleagues (1997) also found that completion of more analytical Raven’s items (which require logical reasoning and cannot be solved by visuospatial analysis alone according to Carpenter et al., 1990) activated left frontal regions of the brain associated with visual working memory tasks involving verbal stimuli such as letters, digits and phonological information (Paulesu, Frith, & Frackowiak, 1993; Petrides, Alivisatos, Meyer, & Evans, 1993; Smith et al., 1996).

Interestingly, comparison of performance on the RCPM and performance on the Peabody Picture Vocabulary Test – Third Edition (PPVT-Third Edition) (Dunn & Dunn, 1997) by Kilburn, Sanderson and Melton (1966) indicated a positive correlation between successful completion of reasoning by analogy items on the RCPM and receptive language in TD individuals. The fMRI and the psychophysical findings of Prabhakaran et al. (1997) and Kilburn et al. (1966) respectively suggest that verbal reasoning may facilitate solving of the more “difficult” reasoning by analogy RCPM items.

The aim of this study was to inform the Developmental and Difference debate by analyzing the validity of the RCPM as a tool for matching ID and TD children on non-verbal mental age. In order to adequately test the Developmental versus Difference models, we included several categories of children with ID of known etiology (DS) and unknown etiology (Idiopathic ID) or genetically unidentified etiology (LF Autism). Children with DS were also selected in order to both replicate and extend the findings of Gunn and Jarrold (2004), whilst children with LF Autism were selected because this diagnosis is currently increasing in prevalence and thus a point of great research and social interest.

It was hypothesized that if the RCPM is to be a valid matching tool, then children with ID and TD children matched on similar number of items correct, will also be correct on similar item types and will make a similar quantity of Raven’s error types, as well as show a similar error type distribution across Corman and Budoff’s four
factors. It was also predicted that TD and ID groups would also make similar number of positional errors. Overall correct performance and error type sophistication was also expected to positively correlate with receptive language (as measured on the PPVT-Third Edition) and visual and auditory short-term and working memory (as measured on the forward and backward digit span) for all groups. Such similarities in performance on the RCPM would suggest that ID is predominately due to developmental delay and thus, similar non-verbal mental age is indicative of similar cognitive processing ability. We also predicted that chronological age would be a less valid rationale for cognitive matching and so expected that it would not correlate well with the RCPM performance of children with ID.

Method

Participants

One hundred and twenty three Participants who completed all the testing included thirty-eight low functioning children clinically diagnosed with Autism (LF Autism) (32 males, 6 females), 17 with Down Syndrome (DS) (8 males, 9 females) and 32 with Idiopathic intellectual disability (ID) (24 males, 8 females) from a special school in a middle class socio-economic area of Melbourne, Australia. The criteria for enrolment in a special school in Victoria is a professional diagnosis of neurodevelopmental disorder and ID according to the DSM-IV criteria (American Psychiatric Association, 2000) and an Intelligence Quotient of below 70 on the WISC-III (Wechsler, 1991a) or WISC-IV (Wechsler, 2003b) at the official age of school entry at 5.5 years and again at 10-12 years, around the time of normal entry into high school. Thus, all ID groups were diagnosed with a neurodevelopmental disorder according to the DSM-IV criteria and degree of disability was based on mild-moderate ID according to an Intelligence Quotient of below 70 and above 50 on the WISC-III (Wechsler, 1991). Thirty-six typically developing (TD) children (17 males, 19 females) attending a non-selective Catholic primary school in a similar middle class socio-economic area within north east Melbourne, Australia, without known neurodevelopmental disabilities participated in this study. All children were volunteered for the study by their parent/s or caregiver/s and were able to complete all items on the RCPM and PPVT-Third Edition test. Ten individuals from the ID groups failed to complete all 36 items of the RCPM and so were excluded from the study.

Males were more predominant in the ID sample presumably because of the 4:1 male to female ratio in Autism (Crewther et al., 2003; Lord & Schopler, 1985; Volkmar,
Szatmari, & Sparrow, 1993; Yeargin-Allsopp et al., 2003). All participants met the inclusion criteria, which included adequate levels of visual function (better than 6/9 acuity and typical colour vision), ability to understand task instructions, visually recognize and name numbers 1-9 and ability to type on a computer keyboard. Children with ID were matched to younger TD children of the same non-verbal mental age (as measured by total score correct on RCPM test) in order to ensure that any between group differences in error type performance could not be attributed to differences in overall test performance.

Ethics approval for the study was obtained from the Swinburne University of Technology Ethics Committee and La Trobe University Human Ethics Committee. Permission to conduct testing in schools was obtained from the Directorate of School Education (Victoria), the Catholic Education Office Victoria, and the Principal of each school. Individual parental/guardian consent was obtained prior to testing and all children were free to withdraw from testing at any time.

Materials

The standard RCPM (Raven et al., 1995) was employed as a measure of non-verbal mental age. The PPVT – Third Edition (Dunn & Dunn, 1997) was used to assess receptive language ability and to ensure children with ID could understand the RCPM task instructions. Auditory short-term and working memory were measured using a custom developed computerized auditory forward and backward digit span task, based on the traditional Auditory Digit Span task of WISC-III (Wechsler, 1991a). A visually presented version of the traditional Auditory Digit Span task, specially constructed for this study was used to measure visual short-term and working memory.

Procedure

Two trained clinicians administered the RCPM individually to participants in a quiet room, on school grounds, during school hours, using the standard administration procedure as prescribed by Raven (Raven et al., 1995). No time limit was assigned for the task (Raven et al., 1995). Participants were instructed to identify the best fit for the missing piece of each matrix, by pointing to or verbalizing the number of the missing piece from among the alternative set of six. The first item of the RCPM was a practice trial where the participant’s answer was either corrected or reinforced with praise. No further assistance or verbal reward was given during completion of the task. The PPVT – Third Edition was then administered by the same trained clinicians according to published instructions, which required participants to respond by pointing to or saying
the number of one of four pictures that best corresponded to the stimulus word spoken by the experimenter.

All participants initially attempted the Auditory Digit Span task; however, insufficient numbers of reliable data were obtained from the ID groups as a result of their inability and/or disinterest in completing the entire task. A visually presented version of the traditional Auditory Digit Span task was then specially constructed for this study, as it was reasoned that the visual working memory mechanisms are more likely to be associated with problem solving on the visually presented RCPM than auditory working memory mechanisms (Carpenter et al., 1990; Fry & Hale, 1996; Prabhakaran et al., 1997). The visual digit span tasks involved sequential one second presentations of single numbers (1-9) on a computer screen (with a 500 ms on/off presentation time), with increasing sequences of numbers presented throughout the task in order to increase task difficulty. For the visual forward digit span task, participants were instructed to type digit sequences that were visually displayed on the computer screen, in order of appearance, after the visual presentation ended. For the visual backward digit span task, participants were required to type the digit sequence in reverse order. Due to time constraints associated within school testing, the visual digit span tasks were only completed by 11 TD children and 16 children with ID, not including children with DS.

Results

Data Analysis

According to Raven (Raven et al., 1995), erroneous responses should be classified as primarily belonging to one of four specified error type categories. However, many individual items on the RCPM require several problem solving strategies (and thus the error responses could belong to more than one error type category). Thus, to be consistent with Raven’s recommendation as above (Raven et al., 1995), each erroneous response in this study was categorized only according to its primary error type category.

Analysis of matching variables

Children with mild-moderate ID (on the basis of a WISC-III score of below 70 but above 50) that fit the study inclusion criteria (including completing RCPM and PPVT-Third Edition test) were first tested on the RCPM and the mean total score correct was calculated to be equivalent to the non-verbal mental age expected of TD children between the ages of 5-11 years. Such TD children were then recruited and tested in order to increase the likelihood that the ID and TD groups would not be
significantly different on non-verbal mental age. The different etiology ID groups were not significantly different on RCPM total score correct, allowing us to collapse and compare the total ID group to the mean score of the TD group. Results of an ANOVA showed no significant difference between TD and ID groups on total score correct ($F(3,119) = 1.57, p > .05$).

All participants’ RCPM total scores correct were transformed into standardized measures of non-verbal mental age based on the 50th percentile (classified as “intellectually averaged”) level for TD children between 5.5-10.5 years, on the 1980 Norms for Queensland, Australia (Raven et al., 1995). Results of an ANOVA comparing TD and ID groups on non-verbal mental age ($F(3,119) = .92, p > .05$) found no significant difference between groups. It is important to note that high scoring participants with ID in the sample were adolescents. As expected groups were significantly different on chronological age, $F(3,119) = 15.19, p < .05$, with the ID groups being older than the TD group.

Furthermore, it was our intent to match TD and ID groups on receptive language score (as measured by the PPVT- Third Edition). However, this was not necessary, as an initial ANOVA showed no significant difference between the TD and ID groups on receptive language score correct, $F(3,119) = 2.32, p > .05$. Table 1 displays each group’s descriptive.
Table 1

Number (N) of participants in each group, chronological age (CA; and age range in years), RCPM score (RCPM; and range in years), RCPM non-verbal mental age (NVMA; and age range in years) and PPVT receptive language test- age equivalent (RL; and age range in years) for the low functioning Autism (LFA), Down Syndrome (DS), Idiopathic intellectual disability (IID) and typically developing (TD) groups

<table>
<thead>
<tr>
<th>Group</th>
<th>CA</th>
<th>RCPM</th>
<th>NVMA</th>
<th>RL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>LFA</td>
<td>38</td>
<td>9.5(5-17)*</td>
<td>3.3</td>
<td>20 (10-35)</td>
</tr>
<tr>
<td>DS</td>
<td>17</td>
<td>11.8(5-18)*</td>
<td>3.7</td>
<td>17 (12-20)</td>
</tr>
<tr>
<td>IID</td>
<td>32</td>
<td>10.6(5-17)*</td>
<td>3.5</td>
<td>18 (7-32)</td>
</tr>
<tr>
<td>TD</td>
<td>36</td>
<td>6.7(5-9)</td>
<td>1.3</td>
<td>20 (8-32)</td>
</tr>
</tbody>
</table>

Comparison to TD group at significance *p < .05

Analysis of Raven’s total correct performance

In order to meaningfully assess error type differences between the TD and ID groups, it was important to ensure that all groups were successfully solving similar item types. Figure 1 presents the percentage of correct responses made by all experimental groups for each of the 36 items on the RCPM. The background shading imposed on the data represents Corman and Budoff’s (1974) four factors that loaded for TD children (shading becomes darker as the factors become more difficult).
Figure 1. The percentage of correct responses made by each group (LFA- low functioning Autism; DS- Down Syndrome; IID- Idiopathic intellectual disability; TD- typically developing) on each of the 36 RCPM items (shown on the x axis) with items shaded to represent Corman and Budoff’s (1974) item Factors in order of difficulty. White denotes Factor 1 (F1; A1-A6; Simple Continuous Pattern Completion), light grey is Factor 2 (F2; Ab1-Ab3, B1-B3; Continuity and Reconstruction of Simple and Complex Structures), mid grey is Factor 3 (F3; A7-A12, Ab4-Ab11, B3-B7; Discrete Pattern Completion), and dark grey is Factor 4 (F4; Ab12, B8-B12; Reasoning by Analogy). The horizontal dashed line at approximately 16% represents the percentage correct at chance level (i.e. guessing).

A series of ANOVAs were used to compare the TD group to each ID group on total percentage of items correct for each of Corman and Budoff’s (1974) four factors, displayed in Figure 2.
Figure 2. Total percentage of correct responses made on each of Corman and Budoff’s (1974) 4 Factors, by experimental groups. Key - LFA- low functioning Autism; DS-Down Syndrome; IID- Idiopathic intellectual disability; TD- typically developing.

A clear progression of difficulty is evident between Corman and Budoff’s (1974) four factors for all groups in Figure 1 and 2. It is important to note that all groups made more errors for “more difficult” item types (i.e. Factor 3 and 4) compared to “easier” item types (i.e. Factor 1 and 2). Results of the ANOVAs comparing groups on total percentage correct for each factor showed a significant difference for Factor 3 ($F(3, 119) = 3.73, p < .05$), but not for Factor 1 ($F(3, 119) = 2.36, p > .05$), Factor 2 ($F(3, 119) = 2.23, p > .05$) or Factor 4 ($F(3, 119) = .72, p > .05$), suggesting that all groups found the same items within Factor 1 and 2 equally easy and items within Factor 4 equally difficult. Furthermore, children with DS made fewer correct responses for items in Factor 3 ($M = 18.88, SD = 12.35$), compared to the TD children ($M = 39.04, SD = 22.02$) and children with LF Autism ($M = 38.09, SD = 24.24$), due to choosing more incorrect responses.

**Analysis of Raven’s error types**

In order to explore any statistical differences between the TD and ID groups on proportion of error types that might affect matching on the RCPM, we first assessed the frequency of error types made by the TD and ID groups. We chose first to examine the frequency of errors as a potentially more meaningful clinical measure. Thus, a series of ANOVAs comparing the mean frequency of error types made by the TD and LF Autism, DS and Idiopathic ID groups was conducted and is shown in Figure 3. There were no significant differences between groups in frequency of Figure Repetition ($F(3, 119) = 1.35, p > .05$), Inadequate Individuation ($F(3, 119) = .31, p > .05$) or Incomplete
Correlate \( F(3, 119) = 1.44, p > .05 \) errors made on the RCPM. However, the LF Autism group \( (M = 2.08, SD = 2.20) \) made one less Difference error \( F(3, 119) = 4.72, p < .01 \) than the TD group \( (M = .64, SD = 1.02) \), which we do not consider to be a clinically significant difference.

\[ \text{Figure 3. Proportion of Raven’s four error types (Difference, Figure Repetition, Inadequate Individuation, and Incomplete Correlate) as defined by Gunn and Jarrold (2004), made by all experimental groups. Key - Low functioning Autism (LFA), Idiopathic intellectual disability (IID), Down Syndrome (DS) and typically developing (TD) groups.} \]

Secondly, to allow direct consideration of our results to those of Gunn and Jarrold (2004), we compared the proportion of errors made (i.e. of number of times an error type was made, divided by number of opportunities to make that error) between the TD and ID groups. This also allowed us to investigate whether Gunn and Jarrold’s observation of different error type patterns made by DS children compared to TD children of similar non-verbal mental age, was unique to DS diagnosis or indicative of the ID diagnosis. Thus a series of ANOVAs were used to compare the proportion of each error type ratio made across RCPM by the TD group and each of the LF Autism, Idiopathic ID and DS groups (see Figure 4).
Figure 4. Frequency of Raven’s four error types (Difference, Figure Repetition, Inadequate Individuation, and Incomplete Correlate) made by all experimental groups. Key - Low functioning children with Autism (LFA), Down Syndrome (DS), Idiopathic intellectual disability (IID), and typically developing (TD) groups.

Results of the ANOVAs showed significant group differences for proportion of each error type (Difference error $F(3, 119) = 6.14, p < .05$; Figure Repetition error $F(3, 119) = 6.29, p < .05$; Inadequate Individuation error $F(3, 119) = 2.79, p < .05$; Incomplete Correlate error $F(3, 119) = 4.82, p < .05$). In all groups, the error type made most often was Figure Repetition error ($M = .55, SD = .20$) and the error type made least often was Difference error ($M = .06, SD = .06$), respectively.

Pair-wise comparison of the simple main effects indicated that TD children made significantly fewer Difference errors ($M = .02, SD = .03$) than children with LF Autism ($M = .08, SD = .08$) and DS ($M = .07, SD = .06$), and significantly more Figure Repetition errors ($M = .70, SD = .18$) than children with LF Autism ($M = .50, SD = .21$), DS ($M = .51, SD = .19$) and Idiopathic ID ($M = .51, SD = .18$). TD children also made significantly fewer Inadequate Individuation errors ($M = .10, SD = .10$) than children with Idiopathic ID ($M = .16, SD = .08$), and significantly fewer Incomplete Correlate errors ($M = .09, SD = .08$) than children with Idiopathic ID ($M = .17, SD = .08$) and DS ($M = .17, SD = .08$). Thus, it appears that while the ID groups showed a similar error type distribution overall, TD children of the same non-verbal mental age showed a different proportion of error types on the RCPM.

Problem Solving Ability and Piaget’s stages of cognitive development
The relationship between sophistication of problem solving ability (as indicated by Raven’s rating of sophistication of error types) and the frequency of each error type made by each group on Corman and Budoff’s (1974) four factors are presented visually (see Figure 5a-5d). Statistical analysis of this data was not possible, due to the limited number of errors made.

(a)

Factor 1: Simple Continuous Pattern Completion
(Items A1-A6)

(b)

Factor 2: Discrete Pattern Completion
(Items Ab1-Ab3, B1-B2)
Figure 5. Frequency of Raven’s Error types across each of Corman and Budoff’s 4 Factors for all experimental groups. Corman and Budoff’s (1974) four factors include: (a) Factor 1 (A1-A6), (b) Factor 2 (Ab1-Ab3, B1-B3), (c) Factor 3 (A7-A12, Ab4-Ab11, B3-B7) and (d) Factor 4 (Ab12, B8-B12). Key - Low functioning Autism (LFA), Idiopathic intellectual disability (IID), Down Syndrome (DS) and typically developing (TD) groups.

If Corman and Budoff’s (1974) Factors are indicative of Piaget’s stages of cognitive development then children with ID and TD (mean non-verbal mental age of 7 years) matched here on non-verbal mental age would have been at the 2nd – 3rd stage of
cognitive development. Thus they would be expected to make more errors on the items requiring more complex reasoning indicative of the later stages of cognitive development (which correspond to Factors 2, 3 and 4), and as shown in the Figure 5a-5d. High frequency of Figure Repetition errors made by all groups may be indicative of the second to third Piagetian stage of cognitive development (Low and high-concrete operations-for solution).

**Position of item response as a problem solving strategy**

In order to determine whether position of item responses was a strategy utilised by the TD and ID groups when completing the RCPM, a repeated measures ANOVA (with chronological age as a covariate, given Raven originally found this error type to be made by young children), was conducted comparing the TD group to the LF Autism, DS and Idiopathic ID groups on frequency of each response position chosen. Figure 6 shows the means and standard error of proportion of errors in each position for each group.

*Figure 6. Mean (and standard error) proportion of errors made in each response position (Positions 1-6 indicated in the small panel insert) for all experimental groups. Key - Low functioning Autism (LFA), Down Syndrome (DS), Idiopathic intellectual disability (IID) and typically developing (TD) groups.
* Between-group significance at $p < .05$.

The findings of the repeated measures ANOVA demonstrated a significant main effect for position, $F(5, 620) = 28.53, p < .05$, but the group by position interaction was not significant, $F(15, 620) = 1.14, p < .05$. A simple main effect showed significant
differences between groups for position 2 only, $F(3, 130) = 5.05, p < .05$. ID groups chose position 2 significantly more often than the TD group.

Whether this positional strategy was utilized for erroneous responses that were made above chance rate in all groups, was also investigated. Eight items were found to have error rates that were above the chance level in all groups, shown in Figure 6 (Items A11-12, B6-9, B11-12). A repeated measures ANOVA showed a significant main effect of position, $F(5, 620) = 15.02, p < .05$, where position 2 was again found to be the most popular position choice for the TD, LF Autism and Idiopathic ID groups, but not the DS group, who chose position 1 more often.

**Relationship between RCPM performance and chronological age**

In order to investigate whether chronological age could be considered a valid measure of matching children with ID and TD children, a correlation analysis was conducted between chronological age (years) and problem solving ability (as measured by RCPM total correct score and proportion of error types) for the TD and ID groups (see Figure 7). Results showed a strong and significant relationship for both the TD group ($r = .57, p < .01$) and DS group ($r = .83, p < .01$), and a weak but significant relationship for the LF Autism group ($r = .39, p < .05$), and a non-significant relationship for the Idiopathic ID group ($r = .16, p > .05$). According to the 95% confidence intervals, the correlation between RCPM raw score and chronological age for the TD group was significantly different from the DS and Idiopathic ID and LF Autism group. However, the LF Autism, Idiopathic ID and TD groups are the only groups for which there was a significant span of chronological ages and hence have a greater spread of RCPM scores for analysis.
Figure 7. The relationship between non-verbal mental age (as measured by RCPM total score correct) and chronological age (yrs) for all experimental groups. Key - Low functioning Autism (LFA), Down Syndrome (DS), Idiopathic Intellectual Disability (IID) and typically developing (TD) groups.

A correlation analysis between chronological age and proportion of each error type for all groups showed a significant positive correlation was found between chronological age and Figure Repetition errors \( (r = .70, p < .05) \) for the TD group. A significant negative relationship was also found between chronological age and Inadequate Individuation errors \( (r = -.65, p < .05) \), Difference errors \( (r = -.37, p < .05) \) and Incomplete Correlate errors \( (r = -.39, p < .05) \) for the TD group. No significant correlations were found between chronological age and error types for the LF Autism, DS or Idiopathic ID groups. These results provides some evidence that improvements in problem solving ability (i.e. increase in Figure repetition error and decrease in Difference errors) is associated with increasing chronological age in TD children, but not ID children.

**Relationship between RCPM performance and receptive language ability (as measured by PPVT- Third Edition)**

The relationship between receptive language ability and problem solving ability (as measured by RCPM total correct score and proportion of error types) was investigated using a correlation analysis for the TD and ID groups. Receptive language test age equivalent was significantly positively correlated with RCPM total score correct for the TD group \( (r = .65, p < .05) \), as well as the LF Autism \( (r = .88, p < .05) \), Idiopathic ID \( (r = .70, p < .05) \) and DS \( (r = .49, p < .05) \) groups, suggesting that an
increase in non-verbal mental age is associated with an increase in receptive language ability, regardless of group membership.

For the TD group, a significant positive correlation was found between receptive language ability and proportion of Figure Repetition errors \((r = .73, p < .01)\) and a negative relationship between receptive language ability and Inadequate Individuation errors \((r = -.61, p < .01)\). This same pattern was also shown for the Idiopathic ID group \((\text{Figure Repetition } r = .36, p < .05, \text{ and Inadequate Individuation errors, } r = -.38, p < .05)\). A negative correlation was found between receptive language ability and Difference errors for all groups: LF Autism \((r = -.37, p < .05)\), DS \((r = -.23, p > .05)\) and Idiopathic ID \((r = -.43, p < .05)\) and TD \((r = -.48, p < .01)\), suggesting that error types become more sophisticated with increasing receptive language, regardless of group membership.

**Relationship between RCPM performance and visual short-term and working memory (as measured by visual digit span tasks)**

In order to determine whether problem solving ability (as measured by RCPM total score correct and proportion of error types) is associated with improved short-term and working memory capacity, a correlation analysis was conducted between visual forward digit span performance and visual backward digit span performance and RCPM total score correct and error type proportions for the TD and ID groups. Most ID children, except the DS group attempted the visual digit span task. By comparison, very few ID participants were able to complete the Auditory Digit Span tasks, and thus, the results are not reported here. A significant difference was not found between the experimental groups performance for the visual forward or backward digit span and so ID groups were collated into one and compared to the TD group. No significant difference was found for the TD and combined ID group for either the visual forward or backward digit span task. A significant correlation between total correct performance on the Visual Forward Digit Span task and overall RCPM total correct performance was found for both the TD \((r = .72, p < .05)\) and ID group \((r = .57, p < .05)\), suggesting the use of short-term memory (but not working memory) in the completion of RCPM in children despite group membership.

Furthermore, result showed no significant relationship existed between visual forward and backward digit span task performance and proportion of error types for the TD and ID groups.
Discussion

This study demonstrated that non-verbal mental age as measured on the RCPM is a valid means of matching intellectual ability of children with ID (of known and unknown or genetically non-identified etiology) and TD children. This was determined by showing that TD and ID children (i.e. LF Autism, DS and Idiopathic ID) with similar number of items correct, make similar frequency of each error type on similar item types and require similar levels of cognitive processing to solve RCPM items. Such cognitive abilities were expected to include receptive language ability (as measured by total score correct on the PPVT- Third Edition), visual and auditory short-term memory capacity (as measured by forward digit span tasks), and working memory capacity (as measured by backward digit span tasks). However, most ID children were unable to participate in auditory digit span testing. Chronological age was also found to be a less valid means of matching TD and ID children on cognitive ability.

This study was an elaboration of the earlier seminal study of Gunn and Jarrold (2004) comparing TD and DS groups of the same non-verbal mental age. However, Gunn and Jarrold did not report on whether the groups were correct on the same type of items, which could have potentially accounted for differences in proportion of error types found between groups. Thus, in the current study we ensured that children with ID, who scored similarly to TD children on overall number of correct responses on the RCPM, did so on similar type of items. It was also our intent to match groups on receptive language (using their total scores correct on the PPVT – Third Edition), in order to firstly ensure that all groups understood the RCPM task instructions and more importantly to determine whether total number of items correct on the RCPM is more than a measure of non-verbal mental age and hence a more valid measure of matching cognitive ability. Indeed, all groups were found to be comparable on receptive language ability simply by being matched for RCPM non-verbal mental age. This finding is very important as it suggests that receptive language and non-verbal mental age are related and could indicate that the process of complex pattern matching and visual reasoning may involve verbal based strategies. Thus, it is possible that children with ID who are limited in their expressive language are still utilizing verbal based reasoning to solve problem on the RCPM. Such a hypothesis requires further investigation.

Furthermore, results showed that non-verbal mental age correlated positively with receptive language (Kilburn et al., 1966; Paulesu et al., 1993; Petrides et al., 1993; Smith et al., 1996) for children with ID and TD children, which suggests greater
language comprehension may facilitate the use of more sophisticated problem solving strategies and overall performance on the RCPM in both TD and ID groups. Importantly, our findings also suggest the RCPM may not necessarily require an accompanying verbal measure (as recommended by Raven) in order to validly measure overall intelligence in children, especially those of limited expressive language ability (Raven et al., 1995). Indeed, this was observed in our DS group, who (though not significantly different) were older and had the lowest receptive language skills and non-verbal mental age than the other groups. Thus, we suggest that the RCPM on its own is a sufficient measure of cognitive ability in children with limited expressive and/or receptive language ability.

Consistent with Gunn and Jarrold’s (2004) findings, our results showed a similar pattern, but different proportion of error types made between the TD and DS groups (as well as LF Autism and Idiopathic ID groups) on the RCPM. However, the TD and ID groups were not significantly different on the frequency of error types made. We suggest that comparing groups on frequency of each error type made on the RCPM is a clinically more meaningful measure which implies that all TD and ID groups of same non-verbal mental age use similar problem solving strategies and thus, can be validly matched on the RCPM.

Our results also demonstrated a similar relationship between the sophistication of error types (i.e. number of aspects of visual similarities incorrect responses share with the correct answer) and Corman and Budoff’s (1974) four factors (i.e. item types). If indeed Corman and Budoff’s four factors are reflective of Piaget’s 4 stages of cognitive development in primary school aged children, then it could be argued that the high frequency of Figure Repetition errors made on the RCPM indicate that test takers are performing according to what is expected of the second to third Piagetian stage of cognitive development (Low and high-concrete operations-for solution), rather than their group membership. Thus, we suspect that as a child moves towards the fourth Piagetian stage of cognitive development (Formal operations-for solutions), and develops greater cognitive ability, they will make more Inadequate Individuation errors (i.e. errors that have more similarities to the correct answer) than any other error type. An alternative explanation for this pattern of findings however, is that children with ID and TD children tend to withdraw their attention on more difficult item types and thus resort to selecting less sophisticated responses (i.e. Figure Repetition errors). Nevertheless, such similarity between groups in error distribution across item types,
suggest that when TD children and children with ID (LF Autism, DS and Idiopathic ID) are quantitatively similar on the RCPM and receptive language ability, they are also qualitatively similar in problem solving ability. This would seem to imply that children with ID are predominantly developmentally delayed and usually able to be matched for intellectual capacity and performance on non-verbal mental age. Thus, even children with Autism who as a group have previously been reported to show superior visuospatial ability (Jolliffe & Baron-Cohen, 1997; Mottron, Belleville, & Ménard, 1999; O'Riordan, 2004; O'Riordan et al., 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998b; Shah & Frith, 1983), perform on visual pattern matching according to the level expected of their non-verbal mental age rather than their etiology, when intellectually disabled.

Children with ID (regardless of etiology) and TD children of non-verbal mental age of around 7 years all made positional errors (originally noted by Raven (J. C. Raven et al., 1995) for difficult items (as indicated by an error level above chance performance). However, our TD group showed no statistically significant location bias in relation to their overall response selection, while the ID groups did and selected the upper central position (Raven’s position P2) more frequently than other positions. It is unlikely that this positional bias suggests a deviant problem solving approach in children with ID. This pattern of responding may be due to a lack of motivation, possibly as children with ID have had more experience with failure and hence may come to expect failure (Clark & Rutter, 1979a; Cole, 1997). Thus, this positional bias presumably demonstrates a purposeful approach to task completion (Clark & Rutter, 1979a; Koegel et al., 1997; Pitcairn & Wishart, 1994). The next step is to determine whether this greater ‘passive task withdrawal’ in the ID groups is intrinsic to ID or can be altered through early intervention.

Our results showed a different relationship between RCPM performances (i.e. total score correct and proportion of error types) and chronological age for the TD group than the ID groups, as previously shown by Gunn and Jarrold’s (2004) findings. Error types changed (i.e. more Figure Repetition errors and less Difference, Inadequate Individuation and Incomplete Correlate errors) with increasing chronological age for the TD group but not the ID group. This lack of improvement in strategy with increasing chronological age in children with ID is most likely due to the plateau effect of non-verbal mental age that occurs at some point during the development of children with ID, supporting the hypothesis that chronological age matching is a less valid means of
matching ID and TD children on cognitive ability. Future studies need to investigate when children with ID plateau in cognitive ability and what problem solving strategies they utilize after this stage.

Non-verbal mental age correlated positively with visual short-term memory performance but not with visual working memory for children with ID and TD children, suggesting that the children tested (regardless of group membership) were probably not able to effectively utilize working memory to manipulate information as a problem solving strategy (Carretti, Belacchi, & Cornoldi, 2010; Lanfranchi, Cornoldi, & Vianello, 2002). This is highlighted by closer inspection of items not successfully solved by any groups (as indicated by Corman and Budoff’s item sophistication index), where items making up Factors 3 and 4 seemed to require the processing of dual components of visual information in order to be successfully solved. It is possible that children with ID and TD children struggled with completion of the more demanding dual task items. Indeed, this explanation would suggest that children with DS struggle more so with dual task processing than TD children and children with Idiopathic ID and LF Autism of similar non-verbal mental age, explaining their especially poor performance on items of Factor 3 compared to the other groups. Indeed, it may be the case that limited working memory in children with ID may be what is limiting them from moving onto the final Piaget stage of cognitive processing. Such a presumption will need to be explored in future studies. Furthermore, it may also be the case that visuospatial abilities, such as the ability to perceive discrete parts of an image as making up a whole image, which is known as global processing or “gestalt” processing of items (Hunt, 1975) are more directly related to error types on the RCPM in children than are dual working memory tasks which require rapid shifts in attention. Indeed, it has been suggested that many items on the RCPM require multiple aspects of visuospatial processing rather than reasoning by analogy (Gunn & Jarrold, 2004; Lezak, 2004; Villardita, 1985b). It remains for future research to explore the relationship between the mechanisms of visual attention and probability of making each error type on the RCPM, in TD children and children with ID.

One major limitation of the current study is that error analysis cannot differentiate between genuine errors of a particular type (i.e. responses where the child thinks they have the correct answer) and guesses or a consistent strategy of passive compliance. Thus as alluded to above, it is often not clear whether impaired performance is due to limited cognitive ability or a result of not trying. Thus, a measure
of non-verbal mental age such as the RCPM can only indicate what children with ID can do, and not, what they won’t try. Futures studies should compare the problem solving approach used on the RCPM to the WISC-IV in children with ID of different etiology compared to a TD group, to further inform debate on cognitive capacities that must be considered when seeking a tool for matching TD and those with ID.

In conclusion, TD children and children with ID of known and unknown or genetically non identified etiology (DS, Idiopathic ID and LF Autism) who scored similar total correct score on the RCPM and hence attained similar non-verbal mental age were found to be correct on the same types of items and show similar frequency and distribution of error types across item types. Total correct score on the RCPM for TD and ID groups also correlated highly with performance on tests of receptive language and visual short-term memory. Such results support the RCPM as a valid tool by which to match children with ID to TD children on general cognitive ability. The greater prevalence of positional errors made by ID groups suggests greater withdrawal behavior and requires further consideration. Our analysis indicates the need for a more conciliatory assessment of the formerly divergent Developmental and Difference theories. Overall, our findings suggest that children with ID (i.e. LF Autism, DS and Idiopathic ID) are developmentally delayed, and it is debatable whether increased positional errors are indicative of a deviant problem solving approach.
CHAPTER FIVE: STUDY 3 - Impaired dual target detection in children with Down Syndrome

The ability to attend adequately to information in the environment is an important component of learning, yet research on the ability of children with Down Syndrome (DS) to sustain and shift visual attention in comparison to typically developing children (TD) of similar mental age is limited and inconclusive. Thus, the current study aimed to investigate sustained and transient attention for single and dual targets in children with DS compared to TD children of similar non-verbal mental age (as measured by the Raven’s Coloured Progressive Matrices). Target detection time and accuracy of DS and TD groups were compared on a number of visual attention tasks, which included a single and dual- target continuous performance tasks measuring sustained attention, a visual change detection task measuring transient attention and a feature and conjunctive visual search task measuring both sustained and transient attention. The results showed that children with DS did not perform significantly differently to TD children on sustained and transient attention tasks that only required the detection of a single unique target, but were impaired in overall accuracy on tasks that required dual-target detection. The findings suggest that children with DS show impairment in working memory. Analysis of error responses on the tasks revealed differences in problem solving strategy used by children with DS compared to TD children, despite similarity in non-verbal mental age. The findings have important implications for the education of children with DS.

This is an original study. It is the first study in the research literature to compare children with DS to TD children of similar non-verbal mental age on a change detection task, continuous performance task and a visual search task. The tasks are all original and were devised especially for this study.
Introduction

Down Syndrome (DS) is the most common form of Intellectual Disability (ID) of known etiology (Brown et al., 2003; Driscoll et al., 2004; Sherman et al., 2007; Silverman, 2007; Trezise, Gray, & Sheppard, 2008), with a reported prevalence of 1 in 650-1000 infants worldwide (Bittles, Bower, Hussain, & Glasson, 2007). Approximately 90-94% of DS cases are caused by trisomy of chromosome 21 (Sherman et al., 2007). Research on the cognitive profile of DS is important in the development and implementation of education interventions for children with DS. Attention and working memory are well regarded as important components of problem solving and learning (Kruschke, 2005). Working memory refers to temporary storage and processing of information in the face of distractions (Baddeley, 1986) and has been shown to be relatively impaired in individuals with DS (Brown et al., 2003; Landry & Bryson, 2004; Munir, Cornish, & Wilding, 2000; Trezise et al., 2008; Wilkinson, Carlin, & Thistle, 2008; Zickler, Morrow, & Bull, 1998). Sustained attention refers to the ability to actively remain vigilant to information at a given location, while transient attention refers to an involuntary capture of attention by a salient sensory stimuli (Ling & Carrasco, 2006). Despite the importance of attentional processes in learning, research on the ability of children with DS to sustain and shift attention compared to TD children of similar mental age is surprisingly limited and inconclusive.

Munir et al. (2000) conducted a study investigating the attentional profile of children with Fragile X syndrome. The performance of 25 children with Fragile X (CA = 10.88 years; MA = 6.77 years) on a series of attentional tasks was compared to 25 TD children with “poor attention” (CA = 7.58 years; MA = 6.96 years), 25 TD children with “good attention” (CA = 7.97 years; MA = 7.77 years) (as rated by the children’s teachers using the Comprehensive Teacher Rating Scale) and 25 DS children (CA = 11.17 years; MA = 6.09 years) matched to children with Fragile X on verbal mental age (as measured by the British Picture Vocabulary Scale Short Form). For the sustained attention task, participants were required to use the computer mouse to click on targets that appeared randomly on the computer screen. Results showed that the DS group made more commission errors than the TD group with “good attention”, who were older than the DS group in verbal mental age. Thus, it was unclear from the findings whether impaired sustained attention in DS was due to a relatively lower mental age or characteristic of the DS diagnosis.

In a more recent study, Lanfranchi, Jerman, Dal Pont, Alberti and Vianello
(2010) investigated executive functioning in adolescents with DS (CA = 15.2 years; MA = 5.9 years) compared to TD children (CA = 5.9 years; MA = 5.9 years) matched on non-verbal mental age. One of the tasks employed was a sustained attention task which required (Self-ordered Pointing Test) participants to view pages of a book with multiple pictures of everyday objects on each page and point to one novel picture per page. Thus, participants were required to remember the pictures they had already pointed to in order to ensure they pointed to a different picture each time. Adolescents with DS were less accurate on this sustained attention task than the TD children. However, given that the sustained attention task involved a working memory component, it was not clear from the results whether children with DS performed relatively worse on the task due to impaired ability to sustain attention or due to impairment in maintaining information in working memory.

Thus, the aim of the current study was to investigate sustained and transient attention to single and dual targets (i.e. with a working memory component) in children with DS compared to TD children of similar non-verbal mental age (as measured by the Raven’s Coloured Progressive Matrices). Differences in problem solving strategies utilised between groups was also investigated. This aim was achieved by comparing the reaction time and accuracy performance of children with DS to TD children on a single-target continuous performance task, a dual-target continuous performance task (as a measure of sustained attention), a visual change detection task (as a measure of transient attention) and a feature visual search task and a conjunctive visual search task, designed to measure both sustained and transient attention. Differences in percentage of commission errors (responding to non-targets) and omission errors (not responding to targets) between groups for each task were also analysed in order to determine whether children with DS utilize similar problem solving strategies to TD children.

Given previous findings of impaired working memory in individuals with DS (Brown et al., 2003; Landry & Bryson, 2004; Munir et al., 2000; Trezise et al., 2008; Wilkinson et al., 2008; Zickler et al., 1998), it was hypothesized that children with DS would be (1) comparable to TD children in reaction time and accuracy performance for the single-target continuous performance task, but slower and less accurate for the dual-target continuous performance task, (2) slower and less accurate than TD children in detecting visual changes in stimuli colour and identity in the change detection tasks, (3) comparable to TD children in reaction time and accuracy performance for the feature visual search task, but impaired for the conjunctive visual search task, and (4) make
more commission errors than TD children in all tasks, consistent with findings from the study by Munir et al. (2000).

Method

Participants

Participants included 17 children with DS (10 males and 7 females) and 23 TD children (14 males and 9 females). All children attempted the experimental studies, however, many children with DS did not complete all of the tasks in the study due to either an inability to comprehend task instructions, non-compliance and/or lack of motivation (see Table 1 for number of participants who completed each task). The majority of children with DS did not complete the working memory measure (visual forward and backward digit span task) and thus, statistical differences between the DS and TD groups on working memory performance were not able to be undertaken. Children with DS were recruited from a specialist school and TD children were recruited from a mainstream school in middle class socio-economic areas of Melbourne, Australia. A qualified psychologist had previously diagnosed children with DS according to the DSM-IV and ID based on an IQ of below 70 on the Wechsler Intelligence Scale for Children-Third Edition (Wechsler, 1991a). For each task, TD children were matched to children with DS on non-verbal mental age (as measured by the Raven’s Coloured Progressive Matrices) (Raven et al., 1995) in order to ensure that differences between groups in the ability to attend could not be attributed to group differences in reasoning ability. However, children with DS were always significantly older chronologically than TD children for each task (refer to the result section of each experiment for statistical analyses). Table 1 displays the characteristics of each group.

Participants had normal colour vision and normal or corrected to normal vision. Ethics approval for the study was obtained from the Swinburne University Human Research Ethics Committee. Signed informed consent forms from parents/guardians were required from participants prior to their participation in the study. All participants were free to withdraw from the study at any time.
Table 1

Number (N) of participants who completed each task with means (M) and standard deviations (SD) of chronological age, and non-verbal mental age (as measured by the RCPM) in years, for the Down Syndrome (DS) and typically developing (TD) groups in the Single-target Continuous Performance Task (SCPT), Dual-target Continuous Performance Task (DCPT), Change Detection Task (CDT), Feature Visual Search Task (FVST) and Conjunctive Visual Search Task (CVST)

<table>
<thead>
<tr>
<th>Task</th>
<th>N</th>
<th>Chronological age</th>
<th>Non-verbal mental age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DS</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>SCPT</td>
<td>13</td>
<td>13.2</td>
<td>2.7</td>
</tr>
<tr>
<td>DCPT</td>
<td>9</td>
<td>14.0</td>
<td>1.7</td>
</tr>
<tr>
<td>CDT</td>
<td>7</td>
<td>14.0</td>
<td>2.0</td>
</tr>
<tr>
<td>FVST</td>
<td>17</td>
<td>12.4</td>
<td>2.8</td>
</tr>
<tr>
<td>CVST</td>
<td>17</td>
<td>12.4</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Materials

VPixx software version 1.5 was used to develop the single-target continuous performance task (CPT), dual-target continuous performance task (CPT), staircase Parameter Estimation by Sequential Testing (PEST) change detection task (colour or identity), feature visual search task (FVST) and conjunctive visual search task (CVST). All tasks were presented on an iMac computer with a 15-inch display monitor set at 117Hz screen refresh rate and resolution at 640 x 480. Participants’ colour visual integrity was assessed using the Ishihara Test for Colour-Deficiency. A high contrast chart was used to measure visual acuity both monocularly and where possible, binocularly. Raven’s Coloured Progressive Matrices (RCPM) (J. C. Raven et al., 1995) was used as a measure of non-verbal mental age.

Single-target continuous performance task.

Coloured faces of a family of 4 familiar cartoon characters (i.e. Daughter, Mother, Father and Son) were individually displayed on a computer screen for 1.5 seconds each and presented consecutively and randomly for a total duration of 2 minutes. The target was the face of the Son character coloured yellow. The distracters were the face of the Daughter, Mother and Father characters coloured red, green, yellow or blue. The target was unique from the distracters in identity but not colour. The target
and 12 unique distracters were presented in 7 blocks, making up a total of 91 trials. Target to non-target ratio was 1/13. The target appeared a total of 7.69% of the time (i.e. 7 times) and distracters occurred 92.31% of the time (i.e. 84 times).

A small version of the target was permanently displayed on the upper left hand corner of the computer screen, in order to reduce the demand of working memory storage load during task completion (as shown in Figure 1A). Colourful cartoon characters were chosen as the stimuli as a means of gaining and maintaining the motivation and interest of children with DS on the task.

**Dual-target continuous performance task.**

The dual-target continuous performance task (CPT) was similar to the single-target CPT, except two targets (Son character coloured red or green) instead of one target were utilised in the task. The distracters included the Son character coloured yellow or blue, as well as the Daughter, Mother and Father characters coloured yellow, red, blue or green. Thus the targets were unique from distracters in their combination of identity and colour (see Figure 1B). The 2 unique targets and 13 unique distracters were each randomly presented in 7 blocks, making up a total of 105 trials respectively. with the target appearing a total of 13.33% of the time (i.e. 14 times) and distracters occurring 86.67% of the time (i.e. 91 times).

**Figure 1.** Schematic illustration of three consecutive frames of the (A) Single-target CPT and (B) Dual-target CPT. The target is presented in the first frame, followed by two unique distracters. Small versions of the targets are displayed at the top left hand corner of the screen throughout the task.
**PEST change detection task**

The adaptive staircase Parameter Estimation by Sequential Testing (PEST) change detection computerized task stimuli included the coloured faces of a familiar family of 4 cartoon characters (i.e. Mother, Father, Son and Daughter). Two cartoon characters were displayed side by side on the computer screen with a fixation cross in between them for a duration of 4 seconds (Presentation 1; P1), followed by a fixation cross in the middle of the screen for 250 ms and then the re-presentation of the faces for 4 seconds (Presentation 2; P2). In P2, one of the faces had changed either in colour or identity (see Figure 2). The change occurred equally often on the left and right side of the fixation cross.

The PEST task was designed to automatically vary the exposure time of P1 according to the individual’s accuracy response rate, until it established the mean exposure time of P1 that a participant required in order to accurately detect change in P2 at 75% success rate. There were 4 stimulus conditions within the task: 2 colour changes and 2 identity changes, which included (1) Colour 1 condition: Son’s face (next to Daughter’s green face) changed from yellow to blue (Yellow Son/Blue Son); (2) Colour 2 condition: Daughter’s face (next to Son’s green face) changing from red to yellow (Red Daughter/Yellow Daughter condition); (3) Identity 1 condition: Mother’s blue face (next to Son’s red face) changed to the Father’s face (Blue Mother/Blue Father condition) and (4) Identity 2 condition: Son’s yellow face (next to Daughter’s blue face) changed to the Mother’s face (Yellow Son/ Yellow Mother). All stimuli pairs were presented in random order.

![Figure 2](image-url)

Figure 2. Schematic illustration of the PEST Change Detection task. A blank screen (FIXATION) was interspersed between the first presentation (P1) and the second presentation (P2) of the stimuli. Face stimuli on the left hand side changed identity from P1 to P2.
**Feature visual search task.**

The Feature Visual Search Task (FVST) was a 2.5 minute computerised task, made up of 40 trials. The Son character’s face coloured blue served as the target and the Father character’s face coloured red served as the distracter. Targets were unique from distracters in both colour and identity. Trials included distracters with a total display size of either 3, 7, 14 or 34 distracters, each presented 10 times throughout the tasks, with half of them inclusive of the target and the other half exclusive of the target (see Figure 3A).

**Conjunctive visual search task.**

The conjunctive visual search task (CVST) was the same as the FVST, except the Son character’s face coloured red served as the target. Half of the distracters were made up of the Son character’s face coloured blue (which served as the target in the FVST), and the other half of the distracters were the Father character’s face coloured red. Thus, the target shared its colour with one half of the distracters (i.e. the Father character) and its identity with the other half of the distracters (i.e. the Son character; see Figure 3B).

![Figure 3](image)

*Figure 3. Schematic illustration of (A) the Feature visual search task (set size 3, target present); and (B) the Conjunctive visual search task (set size 3, target present).*

**Procedure**

For each task, participants were seated 50 cm from the computer screen and told they were going to play a game. They underwent practice trials and commenced testing once the experimenter believed that they displayed a sufficient understanding of task instructions. The computer recorded participants’ motor reaction time, frequency of correct responses and frequency of commission and omission errors for all trials.
Positive reinforcement and praise were only provided during practice trials. Participants completed each task in silence, while the experimenter sat behind them, well out of their peripheral vision in order to minimise distraction. Participants were tested individually in a quiet room in their school during school hours, across four separate sessions.

The RCPM and colour vision test were first administered, followed by the sustained and transient tasks in counterbalanced order, with the single-target CPT always preceding the dual-target CPT, and the FVST always preceding the CVST. It was important to begin with the easier versions of these tasks, in order to maintain children’s interest and motivation for the second more challenging versions of the tasks.

For the single-target continuous performance task, participants were shown the Son character coloured yellow on the computer screen and instructed to “press the space bar” using their preferred hand as fast as possible only when the target appeared on the screen. Participants were then shown the small version of the target on the left top corner of the screen and informed that this served to remind them of the target’s identity if they forgot. The same instructions used for the single-target CPT were administered for the dual-target CPT, except this time participants were asked to “press the space bar” as soon as they saw the red or green coloured Son character appear on the computer screen and to not respond to any other stimuli, including the Son character coloured either yellow or blue.

For the change detection task, a pilot study investigating a two button keyboard choice response for the change detection task resulted in a significantly high number of incomplete tests in children with DS. Thus, after every trial, the experimenter paused the task and asked participants whether the second picture looked the same or different to the first picture they saw on the computer screen. Participants verbally indicated whether they detected a change by saying “different” or whether they detected no change by saying “same”. For the feature and conjunctive visual search tasks, participants were shown the target on the computer screen and asked to press the space bar on the computer keyboard every time they saw the target appear on the screen.

Data analysis

Between-group and within-group analyses were conducted using either an independent samples *t*-test and pairwise comparison test or their non-parametric equivalents (i.e. Mann-Whitney U test and Wilcoxon Signed rank test) whenever violations of assumptions of normality, homogeneity of variance and sphericity were detected. An adjusted alpha level of .05 was used.
Analysis of matching variables

Children with DS were matched individually to TD children on non-verbal mental age. Participant’s total number of items correct on the RCPM was used to calculate their equivalent non-verbal mental age, which was based on the 50th percentile (classified as “intellectually averaged”) level for TD children between 5.5-10.5 years, on the 1980 Norms for Queensland, Australia (Raven et al., 1995). As a result of this matching procedure, TD children with significantly higher scores on the RCPM test were eliminated from the study sample, which limited the study sample size. Thus, the mean and range of RCPM scores for the TD children in the sample is not necessarily representative of the average RCPM performance in this chronological age group, but is representative of children in the lower end of the TD group.

Therefore, there was no significant difference in non-verbal mental age (as measured by the RCPM total score correct) between children with DS and TD children who completed the single-target CPT ($t(34) = 1.52, p > .05$), the dual-target CPT ($t(29) = -.15, p > .05$), the change detection task ($t(12) = .09, p > .05$) and the FVST and CVST ($t(34) = 1.63, p > .05$). However, as expected, the DS group was significantly older in chronological age than the TD group completing the single-target CPT ($t(29) = -10.58, p < .001$), dual-target CPT ($t(34) = -8.71, p < .001$), change detection task ($t(12) = -6.73, p < .001$) and the FVST and CVST ($t(34) = -6.55, p < .001$) (See Table 1).

Between-group comparison of mean motor reaction time and percentage of correct trials on the single-target and dual-target continuous performance tasks

In order to determine whether children with DS can sustain their attention according to the level expected of the non-verbal mental age comparison group, an independent samples $t$-test was utilized to compare TD and DS groups on mean reaction time and a Mann-Whitney U test was utilized to compare TD and DS groups on percentage of targets correctly detected in the single-target CPT and the dual-target CPT (refer to Table 2 for means and standard deviations). Results showed that in the single-target CPT, the TD and DS groups were comparable in mean reaction time ($t(34) = -.90, p > .05$) and percentage of targets detected ($z = -.82, p > .05$). In the dual-target CPT, groups were comparable in mean reaction time ($t(29) = -.31, p > .05$), however, the TD group was significantly more accurate in target detection than the DS group ($z = -2.46, p < .05$). In fact, the DS group accuracy performance was recorded as close to chance level (i.e. 57%) for the dual-target CPT (see Table 2).
Table 2

Means (M) and standard deviations (SD) of motor reaction time (RT; sec) and percentage of targets correctly detected (PC) in the Single-target Continuous Performance Task (CPT) and the Dual-target Continuous Performance Task (CPT) between Down Syndrome (DS) and typically developing (TD) children

<table>
<thead>
<tr>
<th>Group</th>
<th>Single-target CPT</th>
<th>Dual-target CPT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT</td>
<td>PC</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>DS</td>
<td>.70</td>
<td>.26</td>
</tr>
<tr>
<td>TD</td>
<td>.77</td>
<td>.17</td>
</tr>
</tbody>
</table>

Between-group comparison of error types on the single-target and dual-target continuous performance tasks

In order to determine whether children with DS use similar problem solving strategies to TD children, a Mann-Whitney U test was utilized to compare groups on the percentage of commission errors (responding to non-targets) and omission errors (not responding to targets) made in the single-target CPT and dual-target CPT (see to Figure 4). For the single-target CPT, result showed that the DS group made significantly more commission errors (M = 13.66, SD = 15.98) than the TD group (M = 5.54, SD = 6.08; z = -2.33, p < .05), however no significant difference (z = - .82, p > .05) was found in percentage of omission errors made by the DS group (M = 20.88, SD = 25.16) compared to the TD group (M = 13.67, SD = 18.01).

For the dual-target CPT, the opposite pattern was found. The TD (M = 8.30, SD = 6.07) and DS (M = 19.17, SD = 15.00) groups were comparable in the percentage of commission errors made (z = -1.60, p > .05), however, the DS group made significantly more omission errors (M = 42.86, SD = 28.57) than the TD group (M = 16.23, SD = 18.86; z = -2.46, p < .05).
**Figure 4.** Means and standard error bars for number of omission errors and commission errors made on the Single-target continuous performance task (CPT) and the Dual-target continuous performance task (CPT) for the Down Syndrome (DS) and typically developing (TD) groups.

**Within-group comparison of percentage of commission errors made to distracters according to their colours in single-target and dual-target continuous performance tasks**

One possible response strategy that TD children may have utilised in the continuous performance tasks was to respond to only one salient feature of the target, such as its colour in the single-continuous performance task and either its colour or identity in the dual-continuous performance task. Thus, in order to determine whether groups were using the target’s colour to guide their responses as a problem solving strategy, within group comparisons (Wilcoxon Signed Rank tests) were conducted, comparing percentage of commission errors made to distracters with the same colour as the target/s in comparison to the distracters of a different colour to the target in the single-target CPT and dual-target CPT.

For the single-target CPT, the TD group made significantly more commission errors for distracters with the same colour as the target (i.e. yellow; $M = 29.22$, $SD = 28.42$) than for distracters coloured either green ($M = 15.54$, $SD = 27.90$; $z = -2.34$, $p < .05$), red ($M = 12.43$, $SD = 17.41$; $z = -2.84$, $p < .05$) or blue ($M = 6.22$, $SD = 11.26$; $z = -3.48$, $p < .001$). The DS group made more commission errors for distracters coloured yellow ($M = 37.65$, $SD = 64.41$) than for distracters coloured green ($M = 21.70$, $SD =$
46.45; \(z = -2.38, p < .05\), see Figure 5).

For the dual-target CPT, the TD made significantly fewer commission errors for distracters coloured the same as one of the targets (i.e. red; \(M = 14.92, SD = 20.89\)) than for distracters coloured blue (\(M = 42.88, SD = 36.31; z = -3.39, p < .001\)), and fewer commission errors for distracters coloured the same as one of the other targets (i.e. green) than for distracters coloured yellow (\(z = -2.16, p < .05\)) or blue (\(z = -3.67, p < .001\)). The DS group on the other hand made a comparable percentage of commission errors for distracters coloured yellow, red, green or blue in the dual-target CPT (see Figure 5).

**Figure 5.** Means and standard error bars for percentage of commission errors made for different coloured distracters (yellow, red, green and blue) in the Single-target continuous performance task (ST-CPT) and the Dual-target continuous performance task (DT-CPT), for the Down Syndrome (DS) and typically developing (TD) groups.

**Within-group comparison of percentage of commission errors according to distracter identities in the dual-target continuous performance task**

In order to determine whether groups were using the target’s identities to guide their responses in the dual-target CPT, within group comparisons (Wilcoxon Signed Rank tests) were conducted, comparing percentage of commission errors made to distracters with the same identity as the target/s (i.e. Son character) in comparison to distracters with non-target identities (i.e. Daughter, Father and Mother characters) in the dual-target CPT.
The TD group made significantly more commission errors to distracters with the same identity as the target (i.e. Son; $M = 40.40, SD = 25.75$) than to distracters with the Mother ($M = 17.41, SD = 23.60; z = -3.14, p < .01$), Father ($M = 15.54, SD = 20.18; z = -3.42, p < .001$) or Daughter ($M = 19.90, SD = 31.61; z = -2.33, p < .05$) identity. The DS group showed no significant differences between the percentages of commission errors made for distracters with the same identity as the target, compared with distracters with a different identity to the target (see Figure 6).

![Figure 6. Means and standard error bars for percentage of commission errors made for distracters according to their identity (Son, Father, Daughter and Mother) in the Dual-target continuous performance task, for the Down Syndrome (DS) and typically developing (TD) groups.](image)

**Figure 6.** Means and standard error bars for percentage of commission errors made for distracters according to their identity (Son, Father, Daughter and Mother) in the Dual-target continuous performance task, for the Down Syndrome (DS) and typically developing (TD) groups.

**Between-group comparison of total exposure time for P1 in the change detection task**

In order to determine whether there was a difference between the DS and TD groups (of similar non-verbal mental age) in viewing time required of the first presentation of the stimuli (P1) of the change detection task, in order to detect a colour or identity change in stimuli at the second presentation (P2) at 75% accuracy level, an independent samples $t$-test between groups on duration of P1 was conducted. The results showed a significant difference between groups in exposure time of P1, $t(12) = -3.26, p < .01$. The DS group ($M = 1.48, SD = .82$) required a longer first presentation of the stimuli than the TD group ($M = .37, SD = .36$) in order to obtain the same level of accuracy in detecting either a colour or identity change in the stimuli at P2 (see Figure 7).
Figure 7. Means and standard error bars for threshold viewing time (sec) of the first presentation of stimuli (P1) that the typically developing and Down Syndrome groups required to successfully detect colour or identity change at the second presentation (P2) at 75% level of accuracy.

Between-group and within-group comparison of total exposure time of P1 for colour and identity stimuli conditions

In order to determine whether the exposure time of P1 was dependent on the type of change being detected at P2 (i.e. identity or colour), the exposure time of P1 for each condition was compared within groups and between groups. A Wilcoxon Signed Rank test showed no significant difference for the DS group in exposure time of P1 in the colour or identity conditions (see Figure 8). The TD group on the other hand, showed similar P1 exposure time for the two colour conditions, however, required a significantly longer P1 exposure time for the identity 1 condition (Blue Mother/Blue Father; $M = 1.03, SD = 1.26$) compared to the identity 2 condition (Yellow Son/Yellow Mother; $M = .20, SD = .26; z = -2.37, p < .05$) or the colour conditions combined ($z = -2.20, p < .05$) (see Figure 8).

Exposure times for P1 in the colour conditions were collated for each group and compared to one another. A Mann-Whitney U test found that TD children required a significantly shorter P1 exposure time in order to detect a colour change at P2 with the same level of accuracy as DS children ($z = -2.24, p < .05$). TD and DS groups were comparable in exposure time needed for P1 for both the Identity 1 condition ($z = -1.42, p > .05$) and Identity 2 condition ($z = -1.67, p > .05$) (see Figure 8).
Colour 1 = Yellow Son → Blue Son
Colour 2 = Red Daughter → Yellow Daughter
Identity 1 = Blue Mother → Blue Father
Identity 2 = Yellow Son → Yellow Mother

Figure 8. Means and standard error bars for viewing time (sec) of presentation 1 of the stimuli (P1) for the colour and identity stimuli conditions for the Typically Developing (TD) and Down Syndrome (DS) groups.

Within-group differences in mean reaction time for correct target detection between the FVST and CVST

In order to determine whether there was a difference for each group in target detection time in the FVST compared to the CVST, a Wilcoxon Signed Rank test compared the mean target reaction time for the FVST and CVST within each group. Results showed that the DS group responded to targets in the FVST and CVST for set sizes 3, 7, 14 and 34 at a similar rate. The TD group on the other hand, was significantly slower to detect targets in the CVST than the FVST for set size 3 ($z = -3.52, p < .001$), 7 ($z = -3.46, p < .001$) and 14 ($z = -2.33, p < .05$).

Between-group comparison of mean reaction time and percentage of correct trials for the FVST and CVST

In order to determine whether there was a difference between the DS and TD groups in target detection time in the FVST compared to the CVST, a Mann-Whitney U test compared groups on mean reaction time and found that for the FVST, the TD and
DS groups were comparable on mean reaction time performance for correct responses for set size 3, 7, 14 and 34 (see Figure 9A). However, for the CVST, the DS group was significantly faster than the TD group in detecting targets for set size 7 (TD: $M = 1.19$, $SD = .35$; DS: $M = .69$, $SD = .61$; $z = -2.55$, $p < .01$) (Figure 9B), but comparable to the TD group for mean reaction time performance for set size 3, 14 and 34.

$\text{Figure 9.}$ Means and standard error bars for reaction times of correct responses on the (A) Feature visual search task and (B) Conjunctive visual search task for set sizes 3, 7, 14 and 34 in the Down Syndrome (DS) and typically developing (TD) groups.

In order to determine whether there was a difference between the DS and TD groups in accuracy of target detection in the FVST and CVST, a Mann-Whitney U test was conducted on percentage correct in each task. Results showed that for the FVST, the TD and DS groups were comparable in mean percentage of targets correctly detected for set size 3, 7, 14 or 34 (see Figure 10A). Similarly, for the CVST, the DS
group was comparable to the TD group in percentage of targets correctly detected for set size 7, 14 and 34, but significantly less accurate for set size 3 (TD: $M = 87.25, SD = 25.37$; DS: $M = 52.94, SD = 47.59; z = -2.00, p < .05$) (see Figure 10B).

*Figure 10.* Means and standard error bars for percentage correct for the (A) Feature visual search task and (B) Conjunctive visual search task for set sizes 3, 7, 14 and 34 for the Down Syndrome (DS) and typically developing (TD) groups.

**Between-group comparison of percentage of commission and omission errors made on the FVST and CVST**

DS and TD groups were compared on the percentage of commission and omission errors made on the FVST and CVST in order to determine whether children with DS use a different problem solving strategy than TD children of similar non-verbal mental age. A Mann-Whitney U test was conducted and showed that for the FVST and CVST, TD and DS groups were comparable on mean percentage of commission errors made for set size 3, 7, 14 and 34. Groups were also similar in the percentage of omission errors made on the FVST for all set sizes, however, the DS group made a
significantly higher percentage of omission errors than the TD group for set size 3 (TD: $M = 12.75, SD = 25.37$; DS: $M = 47.06, SD = 47.59$; $z = -2.00, p < .05$) (see Figure 11).

Figure 11. Means and standard error bars for percentage of omission errors made on the Feature visual search task (FVST) and Conjunctive visual search task (CVST) for set sizes 3, 7, 14 and 34 for the Down Syndrome (DS) and typically developing (TD) groups.

Discussion

The aim of this study was to determine whether children with DS can sustain and shift attention in accordance with the level expected of their non-verbal mental age or whether they show an attention and/or working memory impairment. Reaction time and accuracy performance of children with DS and TD children of similar non-verbal mental age (as measured by the RCPM) were compared on visual attention tasks designed to measure sustained and transient attention under different task conditions, which included a single-target and dual-target continuous performance task, a dual target change detection task and a feature visual search task and conjunctive visual search tasks.

Overall, the results indicated that children with DS can sustain and shift attention to maintain a unique target according to the level expected of their non-verbal mental age. However, impaired ability to sustain and shift attention become apparent for detection of dual targets, suggesting impairment in attention and working memory for dual-target detection in children with DS in comparison to TD children of similar non-verbal mental age (Jarrold, Baddeley, & Phillips, 2007; Kittler, Krinsky-McHale, & Devenny, 2008; Kogan et al., 2009; Lanfranchi, Jerman, & Vianello, 2009; Vicari,
The results of the single and dual continuous performance tasks showed that children with DS were comparable to non-verbal mental age matched TD children in their ability to sustain attention for the detection of a single unique target, but were impaired in sustaining attention to accurately detect dual targets, suggesting that children with DS showed impaired working memory and/or an inability to adequately shift attention between the cue (a small picture of the target presented on the left hand side of the screen during task completion) and stimuli in order to update targets in working memory (Goharpey, Laycock, Crewther, & Crewther, 2010; Kwon et al., 2001; Landry & Bryson, 2004).

The results of the change detection task showed that children with DS required longer exposure time of P1 in order to detect colour or identity change in P2 at the same level of accuracy (75%) as TD children. Furthermore, the findings of the feature and conjunctive visual search tasks demonstrated that children with DS are able to visually search for a unique target among distracters according to the level expected of their non-verbal mental age (Wilkinson et al., 2008). However, when required to detect a target that shared two features with its surrounding distracters (CVST) and required participants to withhold their responses to distracters that had served as targets in the FVST, the DS group performed close to chance level in accuracy and missed more targets for set size 3 and 7 than the TD group, suggesting that they may have found the task “too difficult” and passively withdrawn their attention from the task (Kasari, Freeman, & Hughes, 2001; Pitcairn & Wishart, 1994; Wishart, 1993, 1996).

One explanation for the findings is the hypothesis that children with DS have an impairment in Magnocellular pathway function, which results in slow allocation of attention and deficit in working memory (Laycock et al., 2008; Laycock et al., 2007). The Magnocellular Advantage Hypothesis (Laycock et al., 2008), is based on evidence from multifocal VEPs that indicate subcortical magnocellular visual projections arrive in V1 up to 20 milliseconds prior to the arrival of the parvocellular signals (Klistorner et al., 1997), facilitating activation of the parieto-frontal attention mechanisms and object recognition through the ventral stream (Laycock et al., 2008; Laycock et al., 2007). Thus, it is possible that an impaired cortical dorsal stream in children with DS could disrupt object processing and as a result, delay their ability to detect change (Virji-Babul, Kerns, Zhou, Kapur, & Shiffrar, 2006). This delay in allocation of attention could result...
in impaired ability to maintain dual streams of information in working memory long
enough to be able to manipulate them, thus, explaining why children with DS have been
shown to successfully hold visuospatial information in short-term working memory
when cognitive load is low, but not when cognitive load is high (Jarrold et al., 2007;
Kogan et al., 2009; Lanfranchi et al., 2009; Vicari et al., 2006; Vicari & Carlesimo,
2006; Visu-Petra et al., 2007). Therefore, future research will need to investigate
whether impaired processing of dual streams of visual information in DS is primarily
due to impairment in Magnocellular pathway function or a general working memory
deficit. Furthermore, whether dual processing impairment is associated only with the
DS cognitive profile or characteristic of ID per se should also be investigated.

Error analysis between groups on the single-target CPT, dual-target CPT and
change detection task, suggests that children with DS do not use similar problem
solving strategies to TD children, even when their overall correct performance is
comparable. Error type pattern (commission and omission errors) in TD children on
single-target and dual-target tasks was suggestive of a purposeful problem solving
strategy. For example, in the single-target CPT, TD children relied on the target’s colour
to guide their responses, as indicated by significantly more commission errors to yellow
distracters (same colour as the target) than red, green or blue coloured distracters.
Additionally, in the dual-target CPT, TD children relied more on the target’s identity
than its colour as a visual cue to facilitate target detection and in the change detection
task, TD children appeared to be guided by the colour of the stimuli. It is interesting to
note that in all the stimuli conditions in the change detection task, except the Identity 1
condition, at least one of the two cartoon characters was coloured yellow or changed to
a yellow colour. In the Identity 1 condition, the two cartoon characters were coloured
red/blue and changed to blue/blue. Thus, it is possible that as a problem solving strategy,
TD children attended to and responded to the yellow colour of the stimuli as means of
facilitating their rate of responding. However, given this problem solving strategy did
not apply to the Identity 1 condition, TD children may have required greater processing
time (i.e. viewing time) to maintain and process the stimuli in the Identity 1 condition in
working memory, explaining why they required a relatively longer P1 exposure time for
the identity 1 condition (Blue Mother/Blue Father) than for any other condition.

Children with DS on the other hand, appeared to be more concerned with task
completion than task achievement when processing dual-targets, which may be a result
of the strain that task completion had on their working memory capacity. In the single-
target CPT and FVST (though it did not reach significance for the FVST), children with DS made more commission errors than TD children, suggesting that they wanted to complete the task as soon as possible, rather than as correctly as possible. On the other hand, for the detection of dual-targets, DS children made significantly more omission errors in the DCPT and CVST or required longer viewing time of P1 in the change detection task to detect identity or colour change with the same accuracy as TD children. This suggests that DS children perceived tasks requiring detection of dual-targets as “too difficult” and either passively withdrew their attention from the task or physically withdrew their attention from the task, as was the case for the DS children who were excluded from the current studies due to task incompletion (26% of the recruited DS sample).

Interestingly, children with DS did not appear to employ problem solving strategies that would increase the probability of a successful performance, such as trial and error approach, or visual cues as a facilitator to correct responses (i.e. provided in the continuous performance tasks in the form of small targets on the corner of the screen), or altering response selection to responding to only one salient feature of the target (e.g. responding to stimuli with the same colour as the target) to ease the load on working memory. This pattern of findings are supported by Lanfranchi et al. (2010) who found that children with TD employed a positional problem solving strategy (i.e. pointing to the same spatial location) when a sustained attention task became difficult, whereas children with DS did not employ this same strategy but instead continued to make errors. It is speculated that children with DS may be impaired in their ability to utilize cues, much like the children with Developmental Dyslexia in the change detection study by Rotkowski, Crewther and Crewther (2003), which is perhaps one reason why children with DS tend to rely on help from others in everyday life (even when it was not required) and be unwilling to initiate problem solving (Wishart, 1996).

One important limitation of the current study is the response methodology used to indicate the response decision in the continuous performance tasks. The tasks required participants to inhibit responding to non-targets, which does not enable the differentiation between response inhibitions that were purposeful (correct response) and those that were by chance, due to the participant being distracted. An alternative methodology for future studies may be to employ continuous performance tasks where participants are required to respond to all non-targets and withhold responding to targets, such as the Sustained Attention Response Test used by Trezise et al. (2008).
The undeveloped problem solving style of children with DS has implication for the learning and development of new skills, and ultimately has serious implications for prospective educational outcomes. Task completion is usually required of children in an educational setting, so those with DS seem to have adapted to a response strategy of passive withdrawal, with the intention of remaining compliant to teachers and completing tasks, but not with the intention of successfully problem solving (Wishart, 1996). Thus, it is likely to be important to encourage and reinforce successful problem solving in children with DS by using learning material that reduces working memory demands and contains one unique target at a time, rather than dual targets. Working memory should be actively trained in children with DS before more complex tasks are introduced into their learning. In order to aid children with DS to sustain visual attention, educational materials that employ both the child’s motor and sensory visual abilities in unison should be utilised. As demonstrated by Bello, Goharpey, Crewther and Crewther (2008), the physical manipulation of the RCPM response pieces engaged the attention of children with DS on the task and decreased the probability of them becoming distracted. This facilitated task completion. Indeed, the use of this same ‘whole body approach’ when teaching children with DS, will most likely engage their attention, increase their motivation on the task, reduce distractibility and thus facilitate their learning.
CHAPTER SIX: STUDY 4 - Allocation of attention in low functioning children with Autism

Results from experimental studies in the previous chapter showed relatively impaired dual-target processing and problem solving ability in children with Down Syndrome. Therefore, this study investigated whether a similar finding would emerge for low functioning children with Autism (i.e. LF Autism) on visual and auditory discrimination tasks, compared to typically developing (TD) children and children with Idiopathic ID of similar mental age, and if so whether such a relationship was a characteristic of the Autism diagnosis or that of general ID. We were also particularly interested in whether impairment in attention and/or working memory in children with LF Autism affects their problem solving strategies.

The current study compared visual change detection (colour or identity) and auditory discrimination in children with LF Autism to the performance of children with Idiopathic ID and TD of similar non-verbal and verbal mental age. Results showed comparable reaction time and accuracy performance in the auditory discrimination tasks and the visual change detection tasks in all groups. The TD group (who had a larger visual working memory capacity) was also faster than the ID group (LF Autism and Idiopathic ID groups combined) in detecting colour change. However, this difference was no longer present when groups were matched on working memory capacity (as measured by visual forward and visual backward digit span task). Correlation analyses showed that TD children were faster to detect a colour change with increasing working memory capacity, where as children with ID showed improved performance in all tasks with increasing non-verbal mental age, suggesting different problem solving strategies employed on the visual change detection tasks by ID and TD children. Implications of study results for the education of children with ID are discussed.

This is an original study. It is the first study in the research literature to compare children with LF Autism to TD children of similar non-verbal mental age on visual and auditory discrimination tasks. The tasks are all original and were devised especially for this study.
Introduction

Autism is a neurodevelopmental disorder characterized by a triad of symptoms including impaired social and communication skills alongside the presence of repetitive and rigid interests (American Psychiatric Association, 2000; World Health Organization, 1993). Approximately 50-70% of children diagnosed with Autism also show co-morbidity for Intellectual Disability (ID) (Matson & Shoemaker, 2009) when defined as a Wechsler Intelligence Scale - Fourth Edition (WISC-IV) score of <70 (Wechsler, 2003a) and impairment in adaptive functioning. Where and to what objects low functioning children with Autism (i.e. LF Autism) allocate their attention impacts their behaviour and what they learn from their surrounding environment. Thus, investigating whether children with LF Autism allocate their attention to visual and auditory stimuli similarly to TD children of similar non-verbal mental age will inform the design and application of educational material aimed at enhancing their learning.

It has consistently been shown in the literature that high functioning children with Autism (i.e. HF Autism; those without ID) tend to allocate their visual attention more to the local elements of a visual scene rather than the global picture (Frith, 1989; Happé, 1999; Happe & Frith, 1996; Happé & Frith, 2006; Laycock et al., 2008; Mottron & Burack, 2001; Mottron, Dawson, Soulieres, Hubert, & Burack, 2006; Plaisted et al., 1998b; Sutherland & Crewther, 2010). This is evident from numerous studies reporting superior auditory discrimination (O’Riordan & Passetti, 2006) and superior visual search performance in individuals with HF Autism in comparison to Typically Developing (TD) individuals of similar non-verbal and verbal mental age in tasks such as the embedded figures (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983), visual search (M O’Riordan, 2004; M O’Riordan & Plaisted, 2001; Plaisted et al., 1998b), block design (Rumsey & Hamburger, 1988; Shah & Frith, 1993) and the reproduction of impossible figures (Mottron et al., 1999). However, despite the large prevalence of children with LF Autism (Matson & Shoemaker, 2009), research on the visual and auditory attention allocation of these children is surprisingly limited.

The ability to visually search for a target among distracters and the ability to detect changes in a stimuli have been shown to correlate with the same underlying mechanism of focused visual attention (Rensink, 2000). Change detection is often measured using a gap paradigm, which mimics the change blindness that occurs during blinking or when making a saccade (Rensink, O'Regan, & Clark, 1997). In a typical change detection task using the gap paradigm, two visual images, presented side by side
are flashed on a computer screen twice, with a brief interruption (blank screen) in between them. The second presentation of the stimuli includes either a change in one of the images (e.g. change in colour, orientation, part deletion etc) or no change. Change detection is automatic and effortless when the interval between the two visual presentations is short enough (less than 80 ms) to create a transient motion signal that draws attention immediately to the location of change. However, when the interval time between the two visual scenes exceeds 100 ms, the motion signal is eliminated and change is no longer easily detected. Instead, the visual scene must be consciously explored and stored in short-term memory, making change detection an interchangeable measure of attention and short-term encoding for visual memory (Rensink et al., 1997).

It would be expected that children with HF Autism with superior visual discrimination ability (Burack et al., 2009; H. Smith & Milne, 2009), enhanced local processing and impairments in scene schemas (Loth, Gómez, & Happé, 2008) would allocate attention differently to TD children, and that this could be measured in terms of rate and accuracy by which a change in a stimuli was detected. However, despite superior visual search in children with HF Autism, there have been mixed findings in the literature on the ability of HF individuals with Autism to detect change compared to TD individuals of similar mental age. Indeed, the performance of HF children with Autism on a change detection task is largely dependent on the kind of changes being detected; suggesting that object saliency may differ between individuals with HF Autism and TD individuals.

Fletcher-Watson, Leekam, Turner and Mozon (2006) found that individuals with HF Autism were comparable to TD children in the speed and accuracy by which they detected central changes to an object but were slower to detect peripheral changes in a naturalistic scene. Loth, Gómez and Happé (2008) found that individuals with HF Autism did not readily notice when a contextually appropriate object (e.g. chair in a living room) was replaced by an contextually inappropriate object (e.g. bath tub), as readily as TD individuals, indicating little effect of contextual expectations in the ability of individuals with HF Autism to detect change, consistent with reports that children with Autism tend to attend to irrelevant objects in the environment. New and colleagues (2010) also found that children and young adults with HF Autism were comparable to TD children and young adults in detecting changes to animals and people in a naturalistic scene more often than changes to objects, which is contrary to the view of Autism as being characterized by social impairment. More recently, Sheth et al. (2011)
found similar performance between children and adolescents with Autism and TD children and adolescents on a change detection task utilizing social cues and a similar developmental trend in change detection performance.

Only one study (Burack et al., 2009) to date has investigated change detection task performance in children with LF Autism. Using a gap paradigm, Burack et al. found that LF children with Autism matched to TD children on non-verbal mental age, detected changes in the colour, orientation or partial deletion of 24 pairs of everyday objects with similar speed and accuracy as the TD children. However, correlations analyses between error rate and non-verbal mental age in the TD and Autism groups showed that TD children made less errors with increasing development, whereas children with Autism continued to make the same number of errors, suggesting an atypical developmental trajectory for attention allocation in children with Autism. The study by Burack et al. did not measure the short-term and working memory capacity of TD and Autism groups to rule out the possibility that lack of improvements in change detection in the Autism group may have been due to limited short-term and working memory capacity and hence limited ability to encode a visual scene with increasing development.

The aim of the current study was to investigate visual change detection (using a task based on the gap paradigm) and auditory discrimination in children with LF Autism in comparison to TD and Idiopathic ID of similar non-verbal mental age, as measured by the Raven’s Coloured Progressive Matrices (Raven et al., 1995) and receptive language as measured by Peabody Picture Vocabulary Test – Third Edition (Dunn & Dunn, 1997) and short-term and working memory capacity, as measured by visual forward and backward digit span tasks. Both auditory and visual discrimination were investigated, in order to determine whether children with LF Autism showed superior processing of stimuli from either the visual or auditory modality. In order to ensure that novelty did not influence the saliency of any stimuli, familiar everyday stimuli were chosen. The visual change detection task stimuli included cartoon characters, the Auditory identification task stimuli included household and animal sounds, and the Auditory Gender Identification task stimuli were male and female voices. The use of human voices in the Auditory Gender Identification task also served a socially driven purpose of investigating whether children with Autism utilize a person’s voice in order to identify them (in this case according to their gender) or whether they tend to rely solely on the visual cues.
Children with LF Autism were compared to TD children and children with Idiopathic ID on reaction time and accuracy performance on the visual and auditory tasks. Within group comparisons for performance on the visual colour and identity change detection tasks were also employed in order to determine whether groups showed preferential allocation of visual attention to either the target’s identity or colour. The TD group had a larger short-term memory capacity than the Idiopathic ID group and a larger working memory capacity than the LF Autism group. Thus, groups were also matched on memory capacity and compared again on the visual and auditory tasks to determine whether any difference in groups performances could be accounted for by differences in short-term and/or working memory capacity. Furthermore, correlation analyses were conducted between non-verbal mental age, digit span task performance and performance (reaction time and accuracy) on the visual change detection tasks for all groups in order to determine whether improvements in ID and TD groups’ ability to detect change is associated with increasing maturation and/or short-term and working memory capacity. It was hypothesized that (1) consistent with results of past studies, children with LF Autism would perform (i.e. reaction time and accuracy) according to the level expected of their non-verbal mental age and receptive language ability on the visual colour and identity change detection tasks and the auditory discrimination tasks employed in the current study; (2) reaction time and accuracy on the change detection tasks would correlate positively with short-term and working memory and non-verbal mental age for all groups, suggesting similar problem solving strategy employed by children with LF Autism and children with Idiopathic ID and TD children; and (3) Children with Autism would be slower and less accurate in differentiating between male and female voices in the Auditory gender identification task compared to TD and ID children.

Method

Participants

Thirty-six TD children (18 males and 18 females), 17 children with LF Autism (17 males) and 18 children with Idiopathic ID (12 males and 6 females) participated in the current study. TD participants were recruited from a mainstream Catholic primary school and children with LF Autism and Idiopathic ID were recruited from two specialist schools in middle socio-economic areas of Melbourne, Australia. Groups were matched on non-verbal mental age, as measured by the Raven’s Coloured Progressive Matrices (Raven et al., 1995), and receptive language, as measured by the Peabody
Picture Vocabulary Test – Third Edition (Dunn & Dunn, 1997). Groups were significantly different on short-term memory capacity (as measured by visual forward digit span task), working memory capacity (as measured by visual backward digit span task) and chronological age (see Table 1).

Inclusion criteria included demonstrating understanding of task instructions, normal colour vision and normal or corrected to normal vision. Twenty children with LF Autism were excluded from the study on the basis of inadequate comprehension of the task instructions. As a requirement of special school entry, participants with LF Autism and Idiopathic ID were previously diagnosed by a psychologist with a neurodevelopmental disorder according to the DSM-IV criteria (American Psychiatric Association, 2000), and ID based on an IQ <70 on the Wechsler Intelligence scale - Third Edition (Wechsler, 1992).

Ethics approval for the study was obtained from the Swinburne University of Technology Ethics Committee. Permission to conduct testing in the school was obtained from the Directorate of School Education (Victoria), the Catholic Education Office Victoria and the Principal of each school. Individual parental or guardian consent was obtained prior to testing and all children were free to withdraw from testing at any time.

Table 1
Means (M; ranges) and standard deviations (SD) for chronological age (CA), non-verbal mental age (NVMA), receptive language mental age (VMA), Visual Forward Digit Span (VDSF) and Visual Backward Digit Span (DSB) for the low functioning Autism (LFA), Idiopathic Intellectual Disability (IID) and Typically Developing (TD) groups

<table>
<thead>
<tr>
<th>Group</th>
<th>CA M (range)</th>
<th>NVMA M (range)</th>
<th>VMA M (range)</th>
<th>DSF M (range)</th>
<th>DSB M (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFA</td>
<td>10.4 (7-15)*</td>
<td>8.9 (5-12)</td>
<td>6.1 (3-10)</td>
<td>4 (2-5)</td>
<td>3 (1-5)*</td>
</tr>
<tr>
<td>IID</td>
<td>12.5 (7-18)*</td>
<td>7.9 (5-12)</td>
<td>7.1 (4-9)</td>
<td>3 (1-5)*</td>
<td>1.4</td>
</tr>
<tr>
<td>TD</td>
<td>7.9 (5-11)</td>
<td>8.7 (5-12)</td>
<td>7.1 (4-9)</td>
<td>5 (3-6)</td>
<td>4 (2-7)</td>
</tr>
</tbody>
</table>

*Comparison to TD group significant at \( p < .05 \)
Materials

Visual and auditory stimuli for the visual colour change detection task, visual identity change detection task, auditory discrimination task and auditory gender identification task were designed using VPixx version 1.5 and presented to participants on a 15-inch iMac computer. The VPixx program automatically recorded participants’ motor reaction time and accuracy per task trial onto a text file. Participants’ colour visual integrity was assessed using the Ishihara Test for Colour-Deficiency. A high contrast chart was used to measure visual acuity both monocularly and where possible, binocularly. Raven’s Coloured Progressive Matrices test (RCPM) (Raven et al., 1995) was used as a measure of non-verbal mental age, the Peabody Picture Vocabulary Test – Third Edition (PPVT – Third Edition) (Dunn & Dunn, 1997) was used as a measure of receptive language ability and the visual forward and backward digit span tasks were used to measure short-term and working memory capacity.

Visual colour change detection task

The visual colour change detection task consisted of faces of two familiar cartoon characters (Son, Daughter, Father and Mother), coloured Red, Yellow, Green or Blue. For each trial, pictures of two cartoon characters were flashed on the screen twice for 4 seconds each time. A fixation cross on a blank screen was presented in between the presentations for 250ms. The second stimuli presentation, which lasted for 4 seconds, contained either a colour change to one of the stimuli or no change (see Figure 1A). The task lasted 2 minutes and was made up of a total of 12 trials, 9 of which contained a colour change and 3 of which there was no change. Reaction time and accuracy measures were used to record detection of change.

Visual identity change detection task

The visual identity change detection task (i.e. Identity CD task) was the same as the visual colour change detection task, except cartoon characters changed their identity rather than their colour (see Figure 1B).

Auditory discrimination task

The auditory discrimination task consisted of a 1 sec presentation of either an animal sound (barking or meowing), or a household sound (toaster releasing bread or toilet flushing), presented consecutively and in random order. The task lasted 2 minutes and was made up of 24 trials, with each of these four unique sounds presented a total of 6 times each.
Auditory gender identification task

The auditory gender identification task consisted of a male or a female voice asking “Am I a girl?” or “Am I a boy?” consecutively and in random order. Each stimulus lasted one second in duration. Three different male and three different female voices were used. The task lasted 2 minutes and was made up of 24 trials, with each stimuli being presented 4 times. For half the trials, a male voice asked “Am I a girl?” (6 trials) or “Am I a boy?” (6 trials). For the other half of the trials, a female voice asked “Am I a girl?” (6 trials) or “Am I a boy?” (6 trials).

Figure 1. Schematic illustration of (A) the visual colour change detection task (colour change occurred in P2) and (B) the visual identity change detection task (change occurred in P2). P1=first presentation, Fixation= blank screen with cross, followed by P2= re-presentation of the stimuli with either a change or no change to one of the stimuli.

Procedure

Participants were tested individually in an empty classroom at their schools during school hours, across two separate sessions. In the first session participants underwent an auditory and visual screening and then completed the RCPM (Raven et al., 1995), PPVT – Third Edition (Dunn & Dunn, 1997) and the visual forward and visual backward digit span tasks. For each of the 36 items of the RCPM, participants were required to select one of six alternative patterns that would successfully complete a matrix. For the PPVT – Third Edition test, participants had to identify one of four pictures that best described the verbal label spoken by the experimenter. For the visual
forward digit span task, participants were required to view digits presented one at a time (with a 500 ms on/off presentation time) on a computer screen and type the digits in the same order that they were presented. For the visual backward digit span task, participants were required to type the digits they saw on the computer screen in the reverse order that they were presented. Participant’s digit span score was the number of digits they could reproduce correctly without making any mistakes. In the second session, participants completed the visual colour change detection task, visual identity change detection task, auditory gender identification task and the auditory discrimination task, in a pseudo random counterbalanced order. Each task was completed twice. For all task trials, participants were required to provide either a “yes” or “no” response, by pressing the ‘z’ key on the computer keyboard covered by a green tick for a “yes” response, or the ‘/’ key covered by a red cross for a “no” response. For the visual colour and visual identity change detection tasks, participants indicated whether there was a colour or identity change in each pair of stimuli presented. For the auditory identification task, participants answered the auditory questions presented and for the auditory discrimination tasks, participants indicated whether or not they heard an animal sound.

The computer recorded participants’ motor reaction time and frequency of responses for all trials. Participants completed practice trials for each task and commenced testing once the experimenter believed that participants had displayed a sufficient understanding of task instructions. Positive reinforcement and praise were only provided during practice trials. Participants completed each task in silence, while the examiner sat behind them, well out of their peripheral vision in order to minimize distraction.

Data Analysis

Mean motor reaction time (ms) for correct responses and percentage of correct responses were recorded for each task trial. Violations of the assumptions of normality, homogeneity of variance and sphericity were observed in the data and thus, a non-parametric version of between group and within group tests (i.e. Kruskal-Wallis H test and Wilcoxon Signed-Rank test) were employed. An adjusted alpha level of .05 was used to control for Type 1 error.

Results

Analysis of matching variables

In order to determine whether children with LF Autism detect colour and
identity change and discriminate auditory stimuli according to their developmental level, children with LF Autism were matched to children with Idiopathic ID and TD children on non-verbal mental age (as measured by total score correct on the RCPM) and receptive language (as measured by total score correct on the PPVT-Third Edition). Participant’s RCPM total correct score was first transformed into their equivalent non-verbal mental age using the 1980 Norms for Queensland (Australia), based on the 50th percentile (classified as “intellectually averaged”) level for TD children between 5.5-10.5 years, in the RCPM manual (Raven et al., 1995). Total correct score for the PPVT – Third Edition was also calculated.

A between group comparison was then conducted and showed no significant difference between groups on non-verbal mental age \((F(2,68)= 1.56, p >.05)\) and receptive language \((F(2,36)= 1.07, p >.05)\). As expected, children with LF Autism and Idiopathic ID were significantly older in chronological age than the TD children \((F(2,68)= 21.31, p >.05)\) (see Table 1). Children with LF Autism also had significantly less working memory capacity than the TD children \((F(2,39)= 4.07, p <.05)\) and children with Idiopathic ID had significantly less short-term memory capacity than the TD group \(\chi^2 = 7.62, p < .05\). As a result of this matching process, the TD children who participated in the study are representative of the lower scores on the RCPM and PPVT-Third Edition in their chronological age range.

**Between-groups comparison of mean reaction time and percentage of correct responses on the visual and auditory tasks**

In order to determine whether children with LF Autism could discriminate visual and auditory stimuli similarly to children with Idiopathic ID or TD children, a Kruskal-Wallis H test was used to compare the mean reaction time and accuracy performance (i.e. correct target detection) of children with LF Autism on the visual and auditory tasks to children with Idiopathic ID and TD children. Results showed no significant difference in mean reaction time or percentage of correct response between the LF Autism, Idiopathic ID and TD groups on the visual colour or identity change detection tasks or the auditory gender identification and auditory discrimination tasks (see Table 2 and Table 3).

Thus, task performances of the LF Autism and the Idiopathic ID groups were collated (and henceforth will be referred to as the ‘ID group’) and compared to the TD group in order to determine whether there were visual or auditory processing differences associated with the ID diagnosis. Results of the Kruskal-Wallis H tests showed no
significant difference in mean reaction time or percentage correct between the ID group and the TD group for either the visual or auditory tasks.

Table 2
Means (M) and standard deviations (SD) for motor reaction time (sec) performance on the Visual Colour Change Detection task (VIS COL), the Visual Identity Change Detection task (VIS ID), The Auditory Gender Identification task (AUD ID) and the Auditory Discrimination task (AUD DIS), by the Low Functioning Autism (LFA), Idiopathic Intellectual Disability (IID) and Typically Developing (TD) groups

<table>
<thead>
<tr>
<th>Group</th>
<th>VIS COL M</th>
<th>VIS COL SD</th>
<th>VIS ID M</th>
<th>VIS ID SD</th>
<th>AUD ID M</th>
<th>AUD ID SD</th>
<th>AUD DIS M</th>
<th>AUD DIS SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFA</td>
<td>2.40</td>
<td>.30</td>
<td>2.40</td>
<td>.47</td>
<td>1.73</td>
<td>.65</td>
<td>2.81</td>
<td>.38</td>
</tr>
<tr>
<td>IID</td>
<td>2.41</td>
<td>.59</td>
<td>2.32</td>
<td>.63</td>
<td>1.57</td>
<td>.54</td>
<td>2.83</td>
<td>.57</td>
</tr>
<tr>
<td>TD</td>
<td>2.28</td>
<td>.30</td>
<td>2.39</td>
<td>.42</td>
<td>1.53</td>
<td>.40</td>
<td>2.84</td>
<td>.33</td>
</tr>
</tbody>
</table>

Table 3
Means (M) and standard deviations (SD) for percentage of correct responses on the Visual Colour Change Detection task (VIS COL), the Visual Identity Change Detection task (VIS ID), the Auditory Gender Identification task (AUD ID) and the Auditory Discrimination task (AUD DIS), by the Low Functioning Autism (LFA), Idiopathic Intellectual Disability (IID) and Typically Developing (TD) groups

<table>
<thead>
<tr>
<th>Group</th>
<th>VIS COL M</th>
<th>VIS COL SD</th>
<th>VIS ID M</th>
<th>VIS ID SD</th>
<th>AUD ID M</th>
<th>AUD ID SD</th>
<th>AUD DIS M</th>
<th>AUD DIS SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFA</td>
<td>70.83</td>
<td>19.54</td>
<td>73.08</td>
<td>19.75</td>
<td>91.06</td>
<td>9.96</td>
<td>95.19</td>
<td>6.30</td>
</tr>
<tr>
<td>IID</td>
<td>71.43</td>
<td>18.40</td>
<td>74.77</td>
<td>21.76</td>
<td>92.08</td>
<td>8.70</td>
<td>89.53</td>
<td>6.77</td>
</tr>
<tr>
<td>TD</td>
<td>79.51</td>
<td>13.51</td>
<td>79.79</td>
<td>15.06</td>
<td>93.35</td>
<td>8.44</td>
<td>93.27</td>
<td>6.84</td>
</tr>
</tbody>
</table>

However, group differences in working memory performance, may have confounded the findings. Thus, the two highest (in the TD group) and the two lowest scores (in each of the ID groups) on the digit span tasks were removed from the data set. Between groups analyses were conducted and showed no significant difference between groups on non-verbal mental age ($F(2,62)= .89, p >.05$), receptive language ability ($F(2,30)= .83, p >.05$), short-term memory capacity ($\chi^2 = 2.89, p > .05$) and working
memory capacity \((F(2,33)= 1.13, p > .05)\). Groups were still significantly different on chronological age \((F(2,62)= 22.41, p < .05)\) (see Table 4).

In order to determine whether higher working memory performance in the TD group contributed to their faster rate of colour change detection compared to the ID group, a Kruskal-Wallis H test was conducted comparing groups on their performance (reaction time and accuracy) for the visual and auditory tasks. Results of the comparison showed no significant difference between groups for reaction time or accuracy performance on the visual colour or identity change detection task, the auditory gender identification task and the auditory discrimination task.

### Table 4
*Means (M; ranges) and standard deviations (SD) for chronological age (CA), non-verbal mental age (NVMA), receptive language mental age (VMA), visual Forward Digit Span (VDSF) and visual Backward Digit Span (DSB) for the low functioning Autism (LFA), Idiopathic Intellectual Disability (IID) and Typically Developing (TD) groups*

<table>
<thead>
<tr>
<th>Group</th>
<th>CA M (range)</th>
<th>NVMA M (range)</th>
<th>VMA M (range)</th>
<th>VDSF M (range)</th>
<th>DSB M (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFA</td>
<td>10.4 (7-15)*</td>
<td>2.7</td>
<td>8.9 (5-12)</td>
<td>1.9</td>
<td>6.3 (3-10)</td>
</tr>
<tr>
<td>IID</td>
<td>12.5 (7-18)*</td>
<td>3.4</td>
<td>7.6 (5-12)</td>
<td>1.8</td>
<td>7.4 (5-9)</td>
</tr>
<tr>
<td>TD</td>
<td>8.0 (5-11)</td>
<td>1.6</td>
<td>8.6 (5-12)</td>
<td>1.8</td>
<td>6.6 (4-11)</td>
</tr>
</tbody>
</table>

*Comparison to TD group significant at \(p < .05\)

**Within-groups comparison of mean reaction time and percentage of correct responses on the visual colour and identity change detection task**

In order to determine whether children with ID (LF Autism and Idiopathic ID combined) showed preferential allocation of attention to either the stimuli’s colour or identity, in comparison to TD children, a Wilcoxon Singed-Rank test was used to compare mean reaction time and percentage correct on the visual colour change detection task and the visual identity change detection task for the ID and TD groups. When the TD group had a larger working memory capacity than the LF Autism or Idiopathic ID group, results showed that children with ID were significantly slower to detect changes in the stimuli’s colour than its identity \((z = -2.13, p < .05)\), where as TD children did not show such an effect \((z = -1.78, p > .05)\). However, when groups were
matched on short-term and working memory capacity, results of Wilcoxon Singed-Rank test showed no significant difference in the rate or accuracy by which the ID or TD group detected changes to the stimuli’s colour compared to changes to its identity.

**Pearson’s r correlation between performance on visual change detection tasks and non-verbal mental age and short-term and working memory for all groups matched on short-term and working memory capacity**

Pearson’s r correlations were used in order to determine whether improvements in rate and accuracy by which children with ID and TD children detected a change in colour or identity was associated with increases in cognitive development (non-verbal) and/or memory capacity (i.e. short-term or working memory capacity). For the TD group, rate of colour detection was negatively correlated with working memory performance ($r = -0.60, p < .05$), suggesting a faster detection rate of colour change with increasing working memory capacity in TD children. For the ID group, increasing non-verbal mental age was associated with faster ($r = -0.41, p < .05$) and more accurate ($r = 0.56, p < .001$) detection of colour change, as well as faster ($r = -0.38, p < .05$) and more accurate detection of identity change ($r = 0.36, p < .05$).

**Discussion**

The aim of this study was to investigate whether children with LF Autism detect visual change (identity or colour) and discriminate auditory stimuli at the level expected of their non-verbal mental age. Results of the study showed that when matched on non-verbal mental age, receptive language, short-term and working memory capacity, children with LF Autism were comparable to children with Idiopathic ID and TD children in their performance (reaction time and accuracy) on the visual change detection tasks and auditory discrimination tasks, consistent with Burack et al. (2009) study findings. Children with LF Autism did not show superior visual discrimination in comparison to TD children, as frequently observed in children with HF Autism (Joliffe & Baron-Cohen, 1997; Mottron et al., 1999; O’Riordan, 2004; O’Riordan & Plaisted, 2001; Plaisted et al., 1998b; Rumsey & Hamburger, 1988; Shah & Frith, 1983, 1993). Interestingly, even though the Auditory gender identification task used a more socially salient stimuli (human voices) than the Auditory discrimination task (household and animal sounds), children with LF Autism did not show relatively significant delays or inaccuracies in identifying which gender each voice belonged to, as was expected. This suggests that children with LF Autism performed at mental age level when identifying a person’s gender, from the sound of the person’s voice.
However, despite similar task performance between the ID and TD groups, within group analyses showed that when the ID group (LF Autism and Idiopathic ID groups combined) had significantly less short-term or working memory capacity than the TD group, they were significantly slower at detecting changes in a stimuli’s colour than its identity, whereas TD group did not show a significant preferential allocation of visual attention to either colour or identity. However, this within group difference disappeared when the ID group was matched to the TD group on short-term and working memory capacity (and their short-term and working memory capacity increased slightly as a result). This suggests that children with ID find an object’s colour less salient than its identity and hence require greater short-term and working memory capacity in order to effectively code, store and retrieve information regarding a stimuli’s colour than its identity.

The findings are consistent with findings of a recent study (Sutherland & Crewther, 2010) which showed that individuals who scored high on the Autism Spectrum Quotient showed impaired detection of the global component of a Navon figure when its colour was incongruent to the colour of its local component, than when it was congruent, suggesting a deficit in colour discrimination is associated with Autism characteristics. However, it cannot be determined from the findings of the current study whether children with LF Autism or Idiopathic ID are developmentally different in the rate at which they allocate their attention to an object’s colour or whether an object’s identity has been artificially allocated more saliency or importance to children with ID by their carers and educators than object attributes (such as colour). Thus, the preferential allocation of attention to object identity rather than colour in children with ID may be a result of environmental training of their attentional focus rather than reflective of their developmental trajectory. Future studies could investigate this hypothesis and whether the study findings are characteristic only of LF Autism and Idiopathic ID diagnosis or of individual with ID per se.

Furthermore, the results of the correlation analyses implied faster detection of colour changes with increased working memory capacity in TD children, which suggests that the ability to encode, store and retrieve information from working memory plays an important role in the ability of TD children to detect change. This was again demonstrated when TD children’s faster rate of detecting colour changes in comparison to the ID group disappeared once they were matched to the ID group according to a lower working memory capacity. For the ID group on the other hand, an improvement
in rate and accuracy of colour and identity change detection with increasing non-verbal mental age was found. The results suggest that despite similar performance between the ID and TD groups on the change detection tasks, children with ID do not use the same strategy to detect change as TD children. Whereas TD children appear to be improving their ability to detect colour changes with increasing working memory capacity, children with ID may not be relying as much on their working memory to detect such changes. Indeed, many studies in the literature have shown that children with ID show impairments in working memory capacity (Van der Molen, Van Luit, Van der Molen, Klugkist, & Jongmans, 2010), perhaps explaining why change detection performance and working memory was not significantly correlated in ID groups, as it was in the TD group. Even though we assume short-term and working memory capacity were important in the ability of ID children to detect colour changes, we suspect that with increasing cognitive development (i.e. non-verbal mental age), children with ID are relying on a different problem solving strategy to TD children. Future studies could investigate this hypothesis further, as the findings could benefit the education of children with ID.

The results of the current study have important practical implications for the education of children with LF Autism and Idiopathic ID. They suggest that computerised educational programs involving visual changes relating to character and object identity, for example, letters, and auditory discrimination of familiar sounds are likely to be of limited value if the means of attracting and sustaining attention to facilitate learning and remembering are not elucidated better. Certainly, colour changes in a visual array need to be large in the centre of the screen and need to change reasonably quickly so transient onset is detected and change detection is facilitated rather than obscured in children with LF Autism and Idiopathic ID. When teaching children with LF Autism or Idiopathic ID, objects categorized according to identity rather than colour is preferred. A recent study has shown that the working memory capacity of adolescents with ID improved with working memory training (Van der Molen et al., 2010). Thus, it is possible that working memory training in children with LF Autism or Idiopathic ID may be associated with improvements in the detection of colour changes, as has been shown to be the case for TD children in the current study. Further research could explore the object properties that are most salient to children with Autism and ID using eye tracking technology, as a means of determining where in the visual scene, attention is allocated. Indeed, further investigation of visual and
auditory change detection in children with ID of different etiologies, is desirable in order to further understand how to enhance educational learning in these children by making subtle changes in the environment more salient and noteworthy and memorable to them.
CHAPTER SEVEN: STUDY 5 - Multisensory integration in low functioning children with Autism is more representative of non-verbal mental age than clinical diagnosis

Chapter 6 demonstrated that children with Intellectual Disability (ID) (low functioning Autism and Idiopathic ID) discriminate visual and auditory information according to the level expected of their non-verbal mental age, but show slower detection of colour changes when impaired in short-term and/or working memory capacity. An important question that remains is whether they are able to integrate multisensory information comparably to typically developing (TD) children of similar non-verbal mental age. Multisensory integration is an important ability in every day functioning, learning and problem solving, as it is rarely the case that information is presented to one modality alone. Despite its importance, multisensory integration has seldom been investigated in TD children and certainly not in children with ID, especially those with low functioning Autism (LF Autism). Such information is very useful for determining best educational practice for children with ID and thus has implications for the conceptualisation of ID. Therefore, the fifth empirical study of this thesis investigated multisensory integration in children with LF Autism in comparison to children with Idiopathic ID and TD children of similar non-verbal mental age, receptive language, short-term memory and working memory capacity.

Two audiovisual tasks were devised to test groups on speed and accuracy detection of congruent pictures of animals and animal sounds or animal names. The results of the study showed similar task performance between groups, suggesting that children with LF Autism integrate multisensory stimuli according to the level expected of their non-verbal mental age, receptive language and short-term and working memory capacity. Implications for the use of multisensory stimuli in education of children with LF Autism are discussed.

This is an original study. It is the first study in the research literature to compare children with LF Autism to TD children of similar non-verbal mental age on a multisensory task. The tasks are all original and were devised especially for this study.
Introduction

Autism is the most severe form of the Autism Spectrum Disorders and is primarily characterized by a deficit in social and communication skills, and excessive repetitive and rigid behaviours (American Psychiatric Association, 2000). Though not yet considered a primary characteristic, an abnormal sensory profile, including hyper-responsiveness and/or hypo-responsiveness to sensory stimuli, is commonly observed in individuals with Autism (Baranek, Boyd, Poe, David, & Watson, 2007; Baranek, Parham, & Bodfish, 2005; Bettison, 1996; G. Dawson & Watling, 2000; Grandin, 1992, 1997; O'Neil & Jones, 1997; Rosenhall, Nordin, Sandström, Ahlsén, & Gillberg, 1999) and can significantly limit their social interaction, exploration of their environment and learning opportunities (Baranek et al., 2002). An abnormal sensory profile has also been suggested to give rise to impaired multisensory integration processing in children with Autism (Dowell & Wallace, 2009; Foss-Feig et al., 2010; Iarocci & McDonald, 2006).

Multisensory integration has been shown to be a more effective means of learning from the environment than processing information from one sensory modality alone (Lehmann & Murray, 2005), as the integration of cross-modal stimuli is usually faster than processing information from only a single modality (Barutchu, Crewther, & Crewther, 2008; Calvert, 2001; Stein & Meredith, 1993). This has given rise to the two main models of Multisensory integration: the Race model (Raab, 1962) and the co-activation model (Miller, 1982). According to the race Model, multiple sensory perceptions are detected and processed in separate brain pathways, with the one that is processed fastest, initiating the perceptual response (Raab, 1962). The co-activation Model of multisensory integration, on the other hand, suggests that when multiple sensory stimuli are presented simultaneously, each unisensory stimuli activates separate neural networks, which combine together in multimodal neurons, reaching perception of the multisensory information faster at a lower threshold limit. Thus, multisensory processing in adults is faster than unisensory processing because the response criterion is reached faster when inputs from multiple rather than one sensory modality are processed simultaneously (Miller, 1982).

Barutchu et al. (2008) found that by 10-11 years of age, a developmental transition from the race model to the co-activation model process of multisensory facilitation occurred for approximately 40% of the population investigated. It is currently unknown whether the multisensory integration process in children with Autism follows this typical developmental trajectory, however, given evidence of
superior visual search ability in high functioning children with Autism (i.e. HF Autism; who do not have intellectual disability) (Jolliffe & Baron-Cohen, 1997; Mottron et al., 1999; O’Riordan, 2004; O’Riordan et al., 2001; Plaisted et al., 1998b; Shah & Frith, 1983) may suggest a reliance on the visual modality in Autism, reflective of the race model of multisensory processing.

The pattern of findings presented to date, suggest that multisensory integration in high functioning children with Autism is intact for simple/everyday stimuli (i.e. object properties such as size match/mismatch), but impaired for complex/social stimuli (i.e. involving human faces or speech congruency) (Dowell & Wallace, 2009; Foss-Feig et al., 2010; Lovaas et al., 1971; Loveland et al., 1995; Mongillo et al., 2008; E. Smith & Bennetto, 2007; Van der Smagt, Van Engeland, & Kemner, 2007; Williams, Massaro, Peel, Bosseler, & Suddendorf, 2004). However, few studies have investigated multisensory integration in low functioning children with Autism (i.e. LF Autism, with ID), who make up approximately 50-70% of individuals with Autism (Matson & Shoemaker, 2009). One such study was by Lovaas and colleagues (1971) who found that compared to TD children and children with Idiopathic ID, children with LF Autism showed a deficit in multisensory integration. Using the preferential looking paradigm, Bebko, Weiss, Demark and Gomez (2006) found that children with LF Autism displayed more difficulty in cross modal matching of faces to corresponding audio information than chronological and verbal age matched children with Down’s syndrome (DS). However, Lovass et al. (1971) or Bebko et al. (2006) did not match groups on non-verbal mental age in their studies. Thus, it is currently unclear whether differences between groups in level of mental maturation accounted for group differences in task performance.

The aim of the current study was to investigate whether children with LF Autism integrate multisensory stimuli according to their maturation level. To test this aim, the performance (reaction time and accuracy) of children with LF Autism on two multisensory tasks were compared to children with Idiopathic ID and TD children of similar non-verbal mental age, receptive language ability, short-term and working memory capacity. Within group analyses were also conducted on task performance in order to determine whether groups processed stimuli from each task similarly. Consistent with previous study results of intact multisensory integration of non-social stimuli in children with HF Autism (Dowell & Wallace, 2009; Foss-Feig et al., 2010; Lovaas et al., 1971; Loveland et al., 1995; Mongillo et al., 2008; E. Smith & Bennetto,
2007; Van der Smagt et al., 2007; Williams et al., 2004), it was hypothesized that the LF Autism group and Idiopathic ID group would perform comparably to the TD groups on integration of simple audiovisual stimuli, in the Audiovisual Animal Sound task, but show relatively impaired performance on the Audiovisual Animal Name task, because it involves more complex semantic matching. As children with ID usually show deficits in language and communication, we expected that the Audiovisual Animal Name task would be more difficult for them to complete than for TD children of similar non-verbal mental age. For the present investigation, stimuli included animal images and sounds, as these were expected to have greater familiarity and hence greater immediacy of recognition. The design of tasks was also similar to those employed in the multisensory literature with TD children and children with HF Autism (Ciesielski, Knight, Prince, Harris, & Handmaker, 1995; Mongillo et al., 2008; Van der Smagt et al., 2007), in order to enable comparability of the results to the wider multisensory literature.

Method

Participants

Thirty-seven TD children (19 males and 18 females) aged 5-11 years, 17 children with LF Autism (17 males) aged 8-14 years and 20 children with Idiopathic ID (13 males and 7 females) aged 6.75-18.10 years who participated in the current study were included in the analyses. Twenty children with LF Autism were excluded from the study on the basis of inadequate comprehension of the task instructions. Inclusion criteria for the current study included understanding of task instructions, ability to label all stimuli used in the tasks, normal colour vision and normal or corrected to normal vision. Groups were matched on non-verbal mental age, as measured by the Raven’s Coloured Progressive Matrices test (Raven et al., 1995), receptive vocabulary, as measured by the Peabody Picture Vocabulary Test - Third Edition (Dunn & Dunn, 1997), short-term memory (as measured by visual forward digit span task) and working memory (as measured by visual backward digit span task). Groups were significantly different on chronological age (see Table 1).

TD participants were recruited from a mainstream Catholic primary school and children with LF Autism or Idiopathic ID were recruited from two specialist schools in middle socio-economic areas of Melbourne, Australia. Participants with LF Autism and Idiopathic ID were previously diagnosed with a neurodevelopmental disorder by a psychologist according to the DSM-IV-TR criteria (American Psychiatric Association, 2000), and with ID based on an IQ <70 on the Wechsler Intelligence scale for children-
Third Edition (Wechsler, 1992), as a requirement of entry into their specialist school. Ethics approval for the study was obtained from the Swinburne University of Technology Ethics Committee. Individual parental or guardian consent was obtained prior to testing and all children were free to withdraw from testing at any time.

Table 1

Means (M; ranges) and standard deviations (SD) for chronological age (CA), non-verbal mental age (NVMA) and verbal mental age (VMA) for the low functioning Autism (LFA), Idiopathic Intellectual Disability (IID) and Typically Developing (TD) groups

<table>
<thead>
<tr>
<th>Group</th>
<th>CA</th>
<th>NVMA</th>
<th>VMA</th>
<th>DSF</th>
<th>DSB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>LFA</td>
<td>10.4 (7-15)*</td>
<td>2.7</td>
<td>8.9 (5-12)</td>
<td>1.9</td>
<td>6.3 (3-10)</td>
</tr>
<tr>
<td>IID</td>
<td>12.5 (7-18)*</td>
<td>3.4</td>
<td>7.6 (5-12)</td>
<td>1.8</td>
<td>7.4 (5-9)</td>
</tr>
<tr>
<td>TD</td>
<td>8.0 (5-11)</td>
<td>1.6</td>
<td>8.6 (5-12)</td>
<td>1.8</td>
<td>6.6 (4-11)</td>
</tr>
</tbody>
</table>

Comparison to TD group at significance *p < .05

Materials

Visual and auditory stimuli for the Audiovisual Animal Sound task and the Audiovisual Animal Name task were designed using VPixx version 1.5 and displayed on a 15-inch iMac computer. The VPixx program automatically recorded task related motor reaction time and accuracy (i.e. number of items correct) per trial into a text file. Participants’ colour vision integrity was assessed using the Ishihara Test for Colour-Deficiency and a high contrast chart was used to measure visual acuity both monocularly and where possible, binocularly. Raven’s Coloured Progressive Matrices (RCPM) (Raven et al., 1995) was used as a measure of non-verbal mental age and the Peabody Picture Vocabulary Test - Third Edition (PPVT – Third Edition) (Dunn & Dunn, 1997) was used as a measure of receptive language ability. Visual forward digit span task was used on the computer as a measure of short-term memory and visual backward digit span task was used as a measure of working memory capacity.

Audiovisual Animal Sound task

The Audiovisual Animal Sound task, was made up of a cartoon picture of either a cat, cow or horse presented simultaneously with an auditory presentation of an animal sound (“meow, moo or neigh”; see Figure 1A). The visual presentation lasted one
second and the auditory presentation lasted one second in duration. The three visual and auditory stimuli were unique and presented repeatedly through the task. Each animal sound was paired with each visual image at least once in the task. Thus, there were more instances of incorrect than correct pairings. The task lasted for 2 minutes, and included a total of 24 trials presented randomly, in consecutive order. Task performance was measured by motor reaction time and accuracy of target detection.

**Audiovisual Animal Name task**

The Audiovisual Animal Name task was similar to the Audiovisual Animal sound task, but consisted of a one second exposure of either a cat, cow or horse presented simultaneously with a one second auditory verbalisation of one of three animal names (“cat, cow or horse”; see Figure 1B). Each animal sound was paired with each visual image at least once in the task. The task lasted for 2 minutes, and included a total of 24 trials presented randomly, in consecutive order.

![Figure 1. Schematic illustration of (A) the Audiovisual Animal Sound task and (B) the Audiovisual Animal Name task. Match and mismatch visual animal images were presented simultaneously with auditory animal sounds/ names.](A.png)

**Procedure**

Participants were individually tested in a quiet room in their school during school hours, across two separate sessions. In the first session, participants underwent a visual screening and then completed the RCPM (Raven et al., 1995), PPVT – Third Edition (Dunn & Dunn, 1997) and visual forward and visual backward digit span tasks. For each of the 36 items of the RCPM, participants were required to select one of six alternative patterns that would successfully complete a matrix. For the PPVT– Third Edition test, participants had to identify one of four pictures that best described the
verbal label spoken by the experimenter. For the visual forward digit span task, participants were required to view digits presented one at a time (with a 500 ms on/off presentation time) on a computer screen and type the digits in the same order they viewed them. For the visual backward digit span task, participants were required to type the digits they saw on the computer screen in reverse order. Participant’s digit span score was the number of digits they could reproduce correctly without making any mistakes.

In the second session, participants were given task instructions for the audiovisual tasks and completed practice trials, using the same stimuli as used in the actual task. Once the experimenter decided that participants had demonstrated full understanding of task instructions, participants were asked to complete the Audiovisual Animal Sound task and the Audiovisual Animal Name task twice each, in a counterbalanced order. For each trial, participants were asked to indicate whether or not the animal sound and picture displayed together on the computer screen matched, by pressing either the ‘z’ keyboard button covered by a green tick for a ‘yes’ response, or the ‘/’ keyboard button covered by a red cross for a ‘no’ response.

Data analysis

Mean motor reaction time (ms) for correct responses and percentage of correct responses were recorded for each individual trial of the Audiovisual Animal Sound task and the Audiovisual Animal Name task. As the data did not meet with the assumptions of normality, homogeneity of variance and homogeneity of covariance, non-parametric statistics (i.e. Kruskal-Wallis H test or Wilcoxon Signed-Rank test) were used to analyze the data. An adjusted alpha level of .05 was used to control for Type 1 error for these multiple comparisons.

Results

Analysis of matching variables

In order to determine whether children with LF Autism integrate multisensory stimuli according to their maturation level, they were first matched to children with Idiopathic ID and TD children on non-verbal mental age (as measured by RCPM), receptive language ability (as measured by Peabody Picture Vocabulary Test – Third Edition), short-term memory (as measured by visual forward digit span) and working memory (as measured by visual backward digit span). Participant’s total score correct on the RCPM was transformed into non-verbal mental age equivalents using the 1980 Queensland, Australia normalization table in the RCPM manual. In order to match
groups on the matching variables, high TD scorers (2 participants) and low ID scorers (2 participants from each ID group) on each of the measures were eliminated from the data analysis. A between group comparison was then conducted and showed that children with LF Autism were not significantly different to children with Idiopathic ID or TD children on non-verbal mental age ($F(2,62)= .89, p > .05$), receptive language ($F(2,30)= .83, p > .05$), short-term memory ($\chi^2 = 2.89, p > .05$) or working memory ($F(2,33)= 1.13, p > .05$). As expected, children with LF Autism and Idiopathic ID were significantly older (chronologically) than TD children ($F(2,62)= 22.41, p < .05$) (see Table 1).

**Between-group comparison of mean reaction time and percentage of correct responses on the Audiovisual Animal Sound task and the Audiovisual Animal Name task**

In order to test whether children with LF Autism integrate multisensory stimuli according to their maturation level, a Kruskal-Wallis H test compared the reaction time (for correct responses) and accuracy performance of children with LF Autism to children with Idiopathic ID and TD children on the Audiovisual Animal Sound task and the Audiovisual Animal Name task. Results of the comparisons showed no significant difference between groups on the Audiovisual Animal Sound task in mean motor reaction time ($\chi^2 = 1.10, p > .05$) or percentage of correct responses ($\chi^2 = .91, p > .05$). In addition, for the Audiovisual Animal Name task, no significant differences were found between groups in mean motor reaction time ($\chi^2 = 2.07, p > .05$) or percentage correct ($\chi^2 = 3.57, p > .05$; see Table 2).

Table 2

<table>
<thead>
<tr>
<th>Mean Reaction time (sec)</th>
<th>Percentage correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>AV NAME</td>
</tr>
<tr>
<td></td>
<td>M</td>
</tr>
<tr>
<td>LFA</td>
<td>1.75</td>
</tr>
<tr>
<td>IID</td>
<td>1.61</td>
</tr>
<tr>
<td>TD</td>
<td>1.71</td>
</tr>
</tbody>
</table>
Within-group comparison of mean reaction time and percentage of correct responses on the Audiovisual Animal Sound task and the Audiovisual Animal Name task

It was important to determine whether any groups showed a processing advantage to stimuli from one task over the other. Hence, for each group a Wilcoxon Signed-Rank test was used to compare the mean reaction time and accuracy performance on the Audiovisual Animal Sound task to the group’s performance on the Audiovisual Animal Name task. Results of this comparison showed that children with LF Autism ($z = -2.33, p < .05$), Idiopathic ID ($z = -2.10, p < .05$) and TD children ($z = -4.11, p < .001$) were significantly faster at detecting congruent stimuli in the Audiovisual Animal Sound task than for the Audiovisual Animal Name task. Children with LF Autism ($z = -.560, p > .05$), Idiopathic ID ($z = -1.18, p > .05$) and TD children ($z = -1.39, p > .05$) also showed a similar level of accuracy in detecting congruent stimuli in both tasks.

Discussion

The current study compared reaction times and accuracy performance on two match-to-sample audiovisual tasks (i.e. the Audiovisual Animal Sound task and the Audiovisual Animal Name task) of children with LF Autism to children with Idiopathic ID and TD children of similar non-verbal mental age, receptive language, short-term memory and working memory capacity. Consistent with our hypothesis, children with LF Autism performed comparably (in speed and accuracy) to the Idiopathic ID and TD groups by which they identified congruent audiovisual stimuli, indicating an intact ability to integrate multisensory information for simple every day stimuli (i.e. common animals) in children with LF Autism. Furthermore, all groups showed a significantly faster detection of congruent stimuli in the Audiovisual Sound task than the Audiovisual Name task, suggesting that at non-verbal mental age of approximately 8 years old, children are faster at processing animal sounds than names of animals, regardless of membership group. This is particularly important as it suggests that children with ID are processing the more complex semantic matching task (i.e. Audiovisual Name task) according to what is expected of their non-verbal mental age rather than their ID. Indeed, this finding is consistent with a study by Goharpey, Crewther & Crewther (in press) investigating error type performance of children with ID and TD children on the RCPM, which found a positive correlation between children’s receptive language and their
RCPM performance.

It is important to note that just because groups performed similarly on the audiovisual tasks, it does not necessarily suggest they employed similar neural mechanism to integrate multisensory information. Indeed, the vast evidence of superior visual search in children with HF Autism (Jolliffe & Baron-Cohen, 1997; O’Riordan & Plaisted, 2001; O’Riordan et al., 2001; Plaisted et al., 1998a; Shah & Frith, 1983), could suggest that children with LF Autism relied solely on their visual modality to integrate audiovisual information, which would be in accordance with the race model theory of multisensory integration. This hypothesis cannot be addressed with the data from the current study. However, future research should more directly investigate whether children with LF Autism integrate multisensory information according to the race model or the co-activation model. Furthermore, future studies could investigate whether similar rate and accuracy of multisensory integration between groups was due to similar non-verbal mental age, receptive language, short-term memory capacity, working memory capacity or a combination of all abilities and whether children with LF Autism or Idiopathic ID utilize a response strategy associated with the ID diagnosis.

An implication of this finding for the education of children with LF Autism and children with Idiopathic ID is that despite their limited expressive and receptive language, in order to facilitate their learning, educational material should be directed to both their visual and auditory senses simultaneously, as is the case for TD children of the same non-verbal mental age. However, presentation of words with pictures (as is often the case when reading out loud to children) as a means of teaching, should be used even more particularly with children with LF Autism and Idiopathic ID, so that they benefit from this multisensory presentation of information.
CHAPTER EIGHT: General Discussion

Introduction

When working with children with intellectual disability (ID), educators often teach to the child’s ID, rather than to the child’s neurodevelopmental disorder. In other words, it is the severity of ID that guides one’s interaction with the child more so than the specific etiology. Thus, in their interactions with ID children, educators tend to use simple language, provide very simple one step instructions and provide adequate processing time when waiting for the child’s response. Educators also tend to interact with and speak to a child with ID according to their developmental age rather than their chronological age. This thesis provides evidence as to why these educational strategies are the most valid theoretically and work practically.

The aim of the thesis was to extend the current cognitive construct of ID proposed by Anderson (1992, 2001), which claims that children with ID are both developmentally delayed and also show deviations within each developmental stage due to slow information processing speed. The goal of the thesis was not to test Anderson’s construct of ID, but rather add to it by asking if cognitive processes associated with fluid intelligence (i.e. attention and working memory) are impaired in children with ID (of different etiologies) and if so, whether this is due to a developmental delay or deviation from typical development. We accept the obvious delay or slowness in information processing, so have not investigated this further. Rather, we have investigated the performance (reaction time, accuracy and error type performance) of three groups of children with ID (low functioning Autism, Down Syndrome and Idiopathic ID) compared to TD children of similar non-verbal mental age, as measured by Raven’s Coloured Progressive Matrices (RCPM) (Raven et al., 1995) on a series of computerized attention and working memory (visual and auditory) tasks. The non-verbal mental age of children with TD and ID who participated in the thesis experiments was approximately 7 years, which is equivalent to the Piagetian Preoperational-intuitive to Concrete thinking operations stage of cognitive development (Grossman & Begab, 1983). The results of this thesis are interpreted according to the intelligence and ID literature, particularly of the most recent times, and have implications for the theoretical construct of ID as well as the teaching practices used for children with ID.

In summary, the thesis demonstrates that children with ID of three different etiologies (i.e. LF Autism, DS and Idiopathic ID) with a non-verbal mental age of 7
years are developmentally delayed in cognitive ability and more often than not appeared to be using an unsophisticated problem solving strategy (i.e. responding based on the items position and not its content) more readily than TD children, i.e. when task items became “too difficult”.

For many years it has been accepted that the RCPM items are representative of Piaget’s cognitive developmental stages in the primary school years (Sigmon, 1984). On the RCPM test, “task difficulty” can be considered as the number of visual streams of information that need to be processed simultaneously in order to find the correct response (Carpenter et al., 1990). Children with ID regardless of etiology showed impairment in processing dual streams of visual information, possibly explaining why many of them are never able to complete the entire RCPM test correctly and thus, traverse all of Piaget’s stages of cognitive development (Grossman & Begab, 1983). Furthermore, low functioning children with Autism (i.e. those with ID) were found to be delayed in cognitive development and did not show superior visual processing ability, as has been reported in high functioning children with Autism (who do not have ID). Autism is still increasing in prevalence, with the majority of children with Autism also being diagnosed with ID. The findings of this thesis suggest that Autism research and the desire to understand what Autism really means behaviourally requires testing children with LF Autism and understanding the role of ID in the presentation of Autism specific characteristics. The thesis findings overall suggest that educational programs should incorporate the training of working memory and attention processes in the teaching of children with ID. The thesis findings and their implications for the education of children with ID are explored in further detail below.

Summary of findings in each chapter

The first experimental chapter of the thesis (presented as Chapter 3) introduced a Velcro™ ‘puzzle’ version of the RCPM which required visually directed motor responses, aimed at maintaining engagement long enough for children with ID to complete the task. In the first part of this study, the validity of the puzzle version and the standard book version of the RCPM were tested in a group of TD children. Results showed that the RCPM puzzle version was just as valid a measure of non-verbal mental age as the standard RCPM version in children with TD. In the second part of the study, the performance and completion rate of the RCPM standard book version and puzzle versions were compared between children with low functioning Autism (LF Autism), Down Syndrome (DS) and Idiopathic ID. The puzzle version of the test was found to be
associated with better overall performance and a higher completion rate than the standard book version in children with ID (regardless of etiology). These findings suggest that the inclusion of the perceptual-motor component of the RCPM puzzle version, demanded both visual and motor attention, which reduced the probability of distraction and increased time on task, as a result.

The second experimental study of the thesis (presented in Chapter 4) aimed to determine whether the RCPM is an appropriate means of matching children with ID (LF Autism, DS and Idiopathic ID) to TD children on non-verbal mental age by determining whether problem solving ability in children with ID is relatively delayed or deviant. This aim was achieved by conducting an error type analysis, in order to determine whether TD children and children with ID with similar total score correct on the RCPM, also show similar problem solving ability (as evidenced by similar error type distribution across similar item types), consistent with the developmental model. The relationship between error type performance and cognitive abilities previously found to be associated with RCPM performance in TD individuals (i.e. working memory and receptive language) was also investigated. Error type analysis on the RCPM showed that children with ID and TD children were comparable in their problem solving ability when matched on non-verbal mental age. Receptive language (as measured by the Peabody Picture Vocabulary Scale-Third Edition) (Dunn & Dunn, 1997) and short-term memory (as measured by visual digit span task) were shown to be positively correlated with RCPM total score correct in both the ID and TD groups. However, evidence of deviant problem solving strategy was evident in children with ID. Children with ID also made significantly more positional errors, which is the least sophisticated problem solving strategy envisaged (and not included in Corman and Budoffs Factor analysis, 1974). Overall, the study findings support the use of RCPM test as a valid means of matching ID children to TD children on non-verbal mental age.

The third experimental study of the thesis (presented in Chapter 5) compared the performance of children with DS and TD children with similar non-verbal mental age (as measured by the RCPM) on sustained and transient attention tasks. The ability to sustain attention was measured using a visual continuous performance task (single or dual target), whilst transient attention was measured using a timed visual change detection task (change of colour or change of identity). A visual search task was also employed to measure both transient and sustained attentional components. The findings demonstrated that in all the tasks, children with DS were comparable to TD children of
the same non-verbal mental age on overall reaction time and accuracy performance for the detection of single targets, but impaired in performance (i.e. accuracy) for dual-target detection. Furthermore, the results also suggested that in the dual-target continuous performance task, TD children coped with the load on working memory by responding to only one salient feature of the target (i.e. its colour) as a problem solving strategy, where as children with DS again showed a preference for a positional response which was indicative of a passive withdrawal strategy.

Study 4 of the thesis (presented in Chapter 6) compared the performance of children with LF Autism and Idiopathic ID to the performance of TD children matched on non-verbal mental age on computer based auditory discrimination tasks and visual change detection (colour or identity) tasks. Results showed comparable performance on an auditory discrimination task and visual change detection tasks (identity or colour) when groups were matched on short-term memory and working memory capacity. However, the ID groups showed significantly less accurate detection of change in colour when they were significantly less able to demonstrate working memory capacity on the digit span task compared to the TD group. These findings suggested that colour was less salient for the ID groups than the TD group, despite being similar in non-verbal mental age. Study 5 (presented in Chapter 7) investigated multisensory integration in children with LF Autism and Idiopathic ID compared with children with TD children of similar non-verbal mental age. The results overall indicated that when matched to TD children on short-term memory and working memory performance (as measured by visual digit span tasks), children with LF Autism and Idiopathic ID detected multisensory stimuli at the performance level expected of their non-verbal mental age.

**Theoretical implications of the thesis findings**

When evaluating a child’s performance on a test, it is important not to only consider test takers correct responses but to also evaluate error types and strategies utilized, in order to determine the task criterion employed during task completion. In other words, did the child try to be correct or did he/she merely try to complete the task quickly and compliantly? To date there has been greater focus in the research literature on what TD children can do at each developmental stage, and less on what they can’t do and why? What do they do when life becomes hard? In other words, there has been little research on what differentiates developmentally appropriate error from developmentally deviant behavior in TD children. The studies of this thesis focused on investigating error type strategies as well as correct responses of TD and ID children as a means to further
develop the construct of ID.

According to Anderson (1992, 2001), children with ID show deviations at each developmental stage due to slow information processing speed. Results of thesis studies found that when processing time was not a variable, children with ID of different etiologies (LF Autism, DS and Idiopathic ID) were developmentally delayed but showed deviation in problem solving only in so far as they made more of a developmentally appropriate error (i.e. positional error) than TD children of similar non-verbal mental age and receptive language. TD children used response positions as a problem solving strategy when completing “very difficult” items of the RCPM (i.e. items correct below chance level). Raven noticed that TD children selected response position 2 errors (central top line) more often than other response position, which is why he randomized position of correct answers on the RCPM (Raven et al., 1995). Indeed, elderly test takers also have a preference for position 2 response than other response positions (Levinson, 1962). A previous study (Lanfranchi et al., 2010) also found that TD children used positional response as a problem solving strategy on a sustained attention task, when the items became more difficult. This suggests that the positional strategy is a developmentally appropriate problem solving strategy that is unsophisticated and may indicate withdrawal of attention to the task and a change in task completion criterion, from aiming to deduce the correct answer to trying to complete the task as soon as possible with least resistance.

This thesis also found that children with ID (regardless of etiology) were comparable to TD children of similar non-verbal mental age on the detection of single targets, but impaired in the detection of dual targets. This impairment was in processing multiple streams of information of the same modality (e.g. vision only), as children with ID showed evidence of intact multisensory facilitation. Whether this deficit in processing dual streams of visual information is due to impaired selective attention, impaired encoding of information or storage of information in working memory is unknown and cannot be accounted for by the current thesis results.

In study 3 (Chapter 5), TD children made more commission errors to distracters that shared the same colour as the target than other distracters, which suggests that they were responding to only one salient feature of the target (i.e. targets colour), as a problem solving strategy to cope with the high load on working memory. Children with DS on the other hand appeared not to simplify the task by selecting the most salient feature of the target to attend to and made more errors in detecting the dual target than
the single target. It is possible that children with DS may have withdrawn their attention from the task in response to the perceived difficulty in processing dual streams of information.

Results of this recent study by Linke, Vincente-Grabovetsky, Mitchell and Cusack (in press) also showed that it was the efficiency of selective attention during the encoding phase of visual information processing and not short-term memory capacity which differentiated the performance of low and high IQ scorers on a visual change detection task (Cusack, Lehmann, Veldsman, & Mitchell, 2009; Linke et al., in press). More specifically, Linke and colleagues found that when the visual load was large, low IQ performers did not select the most relevant information to maintain in working memory, but instead tried to encode all the information available in the visual array. High IQ performers on the other hand were more selective, and chose to process the most relevant visual stimuli available in the limited time.

Even though it seems rather intuitive that our proposed construct of ID should resemble the profile of low IQ scorers on the construct of intelligence proposed by Linke et al. (in press), no one else in the literature has demonstrated this relationship between ID and the Linke et al. theory of intelligence, to date. However, this does not suggest that ID is merely equivalent to “low IQ”. Children with ID are significantly older in chronological age than TD children of similar non-verbal mental age. Indeed, for children with ID the myelination of many CNS pathways is likely to be more complete than for younger TD children. Conduction of the Magnocellular neural pathways has been shown to mature between the ages of 6-12 years (Crewther, Crewther, Klistorner, & Kiely, 1999), so for all of the visual tasks in this thesis, children with ID would be expected to have mature Magnocellular neural pathways, even though they still performed comparably to TD children with immature Magnocellular pathway. Thus, ID is characteristic of a specific impairment in the construct of intelligence, not equivalent to lower intelligence in TD children. Future research will need to investigate other possible explanations for impaired dual processing in children with ID (i.e. LF Autism, Idiopathic ID and DS), including whether impairment in working memory and attention characterized the severity of ID.

**Practical implications of the thesis findings for the education of children with Intellectual Disability**

The findings of this thesis have a number of important implications for the education and research of children with ID. It is important to note that children with LF
Autism and children with Idiopathic ID were found to problem solve according to their cognitive developmental level, being similar in their choice of salience among object attributes and in the processing of audiovisual information according to their developmental level. This suggests that when children with Autism also have ID, they are likely to problem solve according to their developmentally age. They did not show evidence of superior visual processing ability that has often been shown in children with HF Autism (Mottron et al., 2006).

In research studies, children with ID are often matched to TD children and/or children with ID of other etiologies on a possible confounding variable, such as intelligence or chronological age (Mottron, 2004). Findings of study 2 (Chapter 4) of the thesis will add to the growing literature on the RCPM test, showing it to be a valid and appropriate means of matching ID children to TD children (and other ID children) on non-verbal mental age and hence also a suitable measure for the diagnostic assessment of children suspected of having ID in clinical settings. Results of the second study also suggest that when children with ID are matched to TD children on non-verbal mental age, they are also likely to be comparable in receptive language ability. This was an interesting finding and suggests that non-verbal problem solving ability is associated with verbal reasoning. Future studies will need to investigate this association and its implications in the education of children with ID further.

The constant reiteration of the finding that children with ID are developmentally delayed suggests that in an educational setting, children with ID may benefit academically from learning alongside TD children of similar non-verbal mental age. However, this would mean that they would be chronologically older which may pose a limitation in regards to them forming social friendships with TD children. One suggestion is that children with ID be placed in accordance with their chronological age in classes that teach socially relevant topics, such as art, music and life skills. This will enable them to form friendships and learn age appropriate norms that will help them fit in with their age matched peers. Further research will need to explore which educational placement is the best option for children with ID.

Furthermore, educational intervention should be aimed at improving working memory capacity in children with ID, in order to improve their problem solving ability (Conners, Rosenquist, & Taylor, 2001; Perrig, M, & S, 2009). Indeed despite considerable debate on the effectiveness of working memory training in improving fluid intelligence in children with ID, a recent study, (Van der Molen et al., 2010) did find
improved verbal short-term memory in adolescents with mild ID after they underwent ongoing working memory training, which demonstrated that working memory (and possibly problem solving ability) can be trained in children with ID (Perrig et al., 2009). Meanwhile, the use of only single stimuli during teaching in preference of multiple stimuli at any one time (e.g. on computer based educational programs) is likely to benefit the learning of children with ID, as it increases the likelihood they will be successful and not withdraw their attention from the task due to perceived task difficulty. Furthermore, a motor-visual teaching approach should be used with children with ID, as the requirement to physically manipulate an object in order to achieve correct performance has been shown to increase time on task and, thus, increasing the probability of task completion and improved performance (as shown in study 1, presented in Chapter 3).

Additionally, the thesis findings highlight the importance of using stimuli that have a high level of personal saliency (such as familiar cartoon characters) as teaching material. However, whether the saliency of an object or a feature of an object to a child with ID is nominated, rather than naturally preferred remains to be investigated. The current thesis findings suggest that children with LF Autism and Idiopathic ID find an object’s colour less salient a feature than do TD children of similar non-verbal mental age. Whether this finding is due to developmental differences between children with LF Autism and TD children on the saliency of object’s identity or whether the identity or semantic name of an object is appreciated as more salient than colour to children with ID more so than children with TD is unclear. As it stands however, it may be more beneficial if educational material is aimed at teaching object identity rather than object attributes (such as colour). Future research should also aim at further the understanding of what features of objects children with ID find personally salient and how efficiently they can change their attentional focus to a newly nominated salient feature in their environment. Such research will inform intervention programs and hence, better enable children with ID function more independently in their everyday living.

**Limitation of the studies and subsequent recommendations for future studies**

The selection of the RCPM as a more valid measure of non-verbal mental age over the more commonly used WISC-IV was a decision made from studies supporting the effectiveness of the RCPM over the WISC-IV with children with ID. Future studies need to test this assumption by comparing the performance of children with ID and TD on both the RCPM and WISC-IV in order to elaborate better the difference between
these tests. Future studies should also attempt to investigate sustained and transient attention, as well as working memory performance in the different mental age groups of ID and TD individuals, as this will provide a developmental perspective on problem solving ability in ID, helping to develop the ID construct even further.

An important next step in developing the construct of ID is to investigate whether children with ID who showed comparable performance (reaction time and accuracy) to TD children (of similar non-verbal mental age) on the computerized tasks utilised in this thesis also exhibited the same neurological mechanisms and effort as TD children to complete the tasks. It is highly likely that even though children with ID performed similarly to TD children, they exhibited a much greater cognitive effort than TD children to achieve the same outcome. Thus, even though the performance of ID children were similar to TD children in many of the thesis tasks, they may have been more cognitively taxed that TD children when completing the tasks, suggesting a slightly inferior performance overall. In order to test this hypothesis, future studies could test children with ID on attention and working memory tasks using electrophysiology and brain imaging techniques.

The application of electrophysiology and brain imaging techniques in the investigation of time to attention activation to stimuli in children with ID would also provide much needed information on speed of information processing and further inform the debate on the cognitive developmental trajectory of children with ID and the wider construct of ID. Future research needs to also investigate the effect of information processing speed on the attention and working memory capacity of children with ID. For instance, impaired ability to process multiple streams of information observed in children with ID may be due to slow information processing which restricts and limits how fast attention can be allocated, information encoded and maintained in working memory. A lowered rate of information processing will also limit ability to shift attention rapidly between multiple stimuli. Additionally, the question of whether slow allocation of attention and subsequent inability to manipulate multiple streams of information (which is often co morbid with a generalized motor impairment in ID) is associated with imprecise motor movements and eye movements needs investigation. Evidence has shown an overlap in the parietal cortex and frontal eye fields, responsible for executing eye movements, shifting visual attention and visual working memory (Herwig, Beisert, & Schneider, 2010). Thus, it may be the case that slow speed of eye movements will result in slower attentional shifting and hence less attentional resources
available for learning, consequently for working memory processing and thus slow speed of information processing. Understanding these relationships better will determine whether improving motor control in children with ID will also help improve cognitive ability, in a practical educational setting.

Concluding remarks

The developmental versus difference debate on the developmental trajectory of cognition in children with ID is an important one as it informs our construct of ID and ultimately educational approach to children with ID. Anderson suggested in 1991 that both the developmental and difference models applied to the construct of ID. Children with ID are developmentally delayed (in that they eventually reach Piagetian stages of cognitive development but at a much slower rate than TD children), and deviant within each developmental stage due to slow information processing speed. This thesis extended Anderson’s construct of ID by investigating problem solving strategies utilised for visual and auditory target detection and differentiation that required sustained and transient attention and the use of working memory. The result showed that even when speed of processing is not a variable of concern, children with ID showed both a developmental delay with some deviations in problem solving approach. Results also showed that children with ID detected and differentiated single visual objects according to the level expected of their developmental age. However, impairment in dual processing of visual stimuli resulted in the use of an unsophisticated problem solving approach (i.e. positional response); the same approach that is used by TD children on “very difficult” items (Lanfranchi et al., 2010).

Intelligence has long been associated with working memory capacity and sustained attention (Buschkuehl & Jaeggi, 2010; Colom et al., 2007; Colom, Karama, Jung, & Haier, 2010; Fry & Hale, 2000; Shelton, Elliott, Matthews, Hill, & Gouvier, 2010). Indeed the Raven’s matrices have been shown to be strongly correlated with working memory capacity (Carpenter et al., 1990; Prabhakaran et al., 1997). Thus, in order to solve more complex problems, the ability to manipulate information in working memory is required. This constant cognitive impairment in ID explains why such individuals cannot progress past a certain mental age, a lack of one of the key ingredients for intelligence. It also explains why they can learn to differentiate and detect single objects and respond to one step instructions but show increased impairment when they must deal with dual streams of information, such as respond adequately to multiple instructions or carry out tasks that require multiple steps such as
independently using the ATM or catching a bus to school. In reality, the educator or

carer is often acting as the child’s working memory capacity and selective attention

source by prompting the child to attend to what is the most salient or relevant feature of

their immediate environment. One-on-one teaching is certainly beneficial but education

of children with ID may need to incorporate teaching programs that facilitate working

memory and attention. Future research will need to investigate whether the IQ and

problem solving strategy of children with ID benefits from working memory and

attention training and if so, to what extent. Indeed, we propose that studies of working

memory need to differentiate between the holding of a single piece of information (for

matching) against a stream of distracters, versus holding multiple items (of different

content or attributes). This could indeed explain the single/dual attention and working

memory differences in children with intellectual disability and may be informative on

the type of working training that is needed for children with ID.
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Appendix A

All conditions pertaining to the clearance were properly met and annual reports have been submitted.

Swinburne University of Technology
Human Research Ethics Committee Certificate of Approval

<table>
<thead>
<tr>
<th>Project Title:</th>
<th>Increased arousal and its effects on attention</th>
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<tbody>
<tr>
<td>HREC Register No.:</td>
<td>04/31</td>
</tr>
<tr>
<td>Chief Investigator:</td>
<td>A/Prof David Crewther</td>
</tr>
</tbody>
</table>
| Other Investigators: | Ms N Goharpey  
A/Prof S Crewther |
| For period from: | 01-Nov-04 | To: | 01-Nov-06 |
| Approved for (max): | 50 male participants | and | 50 female participants |

Approval is granted subject to the following conditions:

Researchers are required to immediately report anything which might warrant review of ethical approval of the protocol, including: (a) serious or unexpected adverse effects on participants; (b) proposed changes in the protocol; and (c) unforeseen events that might affect continued ethical acceptability of the project. If the research project is discontinued before the expected date of completion researchers must inform the HREC.

A progress report must be submitted annually.
A final report must be submitted at the conclusion of the project.
Special Conditions as indicated below.

Copies of police clearance certificates for chief investigators to be submitted to HREC.

Professor K. Pratt
Chair, Human Research Ethics Committee
Wednesday, 9 March 2005
List of Publications

Published Scholarly Book Chapters:


Published Journal Article:

Submitted Manuscripts:

