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A Comparative Study of Working Memory in Children with Neurodevelopmental Disorders

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Acknowledgments

No matter how thoroughly a person may have learned the Greek alphabet, he will never be in a condition to repeat it backwards without further training.
Hermann Ebbinghaus (1850 – 1909)

This thesis is dedicated to my precious wife, Samra, who is and has been a source of inspiration, patience and encouragement throughout.

And to my children Adam and Guloona, who have taught me a whole new meaning of life.

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Last but not least I think of my late parents who have been my mentors and guide and I am sure they would have loved to see me achieve this goal.

Abstract

Background: Previous research has provided conflicting reports with regards to the functioning of the various components of working memory in children with neurodevelopmental disorders, and in particular in those with autism. This research was initiated to answer some of the questions raised by these research studies and to provide a comparison of performance of children with different neurodevelopmental disorders on the same measure of working memory.

Aim: The purpose of this research was to investigate working memory functioning of children with neurodevelopmental disorders including autism spectrum disorder (ASD), intellectual disability (ID), and specific and language impairment (SLI). A group of typically developing (TD) children was also tested for comparison. The groups included in the present study were selected with the aim of identifying varying patterns or profiles of working memory dysfunction, as a function of the different levels of intellectual functioning within these neurodevelopmental groups. The scores of children with SLI were within the average range on the performance IQ scale (PIQ). Low functioning children with ASD have a Full scale IQ (FSIQ) score of less than 70; high functioning children with ASD have a Full Scale IQ score above 70. Children with ID have a FSIQ score of lower than 70. Within each group, there can be considerable variation in IQ score, allowing the examination of working memory as a function of IQ. The research also aimed to explore the relationship between intelligence and memory, with particular reference to crystallized and fluid intelligence and processing speed. The present research study also aimed to examine any particular working memory profiles that might characterise each group; these were predicted to vary across groups. The hypotheses were generated based on previous research in this field, which suggests that children with neurodevelopmental difficulties demonstrate impairments in memory functioning, particularly affecting working memory, compared to typically developing children.

Method: Data were collected from children in pre-schools and schools located in the Munster region of the Republic of Ireland. In total, 96 children participated, with ages ranging from 48 to 192 months. The ASD group consisted of 26 children (23 male; 3 female) with an age range of 49-161 months. The group with ID consisted of 32 children (21 male; 11 female), with an age range of 56-192 months. The SLI group consisted of 15 children (10 male and 5 female) with an age range of 75-154 months. The typically developing children consisted of 23 children (12 male and 11 female) with an age range of 48-190 months. The SLI group had a lower age range when compared to the other three groups; however, this would not have had any substantial effect on the outcome of the results as the test batteries used in the research were age normed. The children were assessed using the Wechsler Intelligence Scale for Children-IV (WISC-IV) or the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III), as appropriate for their age, to determine their level of intellectual ability. The children with a diagnosis of ASD and SLI were assessed by the relevant professionals to confirm their diagnosis. All children were subsequently assessed using a measure of the components of working memory, the Automated Working Memory Assessment (AWMA), in order to identify any relative strengths and weaknesses in their working memory functioning.

Results: The results indicate that the high functioning children with ASD performed equally well on almost all the subtests of AWMA when matched with the typically developing children on IQ and age. There was no difference observed on the memory tasks between the performance of low functioning children with ASD and those with ID. The children with ID performed poorly on the memory tasks compared to the children with average intelligence. The SLI group showed impairment on the verbal memory measures and, when IQ was controlled, the SLI group indicated some further impairment on visual spatial tasks when their performance was compared with the typically developing children. Furthermore, these groups presented their own unique profiles when Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI) and Processing Speed Index (PSI), measures that contribute towards calculating the Full Scale IQ (FSIQ), were statistically controlled. The VCI and PRI are considered to measure crystallized and fluid aspects of intelligence respectively. Correlational analyses indicated a unique profile for each group.

Conclusion: The implications of the findings are discussed with reference to relevant research and interventions for children with neurodevelopmental difficulties. The present research highlights the differential performance of the four groups with respect to working memory, and notes the contribution of intellectual functioning to the memory dysfunction.

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List of acronyms

Acronym	*Detail*
ADI/O	Autism Diagnostic Interview/Observation Schedule
ASD/ASC	Autism Spectrum Disorder/Autism Spectrum Condition.
ADHD	Attention Deficit Hyperactivity Disorder
APA	American Psychological Association
AWMA	Automated Working Memory Assessment
CA	Chronological Age
CANTAB	Cambridge Neuropsychological Test Automated Battery.
CVLT	California Verbal Learning Test
DSM-IV	Diagnostic and Statistical Manual of Mental Disorder-IV
EF	Executive Functions
fMRI	Functional Magnetic Resonance Image.
FSIQ	Full Scale IQ
Gc	Crystallized Intelligence
Gf	Fluid Intelligence
Gv	Spatial Intelligence
HSE	Health Services Executive
ICD-10	The International Statistical Classification of Diseases and Related Health Problems-10
ID	Intellectual Disability
IQ	Intelligence Quotient
LTM	Long Term Memory
MA	Mental Age
MEG	Megnetoencephalographic.
MID	Mild Intellectual Disability
OCD	Obsessive Compulsive Disorder.
PRI/PIQ	Perceptual Reasoning Index/Performance IQ.
PDD	Pervasive Developmental Disorder.
PSI	Processing Speed Index
SAS	Supervisory Attentional System
STM	Short Term Memory
SLI	Specific Language Impairment
TD	Typically Developing
TS	Tourette Syndrome
TOH	Tower of Hanoi
VCI/VIQ	Verbal Comprehension Index/Verbal IQ
WM	Working Memory
WAIS-III	Wechsler Adults Intelligence Scale- 3rd edition.
WCST	Wisconsin Card Sorting Test
WISC-IV	Wechsler Intelligence Scale for Children-4th edition.
WPPSI-III	Wechsler Primary Pre-School Scale of Intelligence-3rd edition
WRAML	Wide Range Assessment of Memory and Learning

Chapter 1 Introduction

1.1 Introduction to the research aims

The purpose of this research is to investigate the functioning of working memory (WM) in children with neurodevelopmental disorders such as autism spectrum disorder (ASD), intellectual disability (ID), and specific language impairment (SLI), compared to the performance of typically developing children. The present research was initiated as a means of better understanding the challenges faced by children with neurodevelopmental difficulties. The three neurodevelopmental groups were selected for the present research with some specific objectives in mind. These groups share many common features, such as difficulties in acquiring age appropriate linguistic skills, but each group also has its own unique strengths and weaknesses on tasks of cognitive functioning. The research aimed to further understanding and to clarify the implications for working memory in these groups, as there have been mixed conclusions from different research studies. The age range of the four selected groups was from 4-16 years. This broad age range was considered for the study as the majority of the children with ID and ASD are assumed to indicate a significant disparity between their chronological and mental age. The age range for the SLI group was slightly narrow compared to the other three groups but this should not have affected the results substantially, because the measures chosen for the present research were age-normed.

The main motivation behind the current piece of research was to understand the challenges faced by children with neurodevelopmental difficulties. Having worked closely with such children over many years, the impact of working memory difficulties on their day to day functioning was apparent. However, available research was ambiguous in terms of predicting the precise deficits in WM that might be associated with a particular disorder. The outcome of the present research would, it was anticipated, therefore, be informative as regards the relationship between WM and intelligence in the neurodevelopmental disorders and would possibly guide future intervention for these children. The importance of early intervention is clear and it can radically change the lives of the children and their families. Memory and intelligence seem to be recognised as two vital factors contributing towards learning. These two psychological constructs go hand in hand. The present research therefore aimed to look at how these constructs interact depending on the particular neurodevelopmental disorder.

Historically, although there has been much research examining the area of memory function, many of the scientific studies of memory have produced conflicting results. The current study aims to contribute to the literature in this area by offering a detailed analysis of the subcomponents of working memory and intellectual functioning comparing four different sample groups within a single study: typically developing children and three groups of children with neurodevelopmental disorders, those with ID, SLI and ASD. This study sets out to measure the functioning and processing of memory of the four groups in a single design and will inform us about the similarity and variation of these groups in terms of their memory functioning. This study will also help us in exploring the variation in impairment within each group and its possible relationship to IQ, in order to identify any unique characteristics in the relationship, for these four groups.

Working memory, a fundamental theoretical concept within cognitive psychology, is considered to play an important role in all types of learning, which encompasses language, literacy, numeracy, and visual spatial skills. The sphere of its influence is far and beyond what may be circumscribed from our day to day activities and includes activities such as remembering appointments with a doctor while going to work, finding your way while driving through a busy route, higher mental cognitive processes such as mental maths, following a lecture in the classroom and complex problem solving.

The term working memory refers to “a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning” (Baddeley, 1992, p.556). This explanation of the term working memory has evolved from the concept of a unitary short-term memory system, which is responsible only for storing information for a short period of time. The concept ultimately developed into a multi-component storage and processing system, which became the more dominant model with time, due to its capacity to deal with higher order cognitive functioning and the processes controlling many of the behaviours related to learning. There are researchers who claim that working memory, largely a function of the frontal lobe, is also instrumental in determining the role of the Central Executive Functions, a group of cognitive processes necessary for flexible, goal-oriented responses in novel or demanding situations and consisting of a number of skills, such as cognitive flexibility, inhibition, planning, working memory, and generativity (Stuss & Benson, 1986). Cognitive flexibility may be defined as an executive component that refers to the capacity to shift attention between different stimuli or switch between strategies or response sets. Response inhibition refers to the conscious suppression of a pre-potent behavioural response (Nigg, 2000). The theoretical framework of working memory, as will be discussed in the following paragraphs, relies heavily on these two functions: response flexibility and cognitive inhibition. It is further envisaged that working memory has a limited capacity; therefore, it has to transmit information with a high speed to keep a balance between remembering/processing information and simultaneously maintaining a link with the central executive/long term memory systems in the process. As we will see in the following discussion, the central executive has a wide variety of roles to fulfil; however, it can only function efficiently if all of its subsidiary systems are feeding correct and reliable information into it – the role of working memory has a unique place in this system.

Keeping in mind the importance of the role of working memory in dealing with higher order cognitive functions, it then becomes pertinent to study its influence not only in terms of the cognitive functioning of typically developing children but also that of the population with neurodevelopmental difficulties. The neurodevelopmental disorders involve impairment in the growth and development of the brain or central nervous system (Reynolds, Cecil, Goldstein, & Sam 1999), and refer to a range of disorders of brain functions, which can affect emotions, learning ability and memory. The neurodevelopmental disorders include autism spectrum disorder, intellectual disability, and speech and language disability, groups which are the major focus of this research. The present research will help us in understanding the functioning of working memory for individuals with these disorders and may further guide us in devising intervention programmes for these individuals. Before we go further, it is important to have an understanding of memory as a construct, by looking back into the history of memory research, from which the concept of working memory evolved and developed into its present form.

1.2 Historical perspective

Traditionally, memory is considered to be the ability to store, retain and recall information. History informs us that it was the philosophers who had laid the foundation of studying the intricacies of memory as they attempted to explore the myths around memory as a concept. However, this role was later taken over by experimental psychologists who tried to test memory processes in the laboratory setting. It was during the late nineteenth and early twentieth century when memory came under the paradigm of what was to become cognitive psychology. In recent times, memory has been intensively researched by a branch of science called cognitive neuroscience, an interdisciplinary field linking cognitive psychology and neuroscience. The present knowledge about memory functioning has come mainly from work related to different memory disorders such as amnesia, Alzheimer's disease and dementia, as well as day to day memory phenomena such as the tip-of-the-tongue effect, forgetting as a daily routine activity and so on. More recently, memory research has begun to address the memory problems experienced by children who are struggling with their learning, as they demonstrate difficulties in acquiring skills in the area of language, reading, writing, numeracy, and so on. Further differences in approach to memory are also relevant here. Some research has considered memory as a multicomponent system, such as short term memory, working memory and long term memory, while other approaches strongly argue in favour of a unitary system. All these viewpoints will be discussed in greater detail in the following paragraphs in order to provide a better understanding of the structure and function of the memory system, which in turn will make it possible to understand the implications related to memory impairment in the neurodevelopmental disorders.

If we look at the history of the concept of working memory, as it is conceived today, the first reference appeared in the influential book *Plans and the Structure of Behaviour* by Miller, Galanter and Pribram (1960). At the time, there was no satisfactory theoretical explanation of the processes involved in simultaneous retention and carrying out of an action plan. Miller and colleagues emphasized the need for a theory that could explain the processes that occur between the presentation of a stimulus and the execution of a response. According to Miller et al., "When we have decided to execute some particular plan, it is probably put into some special state or place where it can be remembered while it is being executed" (p.65). Here Miller et al. were referring to working memory in terms of the modern concept; prior to execution of a plan, it needs to be held in memory for some time in order to process it and use it according to the demands of the task. Miller et al. explicitly pointed here to three main ideas, those of storage, processing and a brief interval, which laid the foundation for further research in this area.

This seems to be the first scientific claim to recognize the independent existence of a working memory that allows us to achieve higher and complex cognitive goals. This explanation of working memory (WM) distinguishes it from the earlier concepts of capacity-limited immediate memory and refers to the unique system of working memory which is not only involved in the storage of plans but also their implementation. The limited-capacity immediate memory system is generally conceived as storing information for a very short period of time only; with the introduction of the working memory concept, the limited capacity immediate memory remained within the ambit of short term memory (STM) as the emphasis was on storage only and not the *processing* of the information.

While working memory was referred to in these earlier studies, Baddeley and Hitch (1974) are duly credited with launching the empirical investigation of working memory proper. They began their influential 1974 chapter with the following comments: "Despite more than a decade of intensive research on the topic of short term memory (STM), we still know virtually nothing about its role in normal human information processing" (p.47). Baddeley and Hitch also noted their scepticism over the lack of direction within research when it came to exploring the importance of the role of STM in more complex cognitive behaviour, especially considering the primary role granted to STM in the most influential information-processing models at the time (e.g., Atkinson & Shiffrin, 1968; Broadbent, 1958). They acknowledged, however, that a considerable amount of important research had been conducted to address fundamental questions about STM itself, without referring to the phenomenon of processing while the information is in the store for that very brief interval. For example, there are many research studies that have focused on the processes of encoding, retrieval and decay of information in STM (Brown, 1958; Conrad, 1964; Conrad & Hull, 1964; Keppel & Underwood, 1962; Miller, 1956; Petersen & Petersen, 1959: Reitman, 1971, 1974; Stenberg, 1966, 1969; Waugh & Norman, 1965;

Wickelgren, 1965). These research studies were not considering, in a real sense, the processing function, while the information is stored for a short period of time.

It was Ebbinghaus (1885) who opened a new chapter in the field of experimental psychology by using himself as a subject. He initially gathered data over one year, 1879-1880, and he subsequently replicated the entire procedure during the period of 1883/4. He then published his book *Über das Gedachtnis* in German; this was later translated into English as *Memory: A Contribution to Experimental Psychology.* This monograph can easily be counted as one of the major influences on the beginning of systematic experimental research on higher mental processes and especially memory. Ebbinghaus not only brought learning and memory into the laboratory, but he was a pioneer in setting a standard for careful scientific work in psychology by controlling variables which may have confounded the experiment. His famous experimentation with nonsense syllables is still a key influence for many researchers interested in memory and cognition. Ebbinghaus reported that he could recall without error lists of 7 or fewer nonsense syllables upon a single presentation, but that lists of 8-10 syllables required approximately 5-12 presentations respectively. This suggests that with practice there is more space available to learn new words as the capacity of the storage increases. Or, probably, some of the syllables are transferred to long term memory to have space available for the new incoming information and they are recalled when required. Furthermore, these nonsense syllables would be equivalent to the present-day nonword repetition tasks which have been used intensively in recent research and are considered to be very important in assessing verbal memory. The present research will also use non-word repetition tasks as one of the measures for assessing verbal STM.

Parallel to this development, Jacobs (1887) published the first empirical paper on the memory span task, which is also considered to be an early contribution to the systematic study of individual differences within memory. The sample in this study was between the ages of 8 and 20 years. They were presented with lists of auditory nonsense syllables, letters, or digits and they were asked to recall them back to the experimenter. The largest set reproduced by the subject was referred to by Jacobs as his or her *span of prehension*. The conclusion from the research suggested an increased span outcome not only with age but also with higher school grades. This seems to be a classic reference to the importance of nature and nurture in contributing towards memory functioning. This also points to the relationship between learning abilities and memory, as with learning the capacity of memory seems to improve. These two researchers, Jacobs and Ebbinghaus, laid the foundation for the empirical study of memory and its functioning by introducing two important tasks, Digit Span and Nonsense Syllable lists, which are used extensively by contemporary researchers. However, it needs to be seen how learning impacts on memory for those with developmental delays or disorders.

Galton (1887), around the same time, measured the spans of institutionalized children and young adults. These individuals who were institutionalized were low functioning and were classified as ‘idiot’ (in the terms of the day) with quite limited capacity. They had a span averaging only three to four items for Digit Recall, for example. Here, there is another indication of a relationship between memory function and intellectual functioning, as this research suggested that the capacity of immediate memory, as reflected by prehension span, depended on the level of intellectual ability. This may have been the reason why span tasks were included as part of intelligence test batteries (e.g., Binet & Simon, 1905; Burt, 1909; Cattell & Galton, 1890; Ebbinghaus, 1897). However, these researchers were also aware of the distinct character of the concept of memory and hence suggested separate tasks for its measurement. In summary, these early investigators were instrumental in paving the way for establishing the relationship between IQ and memory, which will be the focus of the present research thesis.

William James (1890), on the other hand, was busy working in parallel to these researchers. He was focused on distinguishing between different types of memory and was the first person to suggest that memory consisted of two major distinct components, i.e., ‘Primary’ and ‘Secondary’ memory. According to James, Primary memory is a function of the current contents of consciousness and is concerned with what is happening immediately in the present surroundings. As the information needs to be processed immediately, therefore restrictions need to be placed on the amount of information for retention. Secondary memory, in contrast, is thought to consist of memories of the distant past and to be unlimited in capacity. Baldwin (1894), another experimenter around the same time, also contended that immediate memory has limited capacity, but plays a crucial role in the development of higher cognitive abilities such as intelligence. Again, we see a reference to the important relationship between memory and higher cognitive abilities.

Cattell and Galton (1890), during the same era, considered the importance of span tasks as a measure of memory and attention. Wundt, in his classic text *An Introduction to Psychology* (1912/1973), regarded the span of memory and the span of prehension as reflecting a common limit to the focus of attention. Bolton (1892) argued that the span tested the ability to concentrate, along with sustained attention. More than 25 years later, Humpston (1919) again emphasized the role of attention as an important factor in the retention of discrete numbers. This could be considered as a significant advancement in understanding the factors responsible for memory by referring to attention, which is subsequently substantiated by Engle (2002) in his theoretical framework of working memory. Furthermore, these earlier authors were strongly viewing memory, attention and intelligence as conceptually related, and arguably measuring the same phenomenon, an argument which will be discussed in detail in the subsequent paragraphs.

Binet (1905), another great name in the field of cognitive psychology, was, however, focusing on sentences and unrelated words in his experiments to test immediate memory. According to Peterson (1925), “Binet favoured [memory tests] for two reasons: (1) memory involves content of the higher mental functions, not mere sensations, and (2) by means of memory tests one can indirectly study the operations and nature of such higher mental processes as discrimination, attention, and intelligence” (p. 125). We see, once again, an emphasis on the interrelationships between memory, attention and intelligence.

Terman (1916) continued the quest for a proper assessment tool of memory with the introduction of a sentence span test along with the Digit Span. These tasks were included in the translation and revision of the later Binet–Simon scales for memory. However, it was included differentially in the test, depending on the age group, due to the nature and complexity of the tasks. The Digit Forward test was administered with children ranging in age from 3 to 11 years, since the researchers at the time considered the test to be relatively simple and young children could easily follow the instructions. Backward Digit Span, somewhat more complex in nature, was administered with children above the age of 7 years. Terman (1916) suggested that “as a test of intelligence, this [Backward Digit Span] test is better than that of repeating digits in the direct order. It is less mechanical and makes a much heavier demand on attention” (p. 208). However, age can be an important factor here. Young children probably are at a preliminary stage, as the skills to simultaneously remember and mentally process the numbers in backward order and to recall it at a later stage is only emerging. Young children may also require concrete instructions as opposed to instructions loaded with many concepts that require understanding and following of complex instructions. This may suggest that the investigators at that particular time were aware of the varied nature of memory and that the distinction between STM and WM was already being considered as applied to young children. Terman also noted that some participants were using an effective strategy such as breaking the sequence of numbers into groups (Miller, 1956). We see here a reference to intelligence and a better strategy to remember information. This also is regarded as one of the early examples of 'chunking' of information in terms of a useful strategy for better recall, which depends to some degree on the intelligence of an individual.

Alongside the specific interest in memory, one also sees the simultaneous development of the modern intelligence tests (e.g., Binet & Simon, 1905/1961) and the first modern theory of intelligence (Spearman, 1904). Largely parallel developments in each field are witnessed around that time. These developments have significantly influenced the subsequent direction of research and memory span tests have been used in almost all the intelligence tests used, mainly without substantial changes (Terman & Merrill, 1937, 1960; Thorndike, Hagen, & Sattler, 1986). The Wechsler scales included the memory component tasks from its earliest edition (the Wechsler–Bellevue; Wechsler, 1944) up to the most current version, the fourth edition of the Wechsler Intelligence Scale for Children (WISC-IV) and Wechsler Adult Intelligence Scale (WAIS–III; Psychological Corporation, 2003). There are other individual subtests which have also included Digit Span as a measure of memory (Anastasi & Urbina, 1997). The only exception involves the younger age group, as the digit span tests are not a part of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III), normed for children between the ages of 2:11 to 7:3 years. The reason for the omission of digit span here could reflect some basic rationales such as the difficulty in distinguishing not only the different levels of memory but also the challenge in distinguishing memory from intelligence within this young group, as around the time the tests were being developed, the concepts of memory and intelligence may have been embedded in each other. This is one of the questions that may be addressed by the present research which explores the inter-relationships between memory and intelligence. Although a majority of researchers consider digit backwards as a true measure of working memory, there are others who consider simple digits and words as a measure of working memory also. For example, the Woodcock–Johnson-III refers to a simple span memory for order of digits and words as a test of auditory working memory, as opposed to backward digits (Schrank, Flanagan, Woodcock, & Mascolo, 2002). In summary, span tasks are used quite extensively to measure memory functioning as STM and WM. However, these tasks are included only in the assessments designed for older children, while younger children are exempted from these tasks. Furthermore, a survey of intelligence tests would indicate that little has changed significantly over time when it comes to assessing memory span. Intelligence theory and basic research on intellectual abilities, in contrast, have involved substantial debate on the role of memory abilities in intelligence. The present research will also use Digit Forward and Digit Backward tasks in combination with other tests, for assessing STM and WM respectively.

The above mentioned historical perspectives can be grouped as ‘capacity’ theories of immediate memory. They all were, to a large extent, based on the capacity of the system which can actively maintain a certain amount of information at once, whether measured by digit or word span. However, subsequent theorists alluded to two additional sources which can be responsible for the loss of information. They contended that information can be lost due to either time or interference. They proposed that information can be retained for a certain time and would tend to decay with intervening factors. These theories have made way for the proposal that memory span tasks measure memory rather than attention (Cowan, 1995). Notwithstanding this contention, it is believed that the tasks measuring IQ and memory require an additional element i.e., attention. An individual has to attend to a task at hand in order to process the information for successful task completion. The tasks become highly demanding on attention as complexity increases. For example, Digit Backwards would require more attention than Digit Forwards tasks, since processing is required along with retention for the former task. However, IQ may be considered as different from memory in terms of its additional demand on cognitive flexibility, required for analyzing a problem by looking at the different options available for successful completion of a task. This view brings IQ and executive functions conceptually quite close together. However, memory can be considered as a ‘third pillar’ which facilitates the entire process of task completion.

Thorndike (1914), on the other hand, introduced the ‘law of disuse’, proposing that memories are quickly lost over time if they are not used, or refreshed. However, this principle does not seem to be applicable to all of long term memory, since we observe and experience in our everyday experience that people can recall their childhood experiences quite vividly, of course, with certain alterations. McGeoch (1932) argued that memory traces do not simply decay over time but may not be retrieved due to the forces of retroactive and proactive interference. This argument appears to be logical, since with some effort people can recall their previous experiences, and at times a chain of thoughts, linking one idea with the other, helps in retrieval of old memories. In fact, McGeoch and subsequent interference theorists argued that there is no distinction between immediate memory and other forms of memory and so the quest to understand the capacity of immediate memory is misguided (Crowder, 1982; Melton, 1963; Nairne, 2002). This approach seems to have taken a full circle backward supporting the unitary system of memory and this could be the reason that earlier research focused only on STM.

As we progress further in our study of memory we find evidence in research within the domain of neuropsychology, such as neuropsychological case studies that have supported the distinction between two systems of memories i.e., short-term and long-term. These investigations involve, for example, temporal lobectomy patients, who demonstrate normal short-term memory capacity but are unable to form new long term memories (Milner, 1966). By contrast, other patients present with problems with their short-term memories compared to their long term memories. For example Shallice and Warrington (1970) studied a patient, K.F.; his performance on LTM-related tasks showed normal function, while he demonstrated significant difficulties with STM-related tasks.

These patients demonstrated a double dissociation of function between long-term memory and short-term memory performance (Baddeley & Warrington, 1970; Shallice & Warrington, 1970; Warrington, Logue, & Pratt, 1971). Patients with damage to temporal lobe structures, such as the hippocampus, usually have difficulties with long term memory. Patients with short-term memory damage typically suffer from more frontal and left parietal damage, suggesting differences in memory systems for the short term and long term retention of information. However, these theoretical constructs are mainly based on the outcome of research conducted on patients with acquired brain injuries, which has its own limitations due to possible alterations to brain function after damage. However, this distinction between long term memory, WM and STM remains, and will be further explained in the following paragraphs.

1.3 Working Memory Models

For a better understanding of working memory, we need to discuss two models in the following sections and consideration of these models will provide further guidance as regard the aims of the present research. These models are the multicomponent working memory model presented by Baddeley and Hitch (1974) and Engle's working memory model (2002).

The Multicomponent Model

Initially, Baddeley and Hitch (1974) proposed a model consisting of three components; they later added another system to the model. The four model component is comprised of an attentional control system, the central executive, together with two subsidiary storage systems, the phonological loop and the visuospatial sketchpad. The fourth component, added more recently, is the episodic buffer.

The Phonological Loop

As the name implies, the phonological loop deals only with speech based and acoustic information, since verbal information is stored temporarily in this system. In order to keep the information active, it needs to be rehearsed or refreshed either overtly or covertly. If there is any hindrance in the process of rehearsal, the memory traces tend to fade away, compromising the retrieval of information. Therefore, to successfully process the information, which includes storage and rehearsal, this component needs an additional mechanism. The mechanism consists of two sub-systems, a phonological store and an articulatory rehearsal system called the articulatory control process. The phonological store is responsible for storing all the information for a short period of time, whereas the articulatory rehearsal mechanism is proposed to be instrumental in refreshing the information through the process of rehearsal. The evidence for the nature of the store originally came from empirical studies which mainly focused on the loss of information due to phonological similarity. This similarity effect suggests that the chances of decay of information increases with the similarity of the information. The similarity effect was researched quite intensively by Conrad and Hull (1964) who used phonetically similar and dissimilar letters in order to see the effect on recall and retention. They demonstrated that sequences of phonologically similar letters were recalled less accurately than dissimilar sequences (e.g., p,b,v versus f,y,d). Baddeley and Hitch (1974) obtained similar results. They presented to subjects phonologically similar and dissimilar sequence of words instead of letters, and recall was better on the dissimilar words compared to similar words. Furthermore, when similarity of meaning was involved, there were no differences observed (Baddeley, 1966). However these researchers used different terminologies to define the same concepts. Conrad and Hull (1964) proposed that STM depended upon an acoustic memory trace, while Baddeley and Hitch (1974) preferred to use the term ‘phonological’ to explain the same concept. The relationship between storage capacity and phonological similarity may need to be explored further.

A different pattern of results emerged when the same set of words was used in a study of long-term memory (Baddeley, 1966). Baddeley (1966) administered the same items in a sequence for several trials. Recall was better when the subjects were familiar with the meaning of a word suggesting that long term memory relies more on the meaning of information. Based on the outcome of these results, Baddeley (1966) advanced the view of a separate phonologically based store for immediate recall of small amounts of information, and a different system for long term memory.

The word length effect on retention and recall is also relevant here. Baddeley, Grant, Wight, and Thomson (1975) found that subjects had significant difficulties when they were asked to recall polysyllabic sequences compared to short words. Subjects were presented with a sequence of five short and five polysyllabic words. Recall was higher for the short words compared to polysyllable words. This supports the assumption that polysyllabic require more space in terms of capacity and allow less time for rehearsal, therefore the result is poorer recall. The assumption follows that memory span relies on two factors: the availability of ‘space’ and the speed at which items can be rehearsed. Not only do shorter words have a better chance to be rehearsed more rapidly leading to a greater span, but also if subjects have the capacity to rehearse rapidly then they have a better chance of recalling well (Baddeley, Thomson & Buchanan, 1975). This hypothesis was further tested and verified when an additional irrelevant word was added to the existing word list. The sample in this case were asked to repeat the word ‘the’ as they were exposed to the words, which showed further decline in recall (Baddeley et al., 1975). This introduction of a minimal memory load had affected rehearsal and thereby impaired performance (Murray, 1968). This impairment would be expected, as repeating a word in this way reduces the effectiveness of rehearsal for maintaining items in memory, a process referred to as articulatory suppression. Articulatory suppression also prevents visual information from entering the phonological store (Baddeley & Hitch 1974).

Some recent neuropsychological studies also support the storage–rehearsal distinction. Some evidence comes from patients with lesions that disrupted either storage or rehearsal (Vallar & Papagno 2002). Neuroimaging evidence has located the storage component in the temporo-parietal region of the left hemisphere while rehearsal is more frontally located in Broca's area (Jonides, Schimacher, Smith, Koeppe, Awh, Reuter-Lorenz, et al. 1998; Paulesu, Frith, & Frackowiak, 1993).

The Visual Spatial Sketchpad

The visuospatial sketchpad performs functions similar to those of the phonological loop but for information of a visual spatial nature. The sketchpad is considered to be responsible for holding and manipulating spatial and visual information, such as remembering shapes and colours, or the location or speed of objects in space. It is relevant for tasks that involve planning of spatial movements, like planning one's way through a complex building or driving through a major city centre for the first time, or remembering and following a road map. The way a sailor or pilot navigates involves this component, as does the way a chess player plans his/her next move. Baddeley et al. (1975) were the first to systematically investigate the visuospatial sketchpad and they suggested that the visuospatial sketchpad consisted of three separate components, involving visual, spatial and possibly kinaesthetic (movement-based) functions. The visual spatial sketchpad is principally represented within the right hemisphere of the brain (Baddeley, 2000) while the phonological loop would seem to involve the left hemisphere of the brain.

Logie (1995) proposed that the visuospatial sketchpad can be further subdivided into two sub-components i.e., the visual cache and the inner scribe. The visual cache is responsible for storing information related to form and colour, whereas the inner scribe processes information relating to location in space and movement. However, the visual cache has an overall role in storage and rehearsal of information and transfers it to the central executive for further actions. This further division of the visual spatial sketchpad creates specialized subcomponents within the subsystem.

Furthermore, some research suggests that visual and spatial information have varied processing mechanisms. There are three main sources which provide evidence for this distinction between visual and spatial parts of the visuospatial sketchpad. First, there appears to be less interference between visual and spatial tasks than between two visual tasks or two spatial tasks (Klauer & Zhao, 2004). This again appears to be based on the logic of similarity effects reported in the preceding section. Secondly, there are reports of patients with brain damage with selective impairment of only one component, without influencing the other. Thirdly, results from brain-imaging show that working memory tasks with visual objects mainly activate areas in the left hemisphere, whereas tasks with spatial information activate areas in the right hemisphere (Smith, & Jonides, 1997).

The Central Executive

The central executive system is considered to be multifunctional in nature as this system is engaged in receiving information from multiple sources such as STM, WM and LTM and subsequently filtering and integrating this information to get a holistic/ gestalt view for its implementation. This also requires coordination and supervision of the flow of information between different systems of memory, which includes long-term memory, visual spatial sketchpad, phonological loop, and the episodic buffer. This requires active coordination among different systems to control the transmission of information between other parts of the cognitive system. These activities are enabled by processing within the central executive, but it has a finite capacity.

There are some researchers who consider the central executive as a unitary system that may form the basis of the general factor of intelligence (e.g., Duncan, Williams, Nimmo-Smith, & Brown, 1993; Kyllonen & Chrystal, 1990). If this is the case, then working memory, a subcomponent of the central executive, would also be influenced by intelligence as there are many common grounds between these two major constructs. This could be the primary reason behind using similar tasks for measuring higher cognitive processes such as executive functions and working memory. However, there are other accounts which suggest that the central executive comprises a range of relatively independent sub-processes that may include planning, attention, flexibility, task coordination, etc. (Shallice & Burgess, 1991; Baddeley, Logie, Bressi, Della Salla, & Spinner, 1986). The central executive is considered to be responsible for carrying out a majority of higher cognitive functioning. Cognitive tasks that have been suggested to involve the central executive include mental arithmetic (Hitch, 1980), recall of lengthy lists of digits, logical reasoning (Baddeley & Hitch 1974), random letter generation (Baddeley, 1966), semantic verification (Baddeley, Lewis, Eldridge, & Thomson, 1984) and the recollection of events from long-term memory (Hitch, 1980). These functions of the central executive suggests its key role in tasks that require decision making, higher order thinking to generate solutions to a problem, and so on.

Given the role of the central executive in higher order functioning, it is clear that it plays a very important function in our day-to-day life. Norman and Shallice (1986) have attempted to provide a framework to explain the performance of the central executive by providing evidence from everyday lapses. According to them, our day to day behaviours are fundamentally controlled by the frontal lobe. In order to regulate these behaviours, the frontal lobe requires two additional operating systems. The first one is relatively automatic as it consists of mostly learned habits and schemes of daily routine whereby predictable events give rise to appropriate behaviour. Driving along a familiar route every day would be a good example, as very little attention is required in performing this task. The other component, which they termed the supervisory attentional system (SAS), is a mechanism required to override the habit patterns that are no longer adequate; for example on a Saturday morning instead of going for a doctor appointment, one might accidentally drive to work instead, out of habit. The change of routine requires an additional level of mental control and attention, which is allowed by the SAS. The SAS appears to be playing a crucial role in performing any novel task, as any new task would require additional attention and control. The SAS would probably have an important role to play in tasks specifically designed for assessing working memory since these tasks are usually novel and require additional attention. This view point will be considered in the current research by examining the working memory/executive functions of the ASD sample, as this group exhibits significant difficulties adapting to change, along with children with ID, who are considered to have difficulties with sustained attention in general.

The central executive is also very important in decision making. Support for the role of the central executive in the planning of future actions came from patients with frontal lobe impairments (Shallice & Burgess, 1991). Experimental tasks specially designed to measure the executive functions have provided an insight into the precise processing of this component. As tasks become more routine and automated, their demands on the central executive are assumed to decrease and they are managed by lower level mechanisms. This process assumes that a task that denies the possibility of automatisation should therefore put great demands on the central executive. Some researchers have observed a stronger tie between executive functions and visual spatial working memory than between executive functions and verbal working memory (Busch, Booth, McBride, & Vanderploeg, 2005; Miyake, Friedman, Retinger, Shah & Hegarty, 2001). Verbal storage is assisted by various identified processes such as rehearsal, whereas visual spatial storage is more dependent on attentional control (Hambrick & Engle, 2002). This argument provides strong support for the importance of rehearsal processes since these help to make a task routine and hence facilitate learning. However, practice is also considered as an important factor in developing visual spatial skills as has been directly observed in my daily clinical practice, whereby some children perform well on tasks of a visual spatial nature once they accumulate experience with the tasks. Consistent with this observation, Fry and Hale (2000) considered how fluid intelligence, which is evaluated using visual spatial tasks in a majority of intelligence tests, as a dynamic instead of a static process, can be affected by maturational and experiential processes. This possibility will be explored in the current research by looking at the relationship of tasks measuring memory and fluid/crystallized intelligence.

The Episodic Buffer

Following a comprehensive discussion in favour of different subcomponents of working memory, Baddeley (1997) claimed that there was something missing, a link that may have the capacity to integrate this multicomponent system and to connect it with long term memory. According to Baddeley (1997), executive functions have a purely attentional and processing role, with no separate capacity as such in order to interact with the other WM subsystems as regards the incoming information itself. A series of studies attempted to look for a separate system which had the capability to link in with the incoming information, which culminated in the introduction of a third slave system (and fourth component) of the central executive: the episodic buffer. This system was assumed to form an interface between the three working memory subsystems and long-term memory (Baddeley, 2000), a system which sifts all the information based on its categories such as visual, verbal, and perceptual. According to Baddeley, it differs from episodic LTM in that it is temporary in nature; however, it can access information from LTM both for learning and retrieval. He also emphasized the role of conscious awareness in the process. The introduction of this additional system brings Baddeley's model closer to other models of working memory (Miyake & Shah, 1999). There seems to be an analogy between the episodic buffer and the SAS presented earlier as both systems are said to filter information by providing additional control and attention.

The evidence for the independent component of the episodic buffer came from research with highly intelligent patients with amnesia. These patients had significant difficulty with encoding new information related to long-term memory, whereas they presented no evidence of impairment with the short-term recall of stories, and they were able to recall much more information than could be held in the phonological loop (Baddeley, Wilson, 2002). The existing theories were not able to explain this phenomenon and other complex aspects of working memory, such as the capacity for remembering large chunks of information. In addition, research was considering individual differences in working memory. These studies were using working memory span tasks in which subjects were required to simultaneously remember and process the information, for example verifying a sequence of sentences and then recalling the last word of each (Daneman & Carpenter, 1980).

Engle's Working Memory Model

Engle's (2002) major emphasis in his working memory model was on attentional control, as he suggested a direct correspondence of working memory capacity with attentional control. He observed that people with high working memory span showed better abilities in attentional control. This model relies less on specialized subsystems and gives preference to the control of attention and task contexts. The emphasis is on the ability to provide undivided attention to tasks for better processing and remembering. This explanation is similar to the previous discussion about SAS, which supports the idea of additional attentional control for a novel task.

Unsworth and Engle (2007) presented a somewhat similar view while describing working memory as consisting of a subset of activated memory units, some of which are highly active and can be considered as having a limited capacity with regard to the short-term component. They refer to these two components as Primary memory and Secondary memory, going back to the terminology used by William James (1890). They consider these two components as qualitatively and functionally distinct from each other. The limited capacity component is important in order to maintain information for a short period of time and a separate system allows more durable information for a longer period (Atkinson & Shiffrin, 1968; Norman, 1968; Raaiijmakers & Shiffrin, 1980; Waugh & Norman, 1965).

However, if we examine the models presented by Baddeley and Engle, there are many similarities. For example, in Baddeley's model (1974, 2000), the phonological loop and the visual spatial sketchpad are analogous to elementary STM processes, which are connected through the episodic buffer, and store information to be processed by the central executive. The central executive as proposed by Engle, Tuholski, Laughlin and Conway (1999) is responsible for maintaining and controlling attention in order to process the information – this is supported by Shallice (1988) also. This relationship is based on the assumption that the central executive is responsible for control, supervision and regulation of information flow between the WM components (Engle et al., 1999). Furthermore, the role of an executive function is extended far beyond attention and control – it is also responsible for retrieving information from other memory systems, such as long term memory (Baddeley, 1996). This means that executive functions are simultaneously processing incoming information while retrieving more information from the long term memory and maintaining attention to hold the information at the same time. The nutshell of this entire debate points towards the importance of the central executive and its reliance on the subcomponents of the memory system, especially working memory. Working memory appears to be playing the role of a lynchpin in the entire process, receiving, storing, processing information from different sources and transferring it to the central executive for final output. This entire argument makes the memory process highly dependent on the activity of the central executive, which includes working memory and its subcomponents and which ultimately relies heavily on attention.

If we analyse the existing literature, it would indicate a lack of consensus among investigators on the structure and function of the executive process of the WM. For example, the theories of Baddeley (1986) and Engle and Kane (2004) both give equal importance to the executive component of working memory. They both consider the executive component of the WM system as a domain-general system. This domain-general characteristic implies that the executive processes control all the information without any discrimination of the content of the material involved. It freely accesses and processes information of both a verbal and visuospatial nature, irrespective of the content. On the other hand, there are other researchers who suggest that the central executive of WM processes information selectively, depending on the specific content and nature of the information. These investigators based their arguments on the results of several neuroimaging and behavioural studies with adults, and therefore they suggest a domain specific role to the executive function (Fletcher & Henson, 2001; Shah & Miyake, 1996). Shah and Miyake (1996) go a step further in differentiating not only separate resources for storage of information for the verbal and spatial domain, but for the processing (executive) components as well. In line with these findings, other studies have provided evidence for domain-specific WM when assessing the structure of the WM (Haavisto & Lehto, 2004; Jarvis & Gathercole, 2003; Ketelsen, Welsh, Holter, & Hue, 2006; Mackintosh & Bennett, 2003; Suss, Oberauer, Wittmann, Wilhelm, & Schulz, 2002). However, there are some questions raised regarding research supporting the domain-specific model of executive processes on methodological grounds (Colom & Shih, 2004).

Further, we need to understand that central executive is an umbrella term which includes not only attention, concentration and processing but it is also regarded as a system which is responsible for planning and organizing along with response flexibility and cognitive inhibition. Based on this assumption, the central executive could be split into two major components, one dealing with processing information mentally (for example mental maths, attending to a lecture in a class) and the other one could deal with actual planning (such as in performing tasks such as Tower of Hanoi, etc). The present study aims to address these issues, as efforts will be made to measure memory functioning which involves attention and concentration along with processing and retention of information simultaneously, as opposed to using a global executive functions task that measures several executive functions occurring simultaneously. This study will also prove useful in determining and identifying the deficits, if any, among children presenting with neurodevelopmental difficulties, when they perform on tasks specially designed to measure attention, concentration, processing, and retention as is required in working and short term memories.

1.4 The relationship between STM and WM

There is agreement yet to be reached over the links between STM and WM. There are many studies which suggest that the systems operate independently, while there are others that propose a single unitary memory system of components, which functionally supplement each other.

There are theorists who consider WM and STM predominantly influencing each other. For example Seamon and Kenrick (1994) postulated that WM is a subset of STM. There are many other researchers who have laid emphasis on the unitary nature of the WM system (Anderson, Reder, & Lebiere, 1996; Colom, Abad, Rebollo, & Shih, 2005; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Colom & Shih, 2004; Kyllonen & Christal, 1990). Colom et al. (2004, 2005) have researched extensively in this area and they have concluded that STM (which they referred to as storage-oriented span) and WM (referred as storage + processing unit) share many things in common while they also have their own specific distinguishing characteristics. There are other researchers who adhere to the idea of a non-unitary character of these systems as opposed to the unitary one (Mackintosh & Bennett, 2003; Shah & Miyake, 1996). For example, Mackintosh and Bennett (2003) suggested that although working memory may be partly general, it is also at least in part domain-specific as it may be related to fluid (Gf), spatial (Gv), and crystallized (Gc) abilities. The present research will, however, look at the relationship of fluid and crystallized intelligence along with the processing speed only. Cattell (1943), introduced the concepts of Gf, an intelligence factor associated with physiologically based abilities, and (Gc), a factor associated with educational and experiential knowledge, as two major types of intelligence. The (Gv) factor represents visual–perceptual processes, such as imagining the way objects may change as they move in space, keeping configuration in mind (Shah & Miyake, 1996).

There are some other studies that have proposed a strong relationship between STM and WM. For example, Engle et al. (1999) suggested that STM and WM are two distinct concepts involving highly related constructs. They also found a strong correlation between WM and Gf. Similar results were obtained by Conway, Cowan, Bunting, Therriault and Minkoff (2002). Kane et al. (2004), Colom et al. (2005), and Colom, Abad, and Shih (2006), while reanalyzing data from different studies found that complex span measures (WM) may not be easily distinguished from simple span measures (STM) as both measures share something in common that could produce their association with cognitive ability measures. This provides strong evidence in support of STM/WM's association with cognitive abilities. If this is the case then there is likely to be a higher chance of memory impairment for low IQ functioning individuals; one of the aims of the present study is to establish the extent to which this applies across a range of neurodevelopmental disorders. The present study includes children with low and high IQ and their performance will be evaluated on both STM/WM components. Conway et al. (2002) demonstrated strong evidence suggesting that WM, but not short-term memory capacity or processing speed, is a good predictor of general fluid intelligence in young adults, an outcome consistent with Engle et al. (1999). Kane et al. (2004) studied several measures of verbal and visual spatial WM and STM, as well as several diverse cognitive ability measures. They found quite high correlation between WM and STM ranging from .63 to .89. These researchers also observed STM to be more domain-specific than WM, as they found the correlation between STM-verbal and STM-spatial was .63, whereas the correlation between WM-verbal and WM-spatial was .83. Finally, Kane et al. (2004) found that fluid intelligence was predicted by the executive attention factor (.52) and by the STM spatial factor (.54). As tasks of fluid intelligence mainly rely on non verbal reasoning abilities and less on verbal reasoning abilities, the strong relationship with the STM spatial factor might be expected. Moreover, the non verbal reasoning tasks are usually novel and individuals may not be familiar with them, therefore these would require executive attention. Colom et al. (2005) also obtained a very high correlation between WM and general intelligence (g) when WM comprises storage-plus-processing elements. However, without the storage component, the relationship between WM and g is revealed to be much more unstable. Colom et al. (2006) analysed the data of Kane et al. (2004) and obtained a highly significant correlation between STM and WM latent factors. Further, these researchers demonstrated that the simultaneous analysis of the relationships among STM, WM, and g showed that both STM and WM (with its storage component partialed out) predict g with the same power.

1.5 Memory and its relationship with intelligence

At this point, after over a hundred years of extensive research and theorizing, we still do not know the precise relationship between intelligence and memory. If it plays a role, then to what extent, and in which direction is this influence? If we examine different intelligence test batteries, a significant case is made in support of the interdependence of these two factors, as a number of subtests within the intelligence tests tap memory in one way or another. There are a few theorists advocating the independent nature of memory and intelligence who consider these two concepts as completely independent of each other (Brown, Guilford, & Hoepfner, 1966; Tenopyr, Brown, Guilford, Hoepfner, 1966), while there are others who support the argument that memory and intelligence measure the same phenomenon (Conway et al. 2002; Engle et al., 1999; Kyllonen et al. 1990) There are research studies supporting the idea that memory and intelligence share some common grounds but it would seem that they also differ from each other in many other ways.

Psychology as a discipline has witnessed much research on intelligence testing which has generated a lot of controversy. These studies ultimately culminated into numerous theories defining intelligence; they can be grouped into three main categories, which have dominated the scene for quite a long time. The first concept advanced by Spearman (1904) is the two-factor, or ‘g’ factor. The second is the group-factor approach (Kelly, 1928; Thomson, 1939), which is supported by Thurston’s principles (1938). However, most modern theories tend to take a middle-ground approach to intelligence, such as the hierarchical model of Vernon (1950; see also Marshalek, Lohman, & Snow, 1983; Snow, Kyllonen, & Marshalek, 1984). Briefly a review of these theoretical perspectives is explained in the following paragraphs, which will further help us in understanding the relationship of memory to intelligence and guide us through the present research.

Spearman (1904), while working with school children, found a significant correlation in performance across different subjects which were seemingly unrelated to each other. He considered a general ‘g’ factor that was influencing the relationship and was considered to provide a binding force between these varied abilities. This argument in certain ways paved the way and became the basis for the advancement of the two factor model, which could explain all the variations in intelligence test scores.

The first factor is related to the attributes specific to a person which makes a person more skilled on one cognitive task than another. For example, a person might be good with number facts. The second factor is considered to be involved in governing the performance of all the cognitive tasks. Spearman (1927) stated that “all the available evidence indicates that ‘g’ is exclusively involved in education and not at all in bare retention” (p. 285). Subsequently, Spearman and Jones (1950) maintained that due to lack of sufficient evidence it is not possible to establish memory as an ability factor. Based on this evidence, Spearman did not believe in a specific memory construct and therefore he did not mention it in his intelligence theory (Carroll, 1993). He probably considered intelligence, especially the ‘g’ factor as an overriding factor which influences all spheres of cognitive abilities, including memory and problem solving abilities.

Spearman (1914), while reanalyzing the data of Simpson (1912), which included memory, verbal reasoning, perceptual speed and perceptual judgment tests, described his theoretical construct of ‘g’ as a “general fund of mental energy” (p.103). On the basis of this re-analysis, Spearman (1914) found that the Ebbinghaus Completion Test, when combined with other verbal and memory tests, had very high correlations with the general factor. This evidence has further strengthened the case for the ‘g’ factor as measuring general abilities. Spearman (1938) later stated that ‘g’ was well represented by individual differences in the Penrose and Raven test (1936) which was later called Raven’s Progressive Matrices (Raven, Court, & Raven, 1977). Thus, the characteristics of Spearman’s ‘g’ factor evolved from various abilities to a test of nonverbal (or spatial) inductive reasoning. These abilities are circumscribed by the fluid intelligence as opposed to crystallized intelligence. Further, the role of the ‘g’ factor started to emerge as a “general fund of mental energy”. However, there is still debate on the nature and characteristics of ‘g’, as a majority of contemporary intelligence theorists have different views about the role of ‘g’ (Messick, 1996), and they prefer to see it as a common variance among cognitive ability tests. There are other researchers who define the ‘g’ factor according to their own theoretical perspectives. For example, Cowan (1997) referred to it as an index of the capability of attention. Engle (2002) proposed ‘g’ as representing the executive processes. Based on this argument then, could the ‘g’ factor account for the variation between STM and WM? It seems as if both of these theorists appear to be quite close in their explanation of ‘g’ factor, as executive process and attentional capabilities highly depend on each other. For instance, even if we agree that executive process is a multifunctional system, since it is considered to measure abilities such as planning, flexibility, inhibition, etc., these tasks could not be successfully carried out unless they were under the constant focus of attention.

If we look at other studies there appears to be a case for a common ground which is shared by memory and intelligence. For example, Kelly's (1928) research focused on finding evidence for a common factor underlying memory span tests. Subsequently, he reported a very high correlation not only among four memory tests but also reasonably strong correlation with a general ability factor along with a separate memory factor. There is very strong evidence in support of the relationship between memory and intelligence. The outcomes of Kelly's research were further reviewed by Blankenship (1938). He observed a definite relationship between memory span and intelligence; however, he avoided a prediction regarding the nature of the relationship due to variations in the outcome of the research. At the same time, Blankenship (1938) observed a very high correlation between the Backward Digit Span and the Army Alpha test in a sample of prisoners. The outcome suggested that the relationship with intelligence increases with higher order cognitive abilities, as Backward Digit Span is considered to be a complex task. However, there were other researchers who considered intelligence and memory tests completely independent of each other. For example, Thurston (1938) incorporated a separate memory factor in his 'Primary Mental Abilities'. Subsequently, Guilford (1956, 1967) and Guilford and Hoepfner (1971) adapted a 'structure of intellect' model. This model consisted of 24 separate memory ability factors (Brown, et al., 1966; Tenopyr, et al., 1966).

These studies culminated in a dichotomous theory of intelligence, i.e., Fluid Intelligence (Gf) and Crystallized Intelligence (Gc). Vernon (1950), while not the one who used the concepts of fluid and crystallized intelligence, referred to them when he put forward the widely accepted hierarchical model of intelligence. In this proposed model, the 'g' factor is at the top of the hierarchy, with verbal-educational and practical-mechanical abilities at the second level. He did not agree with the view that a rote memory factor could in fact be usefully identified separately from the other factors. As mentioned earlier, it was Cattell (1943), who introduced the concepts of Gf, an intelligence factor associated with physiologically based abilities, and Gc, a factor associated with educational and experiential knowledge, as two major types of intelligence. Subsequent researchers were able to direct their pursuit to explore the possible relationship between these two factors and the memory construct. There are studies which have shown a high correlation between the Gf factor and memory tests. Horn (1965), for example, observed a positive relationship of Gf factor with memory compared to a negligible relationship with the Gc factor. Further, Horn (1989) considered backward span memory test a better measure of Gf. The Backward Digit Span (a complex task) is also considered to be a better measure of working memory as is discussed in the previous section.

Kyllonen and Christal (1990) suggested that reasoning ability and WM capacity are largely the same, proposing that working memory plays a central role in cognitive function. In a series of four large-sample studies, Kyllonen and Christal (1990) evaluated the relationship between the constructs of reasoning and WM as well as processing speed and general knowledge. The data indicated very high correlations of .80 to .88 for the WM and reasoning factors. The authors suggested that WM capacity is largely determined by reasoning ability. However, they also found reasoning ability correlated more highly with general knowledge and WM correlated with processing speed. These results could be due to the attention and concentration factors as both WM and processing speed tasks require a high level of attention. The present research will also look at processing speed's relationship with WM.

Conway et al. (2002) studied the relationship of performance on the Raven Advanced Progressive Matrices with WM tasks using a sample of undergraduate students. The WM measures have shown correlations from .49 -.52, a moderate correlation on three working memory tasks (Conway et al. 2002). Engle et al. (1999) obtained an average correlation of .31 across three WM tests, ranging from .28 for the Reading Span task to .34 for the Operation Span task. These correlations, in general, do suggest that WM and general intelligence measure similar constructs.

Colom, Flores-Mendoza et al. (2005) evaluated the role of STM and WM performance with reference to intelligence. They used a statistical approach by which they evaluated the role of STM performance to intelligence prior to the contribution of WM, thus making it possible for STM to relate to intelligence. The overall findings provided evidence in support of the short term storage processes to a greater extent (Colom et al. 2005; Colom, Abad, Rebollon & Shih, 2005), more so than the results of Engle and Kane (e.g., Engle et al., 1999). Results of existing studies that have included all three constructs, STM, WM and intelligence, suggest that both STM and WM performance may be relevant in relation to intelligence (Bayliss, Jarrold, Baddeley, Gunn, & Leigh, 2005; de Jonge & de Jonge, 1996). The present study will also include measures of the three constructs to examine their relationship.

It is important to clarify once again the different subsystems of memory as presented by Unsworth (2010) and to relate it to the present study. Unsworth suggests that there are both similarities and differences among WM, STM and LTM. Each of these system functions predominantly under their own unique capabilities while sharing processes of similar nature. Baddeley's (2007) model of WM suggests that the episodic buffer is important for the interaction between WM and LTM and could potentially account for the overlapping variance between WM and LTM tasks, while the unique variance may be due to specific WM processes. Similarly, Logie (2003) also presented a model that conceptualizes WM as a mental workspace that interacts with incoming perceptual information and stored knowledge.

In one of his studies, Unsworth et al. (2007) also supported the relationship of fluid abilities with WM, in which tasks require additional control of processing as against the tasks measuring the crystallized abilities. Tasks that primarily tap crystallized abilities (vocabulary and general information tests), however, rely more on associative/automatic processes and thus should be weakly related to the memory measures. However, the present researcher considers that any task at the initial stages of learning taps fluid intelligence as it requires an additional amount of control to process and with practice turns into measuring crystallized intelligence. This is based on the direct observation within the specialized services for children with learning disabilities. These specialised settings focus on intensive teaching of skills pertinent to fluid intelligence such as making designs from blocks, putting pieces of jigsaws together, finding similarities between abstract visually presented stimuli, etc. Children attending these services show, in a majority of the cases, improvement in their performance on review when assessed on tasks measuring fluid intelligence, thus indicating the importance of the role of teaching in supporting enhanced abilities on tasks measuring fluid intelligence. Recent research has emphasised the importance of working memory training and its subsequent influence on the Fluid Intelligence (e.g., Perrig, Hollenstein, Oelhafen, 2009*)*. These authors have suggested that the relationship between WM and Gf is the outcome of shared pathways both at the behavioural and at the brain level. Baddeley (2007) has also recently claimed that "working memory span also predicts cognitive functioning much more effectively than measures of either simple word span or episodic LTM" (p. 146; see also Engle et al., 1999).

Our knowledge still seems quite limited in terms of finding a direct relationship between the different components of WM (short-term storage and executive processes) with higher-order cognition. Specifically, there is a dearth of knowledge about the relationship between memory function and higher order functioning in young children. The present study will undertake this task of looking at the relationship of different components of memory with higher order cognition with a focus on children.

1.6 Working memory and processing speed

WM was also at one stage considered to have a strong relationship with processing (perceptual) speed (PS). The PS is also considered as an important factor in contributing towards the performance of working memory, as tasks measuring WM (especially visual spatial) and processing speed appear to be quite similar in nature. However, there are not many studies which have made an attempt to look at the relationship of PS abilities with working memory. Furthermore, PS is included in almost all the intelligence tests, such as WPPSI-III, WISC-IV, WAIS-III, etc. Based on the previous arguments in favour of establishing a link between WM and intelligence, a relationship between PS and WM seems likely. The PS abilities represent basic encoding and comparison of stimuli, across a variety of different contents (Ackerman, 1988, 1990). Carroll (1993) suggested that there were at least two PS factors - one related to finding stimuli in isolation, the other related to comparing sets of stimuli. The PS abilities have also been suggested as an important factor in determining individual differences during the acquisition and maintenance of skilled performance (Ackerman, 1988, 1990, 1992; Ackerman & Cianciolo, 1999; Ackerman & Kanfer, 1993).

Kyllonen and Christal (1990) provided support in favour of WM's relationship with PS compared to reasoning abilities, which would be contrary to the outcome of Conway et al. (2002) presented earlier. Kyllonen et al. indicated a coefficient of .47 between WM and processing speed in contrast to a coefficient of .25 between a reasoning factor and processing speed. This relationship of PS with WM appears to be quite strong. In another study, Oberauer, Süß, Schulze, Wilhelm, and Whittman

(2000) administered 23 computerized WM measures. These authors labelled these tasks with different categories depending on the content (verbal, spatial-figural, and numeric) and function (storage and transformation, supervision, and coordination). The findings indicated that verbal–numerical factor correlated highest with the numerical and reasoning intelligence test scales (r = .46 and .42), and spatial–figural correlated highest with reasoning, spatial, and numerical scales (r =.56, .52, and .48, respectively). The speed/supervision factor related most highly with a speed scale from the intelligence tests at a correlation of .61. As already mentioned, there are not many studies in this area, so the present research will include measures of PS and their relationship to WM.

1.7 Development of the WM System

Working memory continues to develop throughout childhood, with the capacity for abstract thought, planning, and cognitive flexibility developing throughout adolescence (Levein, Culhane, Hartman, Evankovich, & Matson, 1991). Cognitive development highly depends on brain maturation, including synaptic pruning, and elaboration of dendritic arborisation, which are reported to continue into early adulthood (Changeux, & Danchin, 1976; Huttenlocher, 1990), as well as increased myelination (Giedd, Blumenthanl, Jeffries, Castellanos, Lie, et al.,1999; Paus, Zijdenbos, Workley, Collins, Blumnethal, et al., 1999; Yakovlev & Lecours, 1967). These are processes a mammalian brain automatically carries out in order to develop its capability to its full, depending on the strength of the stimulating environment.

There is agreement among researchers that cognitive development during late childhood and adolescence is mainly due to the relatively late integration of the prefrontal cortex, which reflects either late structural maturation (Bourgeois, 1993; Sowell, Thompson, Holmes, Batth, Jernigan, *et al.,* 1999) or reliance on maturation of other neocortical regions (Chugani, 1998; Rakic, 1995;) that influence functional integration with the prefrontal cortex (Thatcher, Walker, & Giudice, 1987). These processes support myelination and pruning within the brain contributing significantly towards the higher order cognitive processes, of which WM and executive functioning are major parts. With new advances in neuroimaging technology, it is possible to examine the developing human brain in vivo. One of the techniques to study patterns of brain activity is the Functional Magnetic Resonance Imaging (fMRI). This advancement in technology is considered to be helpful in exploring developmental growth of the brain especially for the purpose of higher cognitive functioning. Like any neural processes, those of the prefrontal cortex, considered to be responsible for the operation of working memory, continue to develop during childhood, and have been studied extensively. Studies have been carried out on children while they were performing tasks of verbal and visual spatial WM (Casey, Cohen, Jezzard, Turner, Noll, et al. 1995; Nelson, Monk, Lin, Carver, Thomas, et al. 2000; Steenari, Vuontela, Aronenr, Koivisto, Martinkauppi, et al. 2001; Thomas, King, Franzen, Welsh, Berkiwitz, et al. 1999). These studies indicate that when children were tested while performing working memory-related tasks, the activation in the child brain is of greater magnitude and distributed in a more diffuse manner compared with the adult brain. These outcomes are reported by researchers as mainly the outcome of the ongoing maturation and synaptic fine tuning in the child brain (Bourgeois et al. 1994; Casey, Geidd & Thomas, 2000). This would also mean that the brain areas start to function in a more specialized manner as the child gets older. However, there are fMRI studies which have suggested the activation of similar areas by children as adults while performing a WM task (Nelson et al., 2000, Thomas et al., 1999; Casey et al., 1995).

Another interesting question about WM in children relates to capacity. Does the capacity of WM increases with time and at what age do children achieve their maximum capacity? There are studies that suggest that the amount of information one can keep in WM increases throughout childhood and early adulthood (Gathercole, 1999; Hale, Bronik, & Fry, 1977; Luciana & Nelson, 1998). Dempster (1981) suggested that, individual differences in child and adult memory spans aside, the span of the average preschool-age child is approximately one-third that of the average young adult. According to him this improvement mainly comes about during the early school years as the span increases by a little less than one item between 13 years of age and young adulthood. This increase in WM capacity is highly influenced by many of the environmental factors especially when the child starts schooling, as WM capacity is thought very important for the development of a wide range of cognitive skills, including reading and logical reasoning (Engle et al., 1999; Fry & Hale, 1996; Hulme & Roodenrys, 1995). Gathercole and Baddeley (1993), after reviewing the literature on the development of WM, concluded that the capacity of WM in children largely depends on the mode of information being processed. These authors also differentiated between quantitative and qualitative function of memory by referring to the use of different mnemonic strategies used by different children.

As mentioned earlier, research on the sequence of WM development with regards to verbal and visual spatial working memory would help us in understanding this area. There are some studies in this area which have indicated the advantage of visual processing over phonological processing. For example, Hitch and Halliday (1983) demonstrated that children prefer visual processing over phonological processing of visual information. These researchers tested children from 6-10 years old on the recall of one to three syllable words. Half of the children were presented with the words auditorially (e.g., listening to the word 'cat', 'monkey', etc) and the other half were presented with the pictures (so instead of a cat, children were shown the picture of a cat). These researchers found that children from 8-10 years old showed a word-length effect (i.e., recalled fewer long words than short) for names of objects that were presented pictorially and the names of objects presented aurally, whereas the younger group of children showed a word length effect only for aural presentation of words. This finding suggests that, unlike older children and adults, young children do not automatically translate pictorial information into their corresponding object names.

What could be the reasons for the ineffective strategy? Gathercole and Baddeley (1993) proposed that very young children have probably not developed the ability to use phonological recoding of pictorially presented objects which can help in enhancing their recall. These skills are usually manifested when children start to attend school and hence get an opportunity to use these skills on a regular basis. However, these researchers observed that the spontaneous use of active rehearsal starts to emerge corresponding to a child's reading proficiency. This highlights the important contribution of school in enhancing the memory skills.

However, some research with children, like that of Alloway, Gathercole, and Pickering (2006), provides support for a model based on two domain-specific storage components and one domain-general executive component. Jarvis and Gathercole (2003) used a factor analysis on data obtained from children and identified one verbal and one visuospatial factor, each involving both STM and WM performance. Thus, these findings suggest that STM and WM are inseparable in children, in contrast to the findings of Alloway et al. (2006). The present investigation will also make an attempt to investigate whether children perform differently on the tasks involving WM and STM.

Recent work by Cowan and his colleagues (Cowan, 1992; Cowan et al., 1992) has proposed an alternative explanation of poor performance of preschool children when compared to older children on memory span measures. They provided evidence in support of young children's inability to maintain the relation between articulation rate and memory span. For example, a four year old who speaks quickly tends to perform more poorly on memory span tasks. They consider that children with different ages differ qualitatively in their strategies of using mnemonics. Despite the identification of specific qualitative differences between working memory function in pre-school children and school-age children, researchers agree that the improvement in working memory appears to be purely quantitative once they start school (Dempster, 1981, 1992; Gathercole and Baddeley, 1993).

1.8 Neurodevelopmental disorders and memory impairment

The neurodevelopmental disorders are a group of disorders affecting learning, memory, language and/or social-emotional function that become apparent as the child develops. The term encompasses such disorders as autism, Asperger syndrome, traumatic brain injury, speech and language impairment, as well as genetic disorders such as Down syndrome (Ehninger, Li, Fox, Stryker, & Silva, 2008).

Brain development is a complex process which continues throughout the life span (Casey, Tottenham, Listorn, & Durston, 2005; Cicchetti & Cannon, 1999; Nowakowski, 1987; Rakic, 1996; Thompson & Nelson, 2001). There could be many factors that alter the normal progression of brain development, which could range from genetic liabilities to psychosocial stressors to mental disorder. These alterations manifest as different neurodevelopmental disorders, which may include ASD, ID, SLI, ADHD, Tourette syndrome, etc. One of the manifestations of these disorders is in the form of executive and memory dysfunction. To operate effectively, the executive function requires integrated cortical and subcortical systems that are widely distributed throughout the brain. If this system is disrupted at any stage, it can make the entire system ineffective which may have serious consequences on not only the entire executive function but its subsidiary systems such as working memory.

Therefore the present research was undertaken to examine STM and WM function, within the neurodevelopmental disorders and to compare performance of different sample groups on a single instrument. The use of a single instrument would have an advantage over other studies as these groups will be compared, using standardized instruments.

Autism: Definition and explanation

Autism is a severe pervasive developmental disorder (PDD) associated with substantial impairments in terms of social deficits, communication abnormalities, stereotypical and repetitive behaviours and a wide range of clinical presentations (Cody, Pephery & Piven, 2002). The term autism spectrum disorders (ASD) has been used in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR) (APA, 2000) with diagnostic categories Autistic Disorder, Asperger Disorder, and Pervasive Developmental Disorder-not otherwise specified. Recent estimates of the prevalence of ASD are in the range of 2-20 per 1000, with boys being 4-5 times more likely to develop the disorder than girls (APA, 2000). A widespread concern exists among the general population and professionals about the reported increases in the prevalence of ASDs, which include Autism, and Asperger syndrome. The two well recognized systems for diagnosing ASD, the DSM and the International Classification of Diseases (ICD) published by the World Health Organisation have refined their criteria over time. For example, the third edition of DSM criteria specified the age of onset as ‘by 30 months’, whereas in the fourth edition the age of onset was stated as ‘by 36 months’. Another major factor is the availability of valid and reliable instruments such as Diagnostic Instrument for Social and Communication Disorder (DISCO) and the Autism Diagnostic Interview/ Observation (ADI/O). In addition to these resources, the skills of professionals in detecting such disorders have increased, especially with the availability of training in the early identification of ASD features. This has also contributed significantly to the increase in the number of diagnoses.

Although we know much more about autism in the current times and the knowledge base has been expanded significantly, its aetiology remains somewhat mysterious. The underlying reasons for ASD are considered to be elusive as no sufficient biological markers have yet been identified to explain the disorder.

Therefore it is typically defined in terms of observed behavioural characteristics (Bryson & Smyth, 1998). As our understanding and knowledge base is improving, correspondingly the diagnostic criteria for autism are also becoming more refined. However, these revised diagnostic criteria maintain a consistency with the earlier ones as they mainly look for two of the core features as described by Kanner (1943) while describing infantile autism. These are (a) the 'obsessive insistence' for sameness and (b) the characteristic self-isolating behaviours (Happe & Frith, 1996).

Soon after Kanner's (1943) description of early infantile autism, Asperger (1944/1991) published a study describing four boys who displayed similar behaviours to Kanner's children. Meyer and Minshew (2002) reported that Asperger identified boys in his practice who, despite intact linguistic skills, were presenting difficulties with non verbal communication coupled with an unusual intonation. These boys also demonstrated a special preference for following a strict routine and would express their discomfort with change in their environment. Repetition of behaviour was another strong indicator identified by Asperger. This pattern of behavioural manifestations eventually became known as Asperger's disorder. These studies became a focal point of discussion to describe the characteristics of these disorders. Some authorities consider Asperger disorder as autistic individuals with an IQ score over 70 and with better linguistic skills whereas individuals who scored less than 70 are considered to be meeting the criterion of Autism Spectrum Disorder (ASD). It has also been argued that Asperger's disorder simply falls along a continuum of autistic related disorders. Consequently, some authors have suggested that the label 'Autistic Spectrum Disorders' may better characterize and encompass both the conditions (Meyer & Minshew, 2002).

There are several theories advanced to describe and explain this disorder. However, if we analyze these theories, it would suggest that no single theory could sufficiently explain all core features (Joseph, 1999). Consideration will be given to only those theories that bear relevance to the present research. Therefore, the focus here is on the Executive Function hypothesis and the Theory of Mind approach.

Executive Function Hypothesis

The Executive Function hypothesis proposes that autism reflects primary deficits in executive control, which are ultimately responsible for generating typical autistic features. The executive functions involve mental operations such as working memory, planning, inhibition or responses, as well as the maintenance and shifting of mental set (Joseph, 1999; Rabbitt, 1997; Roberts, Robins, & Weiskrantx, 1998;, Stuss & Knight, 2002,). All these functions have been linked to frontal structures of the brain, and especially with the prefrontal cortex, areas which are believed to play a crucial role in guiding everyday actions, the ability to engage and disengage from an activity, taking decisions according to the immediate environment, etc. The present research will help in providing evidence for this hypothesis, if working memory is found to be implicated within the ASD sample, as WM is reported to be a major feeding component of central executive, as was discussed in detail earlier.

The theory of executive dysfunction in autism suggests a strong connection to frontal lobe failure based on similarities of symptoms with those of patients who have suffered damage to their frontal lobes and have impaired executive functions. Moreover this assumption is also linked with resemblance to a wide range of developmental disorders that are likely to involve congenital deficits in the frontal lobes. There is a belief that damage to the interconnected cortical and subcortical brain structures is implicated in developmental disorders, and the ASD population may also have impaired frontal lobe dysfunction (Joseph, 1999; Pennington & Ozonoff, 1996). However, these developmental disorders cover very broad categories which may include Attention Deficit Disorder (ADHD), Autism (ASD), Obsessive Compulsive Disorder (OCD), Tourette’s Syndrome (TS), and Phenylketonuria (Ozonoff & Jensen, 1999; Pennington & Ozonoff, 1996; Sergent, Geurts, & Oosterlaan, 2002). All these syndromes are characteristically so different, with very little in common in their onset or presentation, except their varied level of attention. Therefore, to suggest any similarity only because they fall under the umbrella term of ‘neurodevelopmental disorders’ would be highly misleading. The present study will include three groups with neurodevelopmental disorders which will give an opportunity to see if there are any similarities on the cognitive tasks.

Executive dysfunctions can be seen to underlie many of the key characteristics of autism, both in the social and non-social domains, which are the basis of theory of mind as well, a topic to be explained in the subsequent section. Individuals with ASD like structured environments and prefer to carry out stereotypical activities, which would be a contradiction to the principles of flexibility and set shifting which are considered to be the main pillars of the executive functions. These behavioural characteristics, like inflexibility, rigidity in actions and perseveration, lay the foundation of executive dysfunction which may be explained as a reluctance to initiate new non-routine activity. Individuals with ASD also have the tendency to get stuck in a given task set by repeating the routine actions following certain rituals with intricate details. There is no exaggeration in saying that the lives of individuals with autism are dominated by repetitive actions. It is also well known that individuals with ASD benefit from support such as prompts, which are usually externally provided structures, to initiate these routines or help them switch set. Several studies have found evidence of executive function impairment in persons with autism (Hughes and Russell, 1993; Hughes, Russell & Robins, 1994; McEvoy, Rogers & Pennington, 1993). Damasio and Maurere (1978) hypothesized that deficits in individuals with frontal lobe injury and individuals with autism may be the result of damage to similar brain systems. Subsequent studies have found evidence of prefrontal cortical dysfunction in individuals with autism (Pennington & Ozonoff, 1996).

There are other theorists who used standard executive function measures. For example, Hughes et al. (1994) presented individuals with autism with two tests of executive function, the Tower of London planning task and the extra dimensional set-shifting task. On each of the tasks, the autistic group performed poorly relative to controls. Furthermore, the impairments were most prominent on tasks that demanded the greater executive control.

Hill (2004) found impairments in at least two areas of executive functioning among the ASD sample, which include planning and flexibility. However, Hill (2004) proposed that in order to arrive at some conclusion about the impairment of executive functioning within the ASD population, it is important to select well matched groups and to compare their performance on a wide range of tasks ‘fractionating the executive system’. This would be one of the aims of the present study - to look for working memory tasks which could further subdivide the WM components.

Robinson, Goddard, Dritschel, Wisley and Howlin (2009) examined executive functioning in a group of high functioning children with ASD and compared their performance with typically developing children in the control group. The groups were matched on the basis of age, gender, IQ and vocabulary. These researchers observed significant impairments in the inhibition of pre-potent responses (e.g., Stroop, Junior Hayling Test) and planning (Tower of London) for children with ASD, with preserved performance for mental flexibility (Wisconsin Card Sorting Task) and generativity (Verbal Fluency). These results suggest that children with ASD do not present difficulties on all the tasks measuring executive functioning, and there are intact areas of the brain controlling executive functions. Furthermore, children with ASD performed very poorly on tasks tapping response inhibition and self-monitoring compared to controls. These researchers proposed a multidimensional notion of executive functions which suggests that children with ASD present difficulties with planning and the inhibition of pre-potent responses and self-monitoring, which are believed to be characteristic features of ASD and which are independent of IQ and verbal ability and relatively stable across the childhood years.

There are many other studies which have found implications for executive functioning of children with ASD along with other neurodevelopmental clinical groups. For example, Corbett, Constantine, Hendrem, Rock and Ozonnoff (2009) investigated executive functioning in children aged 7- to 12-years old, which included ASD, ADHD and typically developing children. They used a comprehensive test battery to measure executive functioning. The aim of the study was to compare these groups on response inhibition, working memory, cognitive flexibility, planning, fluency and vigilance. The ADHD group exhibited deficits in vigilance, inhibition and working memory relative to the typical group; however, they did not consistently demonstrate problems on the remaining executive functioning measures. Children with ASD showed significant deficits in vigilance compared with the typical group, and significant differences in response inhibition, cognitive flexibility/switching, and working memory compared with both groups. These results support the previous findings that show that children with autism demonstrate generalized and profound impairment in executive functioning. In addition, these researchers also observed similarity between the cognitive profiles of ASD and ADHD. However, a large number of children with ASD also present with high activity levels similar to ADHD. There are recent studies which estimate that 31% of children with autism spectrum disorders (ASD) meet diagnostic criteria for attention deficit/hyperactivity disorder (ADHD), and another 24% of children with ASD exhibit sub-threshold clinical ADHD symptoms (Yerys, Wallace, et al. (2009) These researchers suggest that the comorbid symptoms of ADHD and ASD could produce multiple effects. These characteristics could further exacerbate the core ASD impairments. There is nothing in common in the description of the diagnostic criteria (DSM-IV), as ADHD is characterized by severe attention problems, hyperactivity, and impulsivity, whereas ASD involves deficits in communication and social interaction as well as their obsessional characteristics. However, the similarities emerge in clinical presentation, as a majority of children with ASD commonly present with hyperactivity and attention problems. They present significant difficulties with their concentration especially if the task does not cater for their obsessional needs. Contrary to this notion, some authors attribute similarities between the two disorders mainly to the overlapping diagnostic criteria resulting in inflated co-occurrence rates (Rommelse, Franke, Geurts, Hartman, & Buitelaar, 2010).

Some researchers have attempted to look at the coordination activities of the brains of the children with ASD in order to link it with executive dysfunction theory. Perez Velazquez et al. (2009) indicated that the coordinated activity in brains of children with autism is lower than that found in participants in the control group. They used magnetoencephalographic (MEG) recordings, on high-functioning children with ASD and control groups, while they were performing executive function tasks. They found disruption of long-range phase synchronization among frontal, parietal and occipital areas which was associated with impaired execution on tasks, compared to enhanced long-range brain synchronization in children in the control group. These results support the notion that brains of individuals with autism may not be as ‘functionally connected’ as those of the controls and therefore problems with tasks of an executive functioning nature emerge.

Executive dysfunction theory has recently been criticized by Baron-Cohen, Ashwin, Ashwin, Tavassoli and Chakrabarti (2009). Their argument is mainly based on one of the characteristics of ASD individuals i.e., hyper-systemization. They argue that hyper-systemizing predisposes individuals to show talent for specific activities, and provided evidence that hyper-systemizing is part of the cognitive style of people with autism spectrum conditions (ASC). The theory suggests that the systemizing mechanism is set too high in people with autism and therefore they can only deal with systems based on rules and regulations, and they are therefore highly resistant to change. Based on this paradigm, these theorists explain that executive dysfunction theory has difficulty explaining the existence of talent in ASC. However, these talents are manifested only in a small proportion of high functioning children with ASD which is called savant syndrome. Treffert (2009) studied savant children and observed that one in ten autistic people have savant skills. Fifty percent of children indicating savant characteristics are autistic, whereas the other 50% often have different disabilities, mental retardation, brain injuries, or brain diseases. The ratio of male to female savants is 6:1. However, savant syndrome is still not fully understood as no accepted cognitive theory explains the combination of talent and deficits found in savants (Pring, 2005). Furthermore, Baron-Cohen et al. seem to have supported the Executive Function hypothesis by acknowledging the ASD population's difficulties in accepting change in their life by engaging in highly systematic but stereotypic activity – we know from our previous discussion that cognitive flexibility is one of the major components of central executive function.

The executive functioning impairment hypothesis does not fully address all the aspects of the ASD disorder and questions are raised about prefrontal impairment in autistic children. Dawson, Munson, Estes, Osterling, Mc Patland, Toth et al. (2002) used a sample of autistic 3-4 years olds to see if they were impaired on ventromedial prefrontal tasks. They also wanted to determine whether such tasks correlated with joint attention ability. This study consisted of three groups of children, i.e., ASD, developmental delay and typically developing, and they were matched on mental age. Results of the study showed that there were no significant differences between the group with ASD and children in the control group. This study appears to have added another dimension to the hypothesis of executive dysfunction. The important aspect of this study was the inclusion of children with an age range from 3-4 years. At this young age, the effect of intervention could be only marginal, if there was any, and therefore their relative performance in this domain may actually point to their intact executive functions, especially in the case of high functioning children with ASD. Hence, the outcomes of the results of these studies point towards the complexity and variation among this group. Furthermore there is no other syndrome which is perhaps as divergent and complex in terms of abilities, behaviour, social skills, etc. as that of the ASD group, which may account for the varied results. Williams, Higgins and Brayne (2006) also found significant variation when they carried out a meta-analysis of electronic databases and bibliographies. They found a high degree of heterogeneity among studies, as 61% of the variation in prevalence estimates of typical autism was due to diagnostic criteria used (ICD-10 vs. other), age of children screened, and study location (e.g. America versus Japan).

Theory of Mind Hypothesis

Baron-Cohen, Leslie and Frith (1985) also examined the relationship between executive function and autism. They presented a story to autistic individuals. The story was based on a doll, whose name was Sally. Sally places a marble in a basket and leaves the room. Another character comes to the room and she takes out the marble from the basket and places it in a box. Participants were asked where Sally would look for the marble when she came back. The findings showed that most of the respondents replied that Sally would look for the marble in the box instead of where she had left it originally. Joseph (1999) maintained that individuals with ASD present difficulties in the area of social communication which emerges from their inability to understand other people's minds and to interpret behaviour in terms of underlying mental states; this view led to proposal of theory of mind. The theory of mind hypothesis places central significance on the inability to take on the perspective of others' mental states (Baron-Cohen et al., 1985).

There are other studies that have examined the link between the theory of mind hypothesis and the executive function account of autism (e.g., Ozonoff & McEvoy, 1994). Although these studies have identified both theory of mind and executive function deficits, the implication of executive function deficit is more widespread and prominent within the ASD population (Joseph, 1999). It has thus been proposed that executive dysfunction is the primary deficit, which in turn, directly affects performance on theory of mind tasks (Joseph, 1999). The executive dysfunction can be seen to underlie many of the key characteristics of autism, both in the social and non-social domains. The behaviour problems addressed by the executive function theory are rigidity and perseverance, explained as poverty in the initiation of new non-routine actions and the tendency to remain stuck in a given task set (Hill, 2004). However, we are still not sure whether individuals with ASD have impaired executive functions or if it is only related to a specific component of executive functions such as WM. This relationship will be discussed in the following sections.

Autism and Working Memory

In the past, many studies focused mainly on the status of memory function in autism. During that time, the major argument was around memory impairment of individuals with autism. Boucher and Warrington (1976) argued that this idea got its support especially from 'amnesia' theory as a result of a similarity between patients with lesions of the limbic areas, including the hippocampus, resulting in a selective, long term memory deficits. Research also attempted to establish a link between autism and Korsakoff's syndrome based on a shared pattern of impaired recall and recognition memory and improvement of recall with cues. Based on this evidence, it was believed that individuals with ASD, like amnesic patients, show intact short term memory and relatively intact performance on visual spatial tasks (Bartak, Rutter, & Cox, 1975). This view of memory dysfunction in autism continued until there were studies which produced results contrary to the already existing knowledge about 'amnesia' in autism (Bennetto, Pennington, & Rogers, 1996; Minshew & Goldstein, 1993; Minshew, Goldstein, Muenz, & Payton, 1992; Rumsey, Hamburger, 1988). Bennetto et al. (1996) demonstrated that individuals with autism had intact functioning on standard declarative memory functions that are typically compromised in classic amnesia patients. In particular, individuals with ASD performed similarly to subjects in the control group on tasks of standard rote memory, verbal long-term memory, or recognition memory, either for verbal or pictorial information. These results were consistent with both previous neuropsychological studies of autism (Minshew & Goldstein, 1993), and behavioural observations of very good rote memory in individuals with autism. Minshew and Goldstein (1993) studied 21 matched pairs of high functioning subjects with autism and compared them with control group. They were tested on 33 variables that were derived from the California Verbal Learning Test (CVLT). Their findings did not support the amnesia theory of autism. However, they observed reduced neural connectivity and deficits in information processing involved in the formation of cognitive strategies for efficient organization of information, as was already discussed in the previous section.

However, these studies were, possibly, not differentiating between high and low functioning group with autism on the basis of their IQ, which could be one of the reasons for the poor performance of some individuals on memory tasks. Minshew and Goldstein (2001) argued that these researchers did not take notice of a critical difference, as memory impairments in autism are usually mild and do not result in the severe inability to form new memories that typifies amnesia. In the current study, the specific deficits in WM and executive functions of those with high functioning ASD are examined and compared to the deficits associated with the mild form.

When the issue of amnesia was resolved, researchers started to analyse the characterization of memory function in autism. If we look at research in this area, it would suggest two hypotheses: the first that memory impairment is a by-product of executive dysfunction (Bennetto, et al., 1996) and the second that memory impairment is the outcome of deficits related to complex information processing (Minshew, Goldstein, & Seigel, 1997). Both accounts, the executive function and the information processing account, are strongly linked with working memory, suggesting impairment in this area.

Minshew et al. (1997) tested the neurobehavioural theories of autism with a special reference to information processing impairments. They suggested core deficits in sensory input or perception, basic attentional abilities or generalized attention to extrapersonal space, anterograde memory, auditory information processing, higher order memory abilities, conceptual reasoning abilities, executive function, control mechanisms of attention, and higher order abilities across domains. These researchers designed a neuropsychological test battery to investigate their hypotheses. The test was administered to individuals with autism with IQ scores greater than 80, and 33 individually matched normal controls. The results were not consistent with mental retardation or with a general deficit syndrome, but rather with a selective impairment in complex information processing that does not involve visual spatial processing. The authors proposed that this neuropsychological profile was consistent with the neurophysiological characterization of autism as a late information processing disorder with sparing of early information processing. This impairment in information processing would subsequently suggest significant difficulties with working memory as well. It is assumed that one of the requirements of working memory is processing along with storage. The quicker one is able to process information, the sooner one will make a space available for more information.

When many researchers refuted the implications of amnesia theory within the ASD population, the organizing abilities of the individuals with ASD were challenged, which has further far reaching consequences for their general cognitive functioning. For example, it was Hermeline and O’Connor (1970) who initially reported limitations in using organizing strategies within the population with autism; these limitations impact on memory functions. They reported similar performance by children with autism and controls on recall of random words, infrequent words, and words arranged into anomalous sentences. The children with autism, in contrast to children in the control group, did not show improvement when words were arranged into sentences, nor did they spontaneously re-group semantic clusters or sentences to facilitate recall. However, the findings of this research may be debated in the context of the high functioning individuals with ASD who may at times be at the other extreme as regards organizational skills. They like their environment to be meticulously organized around them. If they have an interest in a particular activity, they try to maintain all the rituals to be perfect in finishing it. However, a problem may emerge if they are not interested in an activity, which may be the case with the tasks in the previous research. This contention is supported by a number of research studies. For example, Mari, Castiello, Marks, Marraffa and Prior (2003) reported a planning deficit in low-IQ (70-79 IQ) autistic children in comparison to average IQ children suggesting that planning in their tasks was related to IQ rather than to autism. The present research will also attempt to look at the role of IQ in working memory for these individuals.

There are other researchers who looked for other factors which can affect performance on memory tasks. For example, Boucher (1978) found memory impairments related to strategy use, examining recall of the last words in a list, which reflects phonemic (sound-based) encoding, to recall of the earlier portion of a word list and delayed recall, both of which depend on semantic encoding. The children performed equally as well as the control group on the recall of the last words in the list. There was however a significant difference in the delayed recall of the initial words, since children with autism show impairment on these tasks. Boucher (1978) also noted that children with autism demonstrated better performance on digit span than on word span, but not to a major extent compared to the controls. This led her to suggest that recall of digits was not as affected by the variables that impaired recall of words, i.e., the failure to benefit from semantic meaning. These earlier studies have had far reaching effects in setting the direction for the subsequent studies.

Several subsequent studies substantiated the findings of Boucher (1981) which claimed that children with autism showed impairment affecting the ability to process, learn, and remember the information from real life situation. These studies have indicated that individuals with ASD demonstrate reduced learning and point to a generalized inefficiency of memory and learning in non-mentally retarded children, adolescents, and adults with autism (Bennetto et al., 1996; Delis, Kramer, Kaplan, & Ober, 1987; Minshew & Goldstein, 1993).

Boucher's (1981) hypothesis relating memory impairments of the ASD population with social, communication and reasoning difficulties on the outcome of her research needs very cautious interpretation. One of the major criteria in the diagnosis of children with ASD is social impairment. Therefore, there may be a possibility that the sample in the study may have encoded the information from the real life situation (the research was based on a real life situation experiment) but they may have had difficulties in recalling the information and putting it into words, when they were asked to do so, which would be highly demanding of social communication. This argument can be supported by Tager-Flusberg (1985, 1991), who found individuals with ASD needed cues to stimulate recall of unrelated words, and their performance was similar to the controls, suggesting that they had encoded the meaning of the words but failed to spontaneously use linguistic information to facilitate retrieval of stored information.

Rumsey and Hamburger (1988) found that high functioning adults with autism performed as well as controls on the Buschke Selective Reminding Test. However, their performance was significantly lower on the immediate and delayed recall of the Wechsler Memory Scale stories and designs. Fein, Lucci, Braveman and Waterhouse (1996) also reported the same performance for low levels of planning and organization. Fein, Dunn, Allen, Aram, Hall, et al. (1996) found that young intellectually impaired children with autism, who had the least trouble with immediate recall of digits, were having trouble with sentences, and the most difficulty with stories. This outcome is, to a degree, predictable, as a majority of low functioning children with ASD present with difficulties in acquiring linguistic skills that may have affected their performance on sentences and stories.

The initial studies, which mainly used the Tower of Hanoi, and Tower of London as the main methods for measuring working memory, indicated dysfunction of working memory in autism. The simultaneous operations of maintaining a representation on-line while using it to guide behaviour that appear necessary to successful Tower performance have been considered by previous researchers as evidence that such tasks measure working memory (Ozonoff, Pennington, & Rogers, 1991; Pennington, 1994; Shallice, 1982). This conviction is based on five major investigations, relying on the outcome of Tower tasks, which have found statistically significant impairments among autistic samples compared to matched controls (Bennetto at al., 1996; Hughes & Russell, 1994; Ozonoff & McEvoy, 1994; Ozonoff, et al., 1991). The low- and high functioning autistic individuals performed lower compared to both intellectually impaired and typically developing individuals (Hughes et al., 1994; Ozonoff & Jensen, 1999).

However, there are other studies, which present a different outcome. The majority of these studies have used working memory-specific tasks as opposed to tasks measuring executive functions such as Tower of London and Tower of Hanoi. For example, Bennetto et al. (1996) studied high functioning adolescents and adults and they found deficient performance on only two measures of working memory capacity, counting and sentence span tasks. This outcome would suggest impairment in verbal working memory within the ASD population. While the design of this research appeared robust, controlling many possible confounding variables, the authors not only relied on just two measures to assess WM but also defined high functioning children with a FSIQ score of above 69 which is considered to be a borderline range of intellectual impairment as per the current criteria. Ozonoff and Jensen, (1999) like Bennetto et al. (1996), also recruited children for their study with a FSIQ score ranging from above 70. The present study, however, has made use of a battery of WM and STM assessment and high functioning children with an IQ of score above 79 will only be considered following the ICD-10 criterion. Further, the Ozonoff et al. study did not control their group for VCI and PRI as the control group had high scores on these domains compared to the experimental group. Furthermore, these studies appeared to have their main focus on deficits of executive function instead of WM within the ASD group.

On the other hand if we look at the research that Russell and his team proposed, there is no working memory impairment observed within ASD. They failed to find any significant group differences between children and adolescents with autism who were intellectually impaired and controls matched on mental age on three measures of working memory capacity: a dice counting task, an odd-man-out task, and a sentence span task (Russell, Jarrold, & Henry, 1996). The outcome of this research indicates that the ASD population may have an intact verbal and visual spatial working memory because the tasks used in the study include both these measures. Griffiths, Pennington, Wehner and Rogers (1999) studied children with autism to analyse their performance on spatial working memory tasks. They matched children with a diagnosis of autism with those with non-autistic traits on age and ability levels. Eight spatial working memory tasks were used for the purpose. The results indicated no difference between the performance of children with ASD and non-ASD. The researchers therefore concluded that visual spatial WM was intact among children with ASD. This would be very central to the present research – i.e., to look at the functioning of children with ASD on different components of memory and secondly to add to the existing knowledge in this domain.

Some other studies in the visual spatial field can be found that have culminated in supporting the intact visual spatial processing of memory. For example, Hermelin and O'Connor (1970) examined children with ASD on two visual memory tasks. The tasks consisted of pictures of common objects which were arranged either randomly or sequentially. The researchers found that children with autism performed similarly to their counterparts in the control group, on both the tasks. They also noticed an increase in the capacity of children with ASD for span tasks when they were facilitated with an additional support by providing them with semantic meaning. These results were also substantiated by Prior and Chen (1976). However, contradictory results were also documented in other studies. For example, Frith (1970a) examined children with autism and found their performance was impaired on both visual and auditory modalities. The research also provided additional information suggesting that children with autism follow simple rules in tackling their problems and they do not tend to change their strategies with the increasing complexity of their problem. Frith (1970b) reiterated her earlier stance regarding the tendency of children with ASD preference for stereotyped rules as a major hurdle in demonstrating flexibility as is required by the task. The tasks used in these studies need to be examined carefully, as the dominant factor in these tasks may have been geared towards measuring specific flexibility in thinking of a type that children with ASD find difficult. Frith's research would be quite contradictory to ASD general clinical presentation since, it is understood that children with ASD have better memory skills for places and routes as observed by the present researcher in daily clinical practice. In another study, Ameli, Courchesne, Lincoln, Kaufman and Grillon (1988) found high functioning individuals with autism had similar ability to controls for meaningful stimuli but performed less well than controls in recalling complex meaningless stimuli. An explanation for this outcome could be that children with ASD have intrinsic tendencies to look for order and meaning, which may have affected their performance, as opposed to the inability to remember.

In another study of visual memory for pictures with familiar objects and meaningless stimuli, it was demonstrated that high functioning individuals with autism did as well as controls for meaningful stimuli but less well in recalling complex meaningless stimuli (Ameli et al.,1988). ASD is one of the neurodevelopmental disorders which includes individuals with different capabilities, from very low to very high functioning, therefore this factor needs to be considered while interpreting the outcome of the research in this area.

In another study, Williams, Goldstein, Carpenter, Minshew (2005) found participants with ASD, which included children, adolescents, and adults, performing at similar levels relative to the cognitive and age matched controls on the verbal working memory tasks. However, they performed poorly compared to the children in the control group on the visual spatial working memory tasks. This outcome could have been the result of a matching of subjects only on FSIQ and VIQ but not on PIQ – that may have skewed the results to an extent indicating a poor performance by this group on visual spatial tasks. On the other hand, Steele, Minshew, Luna and Sweeney, (2007) found subjects with autism demonstrating an impaired visual spatial working memory by using spatial working memory task from the Cambridge Neuropsychological Test Automated Battery (CANTAB). However, these tasks (as stated by the researchers themselves) also relied on organizational strategies which would be a part of Executive Function rather than WM.

Williams, Goldstein and Minshew (2006) studied the memory profile of children with ASD with an age range of 8-16 years. They included children with a full scale IQ >80 and used a standardized memory assessment tool, the Wide Range Assessment of Memory and Learning (WRAML). The results indicated a significant difference between the profile of the group with ASD and the typically developing children. The results of the study indicated poor performance by the group with ASD on complex tasks both in the verbal and visual domain when compared to their functioning on tasks measuring simple short term memory. Furthermore, there was no difference observed on the delayed recall between the children with autism and the matched control group, except for the thematic verbal material. These results also present a mixed outcome, suggesting intact verbal working memory and impairment on the spatial working memory.

William's et al., (2006) research would in many ways be similar to the present one in terms of both the measures used and sample group. The only difference is the use of computerised assessment in the present research which has been reported to have some contribution towards better performance by the group with ASD. This computer facilitation hypothesis suggests that autism-control group difference are greater when tasks are administered in the standard fashion, by adults, than when they are given by computer (Ozonoff & Strayer, 2001; Ozonoff, 1995; Pascualvaca, Fantie, Papgeorgiou, & Mirsky, 1998). Ozonoff (1995) administered the traditional Wisconsin Card Sort Test (WCST) and a computerised version to a group of children with autism and a group of controls matched by IQ and chronological age, and found that the group with autism performed less well on the standard test, but did not differ from controls on the computerised test. There is a possibility of receiving additional cues from the human examiner, subtle cues which may benefit children with normal development compared to children with ASD, who are considered to be less skilful at interpreting non verbal cues such as facial expression than typically developing children (Bravermann, Fein, Lucci, & Waterhouse, 1989; Davies, Bishop, Manstead, Tantum, 1994; Fein, et al., 1992).

There are some other studies which have explored the possibilities of intact spatial working abilities. For example, Caron, Mottron, Rainville, and Chouinard (2004) studied two groups of adolescent and adult individuals. The clinical group comprised of high functioning autism with IQ scores in the average range and they were matched with typically developing individuals, on gender, chronological age, education, and performance IQ. The sample consisted of 16 participants in each group. The main objective of the experiment was to assess spatial abilities in high functioning participants with autism. Results showed that individuals with autism performed all the tasks at a level at least equivalent to a comparison group. No differences were found in route learning, reversing a route or on a pointing task. Furthermore, superior performance by participants with autism was found on tasks involving accuracy in graphic cued recall of a path, and a shorter learning time in a map learning task was noted. The authors concluded that the storage and the manipulation components of spatial working memory are unremarkable in individuals with autism, a result consistent with the notion of intact working memory in autism for certain types of material.

There are some studies reporting deficits in verbal working memory as against spatial working memory. However, the outcome of these studies are not consistent, as deficits in spatial working memory have also been reported in individuals with autism

(Minshew, Luna, & Sweeney, 1999), in their unaffected family members (Hughes, Leboyer, & Bouvard, 1997; Koczat, Rogers, Pennington, & Ross, 2002), and in individuals with Asperger's syndrome (Morris, Ohman & Dolan, 1999).

As mentioned earlier, many studies have noted issues regarding executive functions in autism. However, in recent years, investigators have directed their focus toward the subcomponents of executive function and their association with autism (Ozonoff, 1997; Pennington & Ozonoff, 1996). This change in direction came after some contradictory results involving executive dysfunction in autism, as there is some evidence to suggest that flexibility operations are impaired in autism. However, general inhibitory functions, on the other hand, are relatively intact; both are aspects of the executive functions (Ozonoff & Strayer, 1997).

Thus, there is still no agreement about the precise nature of dysfunction of working memory in autism. The task is complicated as it is very difficult to design tasks to measure working memory on its own. In the present research, an attempt will be made to use specifically designed tasks that measure working memory.

Ozonoff and Strayer (2001) also studied spatial working memory. They used a computerized spatial memory-span task in which the demand of the tasks on memory load was progressively increased. The participants were required to remember the location of coloured geometric shapes over varying delay periods. The outcome of this research proposed no significant difference in the performance of 25 high-functioning individuals with autism, Tourette syndrome, and healthy children. Once again, a strong indication of intact visual spatial working memory within the ASD population is found.

The question is, then, what contributes to these contradictory results? Some researchers are of the opinion that this lack of evidence of deficiency in working memory could be the outcome of an insufficient level of task difficulty relative to the ability level of participants. This means that to test working memory deficiency, tasks should be designed which would commensurate with the ability and the capability of working memory of the participants. This hypothesis was tested by Morris et al. (1999) and it was found that participants with ASD struggled as the memory load was increased. They used a spatial working memory task with high memory load that required maintenance of information across trials and reported deficits in individuals with Asperger syndrome.

This assumption was further tested by Steele et al., (2007). They examined spatial working memory in an ASD group by systematically varying the working memory load with increased amounts of information that would need to be remembered and the number of trials over which it would be required to be maintained. The study indicated reduced spatial working memory abilities in autism, and the deficits are significant when tasks impose heavier demands on working memory. This finding is consistent with several studies of individuals with autism that have shown a reduced utilization of organizational strategies, and in some cases even failure to use explicitly available structures that typically developing individuals use to enhance memory performance (Ameli, et al., 1988; Bennetto, Pennington, Rogers, 1996; Joseph, Steele, Meyer, & Tager-Flusberg, 2005; Minshew & Goldstein, 1993, 2001).

Recently there has been an increased interest in using neuroimaging techniques in looking at the memory functioning of ASD individuals. For example, Damarla, Keller, Kana, Cherkassky, Williams, et al. (2010) investigated the neural bases of preserved visuospatial processing in high-functioning autism from the perspective of the cortical underconnectivity theory. These researchers used a combination of behavioural, functional magnetic resonance imaging, functional connectivity, and corpus callosum morphometric methodological tools. The participants included thirteen high-functioning individuals with autism who were matched with controls on the basis of age, IQ, and gender. Both groups performed similarly on the Embedded Figures Task. However, the brain imaging results revealed several group differences consistent with the cortical underconnectivity account of autism. This would strongly support an explanation using brain plasticity, as this equal performance by the two groups despite the purported cortical underconnectivity could only be possible if other areas compensate for the affected area. Furthermore, these researchers also observed more activation in the area controlling the visuospatial information compared to the left dorsolateral prefrontal area for the ASD group. The autism group also demonstrated lower functional connectivity between frontal and parietal-occipital areas related to higher-order working memory/executive and visuospatial functions. Thus, these researchers observed that despite ASD showing underconnectivity in the cortical area, performance was at par with the typically developing individuals on the visual spatial tasks.

Ulay and Ertugrul (2009) have reviewed the literature related to the investigation of structural and functional neuroimaging studies, the neuroanatomical changes and possible pathophysiological pathways in autism. These researchers studied all the relevant studies published between 1997 and 2007, suggesting an increase in total cerebral volume, both in grey and white matter in the population with ASD, and these global volumetric changes are reported to be responsible for diffuse disturbance in neural networks during early development. These authors further report research in which individuals with ASD have demonstrated specific abnormal activities in the temporal lobes and amygdale, areas which are involved in the development of language and social cognition, respectively. Notwithstanding the positive outcome of these studies implicating specific areas of the brain, these researchers still showed scepticism by concluding that it was still very early to identify with certainty the neurobiological process responsible for autism. This lack of evidence again strongly justifies carrying out the present study, which may help in improving the knowledge base in this area.

The summary of all these studies is very nicely presented in a review of the literature by Gras-Vincendon, Bursztejn, and Danion (2008). They reviewed the recent literature to explore the memory function of individuals with autism and found mixed results, as some memory subtypes were reported to be intact, whereas others were impaired. For example, they observed that there are many studies which have suggested that the short-term memory, using Digit Forward Span, is intact, while working memory appears to be impaired in some of its components. This means that there are some areas of WM that may remain unimpaired. However, inconsistency in these findings was also noted. There were some recent studies that have demonstrated reduced spatial working memory abilities in autism. These deficits were reported to increase corresponding to the demand of the tasks. However, these researchers could not find clarity around the neuroanatomical basis for the specific memory impairments. These researchers suggested that the difficulties of individuals with ASD are mainly with their encoding of information related to the social aspects of life, which leads to their impairment in the social, communication, and reasoning domains. They also reported that abnormal memory functioning in autism is also related to more general cognitive impairments, including executive function deficits and central coherence weakness. This brings us again to a strong link between IQ and memory functioning.

Thus, understanding whether working memory is deficient in autism is all the more central. In an attempt to clarify the inconsistent results of previous investigations, the present study aimed to look into different aspects of memory functioning of autism and to compare them with children having speech and language impairment, and children with Intellectual difficulties.

The discussion takes us to the next goal of the present research, the study of working memory in children with intellectual disabilities (ID). In the following paragraphs, a literature review will be under taken to look at the implications of working memory within the population with ID.

Working Memory and Intellectual Disabilities (ID)

The prevalence of intellectual disability is about 2-3 percent (Scott, 1994). Although there is no known single cause for intellectual disabilities, a number of factors could contribute towards it. These may include organic, polygenetic and socio-cultural factors (Simonoff, Bolton & Rutter, 1996).

Keeping in view the divergent nature of the ID population, there is still a lack of research in this area to date. Furthermore, very little work has been done in the area of visual spatial working memory, except for a few research studies on Williams syndrome. The existing research has implicated working memory deficits in children with ID (Hulme & Machenzie, 1992; Jarold & Baddeley, 1997; Jarold, Baddeley, Hewes, 1999a, 1999b, 2000; Russell, et all. 1996). These studies have mostly followed Baddeley's model to examine working memory in individuals with ID primarily focusing on the phonological loop component. The limited capacity of phonological loop has been demonstrated both in adults and in children with ID (Henry 2001; Henry & Maclean, 2002; Jarold & Baddeley, 1997; Numminen, Service, Ahonen & Ruoppila, 2001, 2002; Russell et al., 1996). However, a glance through these studies would indicate that a majority of these studies were conducted on participants with a known syndrome. For example, these studies have mainly focused on the Down and Williams syndromes. It is already established that children with Down syndrome have significant difficulties in acquiring linguistic skills compared to those with Williams syndrome, who are considered to have difficulties with visual spatial awareness. While individuals with Down syndrome are considered to have impaired performance on the verbal WM component (Bellugi, Wang & Jernigan, 1994; Vicari, Carlesimo & Caltagirone, 1995), those with Williams syndrome are reported to have deficient abilities on tasks measuring visual spatial WM (Bellugi et al. 1994; Grant, Karmiloff-Smith, Gathercole, Paterson, Howling et al. 1997). There are studies conducted with individuals with Down syndrome and it is still not fully understood whether their difficulties emerge due to an impaired phonological loop system or as a byproduct of both phonological loop and cognitive deficits (Hulmes et al., 1992; Kanno & Ikeda, 2002).

If we analyse the research, there are very few studies that have explored the functioning of working memory of children with mild ID with no known causality. The present research will therefore contribute to this area, as the sample of the present research will include moderate to borderline ID, which will enable the present researcher to study three ID groups simultaneously i.e., moderate, mild, and borderline. Henry (2001), for example, studied children with ID and compared their performance on a number of memory and executive function tasks. The outcome of the research indicated that working memory was markedly lower in children with mild and moderate learning disabilities and somewhat lower in children with borderline learning disabilities. The relationship between working memory and mental age was observed to be uniformly quite high in all of the seven memory span tasks (correlations ranged from .62 to .73). This study, in many ways, is quite similar to the present undertaking, except that the present study has an added advantage of the use of a computerised memory assessment tool, which is considered to be more systematic in terms of standardized administration. Secondly the present study aimed to recruit children of a much younger age group compared to the group that participated in Henry's research (i.e., 11-12 years).

Rosenquist, Conners, and Roskos-Ewoldsen (2003) studied differences in the storage and rehearsal components of the phonological loop and visuospatial sketchpad in individuals with and without intellectual disability matched on memory span. They found that the intellectual disability group performed very low specifically on the rehearsal component of the phonological loop. This was demonstrated by a weak word length effect compared to the group without intellectual disability. On the other hand, there was no difference observed on the storage component of the phonological loop as was studied via the phonological similarity effect. Both groups also performed similarly on the visuospatial sketchpad functions, having comparable visual similarity and visual complexity effects. These studies are crucially important in terms of intervention in order to develop strategies when working with a population with ID.

There are some other studies which have further informed us about the level of functioning by children with ID on tasks of WM. Henry and McClean (2002), for example, compared memory performance of children with mild intellectual disability with children in the control group. According to DSM-IV criterion, children who obtain a score less than 70 on an intelligence test are considered as functioning within the mild range of intellectual disability. These children were matched either on chronological age (CA) or on mental age (MA) for comparison. The results suggest that children with Mild Intellectual Disability (MID) performed poorly on phonological-loop tests and on central executive tests than did children matched for chronological age, whereas children who were matched on mental age did not show much difference in their performance except on a few tasks. This study, similar to the previous one, focused mainly on central executive functioning. Furthermore, based on the pattern observed, these researchers concluded that the findings did not support the hypotheses advanced in explaining ID i.e. the developmental delay and developmental difference hypotheses. The developmental difference hypothesis suggests that cognitive processes in children with mild ID are the same as in typically developing children, but they develop slower and reach asymptomatic levels at an earlier age. The developmental difference hypothesis assumes that mild ID involves a kind of structured deficit (Bennett-Gates & Zigler, 1998). However, if the study is analyzed carefully, it indicates that children with matched mental age performed poorly only on some specific areas. This means that there may be areas, no matter how minute, of intact working memory, that may improve with time. This study was very recently replicated by comparing three groups of children with mild intellectual disability (van der Molen, Van Luit, Jongmand, & van der Molen, 2007). The sample consisted of mild intellectual disability with chronological age-matched control children and mental age-matched children in the control group. The results showed that children with mild ID had intact automatic rehearsal, but they performed poorly on phonological-loop capacity and central executive tests when compared with children matched for chronological age. However, minimal differences were observed when control children were compared with the children matched for mental age. The researchers concluded that the overall pattern of results was consistent with a developmental delay hypothesis of mild ID rather than developmental deficiency.

This hypothesis was recently supported by Henry (2010). In this research, Henry studied the performance of children with ID on three verbal measures i.e., story recall, paired associated learning, and category fluency. These tasks were designed to assess the integration of long-term semantic and linguistic knowledge, phonological working memory and executive resources within the proposed 'episodic buffer' of working memory (Baddeley, 2007). The assumption for this research was based on the theoretical underpinning which had proposed that children with ID benefit from more elaborate long-term memory representation, because of their exposure to greater life experience, despite poorer phonological short-term memory than mental age matched peers. This assumption was substantiated as children with ID performed as well as their mental age matched peers when required to remember stories, associate pairs of words together and generate appropriate items in a category fluency task. However, their performance still could not reach to the level of the chronological age group on any of the tasks. The results suggest that children with ID perform corresponding to their mental age level on verbal 'episodic buffer' tasks, which require integration of information from different sources. This outcome also supported the 'developmental delay' hypothesis as opposed to ‘developmental difference’ hypothesis.

There are very few investigations which have attempted to distinguish memory performance by different degrees of intellectual disability. Schuchardt, Gebhardt and Maehler (2010) recently tried to compare two groups of children, i.e., mild range and borderline intellectual functioning, with an average group of children. All children were administered a comprehensive battery of tests assessing the central executive, the visual spatial sketchpad, and the phonological loop. The results indicated deficits in all three components of working memory, and these deficits increased corresponding to the degree of intellectual disability. The findings also suggested that children with ID show structural abnormalities in the phonological store of the phonological loop, but developmental lags in the other two subsystems. The present study will also attempt to compare children of various ID degrees, which includes children within the moderate range of intellectual functioning.

The role of working memory in updating executive functions and its relationship with fluid intelligence was recently studied by Carretti, Belacchi, and Cornoldi (2010). This is an area which needs intensive research in order to see the role of fluid intelligence weakness as is represented by individuals with intellectual disability (ID), which may also contribute further to their memory impairment. Carretti et al. used a battery of WM tasks varying in the degree of active attentional control and an updating task with groups of ID individuals and typically developing children. Both groups were matched on fluid intelligence performance. The results showed that the two groups were significantly differentiated by the updating measure, despite being matched on the Raven test. The research confirmed the importance of the demand for active attentional control in explaining the role of WM in fluid intelligence performance. It also showed that updating information in WM has an important role to play in differentiating between the typically developing children and individuals with ID. This research supports the importance of attentional control, as presented by Engle (2002).

Having discussed various studies at length, we need to look at the factors contributing towards the diversity in the outcomes of the research. One of the problems identified with the studies in the area of WM and ID is the inconsistent approach defining different terminologies relating to memory. For example, there are studies, particularly in the field of intellectual disability, which have used the term ‘working memory’ in place of ‘immediate memory’ (Bellugi et al. 1994; Hulme & Macenzie, 1992; Mackenzie & Hulme, 1987; Vicari et al., 1995; Vicari Carlesimo & Caltagirone, 1996; Grant et al., 1997) and ‘short-term memory’ (Marcell & Weeks, 1998; Simon, Rappaport & Aggriesti, 1995). For example, Engle et al. (1999) suggested that STM should be included in WM rather than considering it as a separate concept. They propose that STM is not only for short-term storage of information but it also requires a degree of attentional control, which depends on a person’s age, intelligence and developmental level, as well as the requirements of a task (Engle et al 1999). According to these researchers, higher level tasks require a certain amount of attention to process them. This explanation appears to be in line with the suggestion that the requirement for attention is reduced as tasks are engrained into one’s habits. These tasks may then be executed by more elementary STM processes with the decrease on the load of attention. Particularly for people with ID, there is an increasing possibility that the tasks reported to be measuring immediate memory may require the involvement of both storage and controlled attention to process the information.

Notwithstanding the inconsistency in terminology, the findings of most of the research have indicated that people with ID perform poorly on Digit Span Forwards and Backwards tasks, as well as on some other span tasks such as the Corsi Block task, compared to normally developing children of a similar mental age, regardless of level of intelligence or aetiology of ID (Hulme & Mackenzie 1992; Pennington & Bennetto, 1998; Pulsifer 1996). However, some studies have claimed no deficits on Forward Span tasks of people with ID compared to a control group (Vicari et al., 1995).

The difficulties with most of these studies could be, as mentioned earlier, not only due to the inconsistent approach in defining different concepts such as immediate memory, STM and WM, but also the use of instruments to measuring these tasks. At the time there was no standardized instrument specifically designed to measure WM. The majority of these tasks were either designed for a specific purpose with no reliability or validity, or a piecemeal approach was adapted by taking out a subset from a battery of either an intelligence or memory test. The present research will address this problem and will use a reliable and valid instrument for the specific purpose of assessing working memory.

The nature of memory in ID needs further exploration, especially in children, with a special emphasis on finding any link between intelligence and memory functioning. The available research is still not clear about the role of IQ and its implications for WM, especially within the ID population. It is observed that children with ID usually present difficulties of a global nature that have an impact on their attention, concentration, listening, and comprehension skills. The outcome of these global difficulties would have some serious repercussions for memory. Furthermore, children with ID display significant difficulties with language skills which may result in a low performance on tasks measuring the phonological memory skills.

Now we will move on to examine the importance of working memory in language development, which will be another area of focus of this research.

Specific Language Impairment (SLI)

Language development and SLI

SLI is a complex disorder and its aetiology is still not yet fully known. This can partly be attributed to the diversity within SLI as a group. SLI is considered to consist of highly heterogenous characteristics and therefore, the researchers have to use their professional acumen and judgment, supplemented with various assessment measures, to select a homogenous group for their study. Likewise the implication of working memory is not yet confirmed due to divergence in the research outcomes. The current research would, once more, be a step towards understanding the implications as regards working memory within the group with SLI. In order to understand SLI, it is important to first look at the normal pattern of speech and language development.

The frequency of learning new words is quite uneven, as children usually utter their first clear word close to their first birthday having gone through milestones such as babbling, vocalizing, etc. However, it is not usually a single word that the child uses first, rather a combination of a few words, which are important in a child's life, and may appear simultaneously, such as 'mama', dada', etc. Then it takes some time to master the first 10 words or so, since it is understood that typically the rate of learning new words is around 1-3 words per month. This pattern is followed by a sudden spurt when the rate of learning new words accelerates rapidly, leading to a period of 'vocabulary explosion' (Bloom, 1973). Between about 19 months and 2 years, children typically learn about 25 words per month (Nelson, 1973). This shows the improvement in the performance between the initial formative months and when the child turns 2 years in age. But we also need to consider babbling and vocalization as the foundation for any language to be learned and this all happens in the initial months. This rate of acquisition however, further increases during infancy, and children may have acquired nearly 2000 words by their 5th birthday. School probably provides a major impetus for learning new words as children's speed of acquiring new words increases further around this time. A peak rate of vocabulary growth occurs during the school years, and estimates suggest that between the ages of about 7 and 16, children typically learn on average 3000 words every year (Nagy & Herman, 1987). Furthermore, vocabulary building and the ability to use a word in multiple ways is enhanced with age and time. Within the life cycle, acquisition of new words never stops at any stage and it continues to grow later during adolescence and adulthood. Although the rate of learning new words slows down in adulthood, the pattern of later vocabulary building is affected by factors such as a person's social and occupational standing.

The importance of single-word knowledge in the first-few years of life for the subsequent emergence of complex syntactic and semantic structures cannot be underestimated (Barrett, 1989). Furthermore, vocabulary size is strongly associated with a range of abilities including general intelligence, reading ability, reading comprehension, and school success (Anderson & Freebody, 1981; Thorndyke, 1973). Hence, the relationship of WM and vocabulary may also be considered as having strong connections. Accordingly, vocabulary knowledge has been widely employed by experimental, developmental, and educational psychologists as a useful indicator of verbal intelligence, using standardised tests such as the Wechsler Scales for Children (Wechsler, 1974) and the British Picture Vocabulary Scales (Dunn and Dunn, 1982).

SLI is characterised by an abnormal pattern of language development. A child is diagnosed with SLI, when he or she, despite normal cognitive functioning, environmental exposure and sensory profile, has difficulties in developing language at the typical rate. Here, the emphasis is on ruling out all the contributing factors which could adversely affect language development. SLI is reported to be a relatively common developmental condition, estimated as occurring in approximately 7.4% of kindergarten children (Tomblin, Records, Buckwalter, Zhang, Smith et al., 1997) and it is more prevalent in boys than girls (e.g., Choudhury & Benasich, 2003; Flax, Realpe-Bonilla, Hirsch, Brzustowicz, Bartlett, et al. 2003). However, there are many problems in accurately estimating the prevalence of various speech and language disorders in children. There is little agreement over the definition and process of identification of SLI among speech and language therapists and most importantly researchers (Nelson, Nygren, Walker, & Panoscha, 2006), which is a very important factor in making a decision about the accuracy of prevalence figures (Law, Boyle, Harris, Harkness, & Nye, 2000). Secondly, speech and language disorder usually does not manifest itself in isolation; it often presents alongside other behavioural problems (Lubker & Tomblin, 1998).

Children with a diagnosis of SLI have significant difficulties with learning word forms and the grammatical structure of language, while the acquisition of semantics and pragmatics is relatively spared (Leonard, 1998). These difficulties do not follow a common pathway, and its effects could spread out quite disproportionately along the verbal domain. The deficits could even be found in general skills such as processing speed (Miller, Kail, Leonard, & Tomblin, 2001) and hypothesis testing (e.g., Ellis Weismer, 1991; Nelson, Kamhi & Apel, 1987). Furthermore, individuals with SLI commonly experience learning difficulties of a comparable magnitude across all scholastic domains, including mathematics (Arvedson, 2002; Donlan & Ghourlay, 1999; Fazio, 1996) and literacy (Bishop & Adams, 1990; Catts, Fey, Tomblin, & Zhang, 2002; Flax et al., 2003).

Subsequent to our discussion of language development and the SLI, the next step is to look at the role of working memory in language development.

Working memory and language development

There is strong research evidence that working memory plays an important role in the development and execution of linguistic skills. These studies have proposed that children with SLI are limited in their capacity to process and store information (Bishop, 1992; Ellis Weismer, 1996; Gathercole & Baddeley, 1990, 1993; Lahey & Bloom, 1994; Leonard, 1994; Montgomery, 1995, 1996). However, the majority of this research has been mostly on tasks which are targeted to measure verbal and non verbal abilities. These tasks were not specifically designed to measure and evaluate working memory capabilities. Therefore, the research could easily be used in support of a distinction between verbal and non verbal skills rather than suggesting involvement of working memory.

However, there are other studies which have attempted to use tasks specific to working memory. These research studies have used non-word repetition tasks, specifically designed to measure verbal working memory (Bishop, North & Donlan, 1996; Dollaghan & Campbell, 1998; Edwards & Lahey, 1998; Gathercole & Baddeley, 1990; Montgomery, 1995). Furthermore, these tasks were quite extensively used by Baddeley and colleagues as a measure of phonological working memory.

Let us examine some of the research which have produced contradictory results in this area. Gathercole and Baddeley (1990) demonstrated that children with SLI have significant difficulties with phonological working memory compared to children with normal language matched on non verbal cognition or verbal skills. However, van der Lely and Howard (1993) could not find the same relationship on two different measures of immediate recall. Both of these studies have been very influential in this field, so what could have been the reasons for the diverse outcome? The researchers themselves argued that these differences could have been a result of the very nature of the tasks measuring working memory and that of the selection criterion used for SLI (Gathercole & Baddeley, 1995; Howard & van der Lely, 1995). As mentioned earlier, SLI is one of the groups, by virtue of its diversity in profile, that can present as a non-homogenous group when selected for the purpose of research. Furthermore, the findings of Gathercole and Baddeley (1990) were replicated in a subsequent study by Montgomery (1995). Montgomery obtained similar results by demonstrating that children with SLI have reduced capacity for processing phonological information, which may contribute towards their language impairment. Bishop et al. (1996) studied the language development of twins by using non word repetition. They concluded that deficits in non-word repetition tasks would provide important information about developmental language impairment.

This brings us to the issue of the viability of non-word repetition tasks as a measure of working memory. Although, non-word repetition is widely used as a measure of phonological working memory, there are questions raised about the cognitive processes underlying this task, particularly the extent of performance which is constrained by phonological working memory versus long term lexical knowledge (Dollaghan, Biber, & Campbell, 1993, 1995; Gathercole, 1995; Snowing, Chiat, & Hulme, 1991). Gathercole (1995) differentiates between two types of non-word repetition, i.e., Low-word-like and High-word-like. In her opinion, non-word repetition for low-word-like stimuli is largely dependent on phonological memory, and repetition of high-word-like stimuli was additionally mediated by long term memory. Furthermore, children with language impairment have been shown to perform poorly compared to those with normal language on nonword repetition tasks, especially when the 'wordlikeness' of the nonwords was carefully controlled (Dollaghan & Cambell, 1998; Edwards & Lahey, 1998). Great care would be required when selecting the non-word task, as they should consist of nonwords with least wordlikeness.

However, there are also some studies that assume that nonwords do not play a key role in measuring working memory. They consider that inaccurate nonword repetition does not reflect working memory deficits but taps processes underlying these differences (Edwards & Lahey, 1998). This scepticism about the validity of particular tasks makes it hard to interpret the outcome of a study especially when these tasks are being used in a majority of studies on working memory. However, the support for non-word tasks as a measure of working memory outnumber the criticisms, therefore, their use is retained in the present research, in the interest of comparison across studies.

If there is evidence of impaired working memory within the SLI population, then what could the possible reason for this be? The major argument is around capacity and the speed with which information can be processed. For example, the limited capacity of working memory has been discussed by many researchers in the field of cognitive psychology (Baddeley, 1986, 1996; Bloom, 1993; Gathercole & Baddeley, 1993; Just & Carpenter, 1992). They contend that as the demand on the storage capacity exceeds the available resources, correspondingly the ability to process linguistic information is compromised. According to this view, the ability to actively maintain and integrate linguistic material in working memory has a direct outcome in terms of success in comprehending and producing language. This factor influences the trade-offs within and across language domains to provide space for the new information.

There are many other factors which can contribute to linguistic skills in general. For example, some investigations have been able to show that adults' speed and accuracy of linguistic processing declines with the increase in cognitive load. The factors which may influence linguistic processing include constraints on processing time (Miyake, Carpenter & Just, 1994), degree of lexical ambiguity (MacDonald, Just & Carpenter, 1992), and degree of syntactic complexity or ambiguity (Carpenter & Just, 1989).

One may come across a trend in a few studies that points to phonological memory as crucial for acquiring vocabulary at age 5 years and phonological memory predicts children's ability to learn new words (Michas & Henry, 1994). The role of short-term phonological memory in the acquisition of phonological forms of new words has been demonstrated in a number of studies. The relationship between phonological working memory and long-term phonological learning ability in the neuropsychological research has also raised the possibility that phonological memory skills in children may influence their ease in learning new words. If this is the case, then phonological memory skills and vocabulary knowledge should be closely associated with one another. This hypothesis has now been tested in a series of studies of both unselected samples of children and children with pathological deficits of language processing which has established some basis for a close link between phonological memory skills and vocabulary development. This evidence was based on a neuropsychological study in which a selective deficit of the phonological loop was demonstrated. This study examined a woman who had a severe and highly specific impairment of phonological working memory as a result of damage to her left hemisphere by a stroke, suggesting highly selective deficits of the phonological loop (Vallar & Baddeley, 1984). She, nevertheless, presented with intact speech, auditory processing and written language abilities. These specific difficulties led the researchers to propose that her primary impairment was due to damage to the storage system for phonological information, which was causing her difficulties with retention of new information. In addition, she also appeared to have difficulties in rehearsing subvocally and in maintaining the decaying information in a phonological form. Furthermore, when she was tested on the word-nonword paired tasks, her performance was reported to be very low compared to the control group. However, she showed the capacity to learn visually presented word-nonword pairs (although not as many as in the control group) and pairs of familiar words at a normal rate. The correspondence between this patient's long term phonological learning deficits and her phonological working memory impairment was quite notable. Thus, her phonological loop deficits were most apparent when the task involved genuine long-term phonological storage.

Similar results were obtained in a single case design by Vallar and Papagno (1993). The study was conducted on an Italian girl with Down syndrome. This girl presented the opposite features than those discussed above. This girl, when tested on the phonological short-term tasks, performed well, despite her relatively low general intelligence. She did not present any difficulties in acquiring unfamiliar Russian vocabulary items, while her capacity for associating pairs of familiar words, which typically depends on semantic coding, was impaired. This pattern of results was reflected in her real-life achievements; for example, in addition to her native Italian, she could speak both English and French with reasonable fluency.

Baddeley and Wilson (1985) investigated the short term memory characteristics of a young man with a head injury. This man was unable to speak as a result of paralysis of motor speech mechanisms. However, he could communicate in writing, since his written language was completely intact. While using a pointing procedure to measure his recall, the results indicated an entirely normal working memory. He had an unimpaired memory span, and showed the usual adverse effects of phonological similarity and word length with visual presentation. Similar results were obtained when the procedure was repeated on five other patients suffering from acquired dysarthric impairment.

Gathercole and Baddeley (1990) investigated this hypothesis further. They recruited children who had a diagnosis of specific language impairment (SLI). These children had a mean age of eight years and normal non-verbal intelligence. Their language development was assessed to be at a test age of six years, and these children were found to have significant difficulties in their capacity to repeat non words. The difficulties were also observed on typical monosyllabic words. When children with SLI were tested on the multisyllabic words they performed poorly, compared to typical six year olds, their performance being about appropriate for children of four years of age (Gathercole et al., 1990).

Archibald and Gathercole (2006) proposed a ‘double-jeopardy’ hypothesis which suggests dual problems with the phonological loop and executive functions. However, the hierarchical relationship between the ‘slave’ systems (temporary storage) and the central executive components presents a particular challenge for translating working memory profiles within a tripartite model. Briscoe and Rankin (2009) studied the ‘double jeopardy’ hypothesis among children with SLI. The central theme of the study was to look at the hierarchical relationship between the phonological loop and the central executive components of the working memory model in children with SLI. Hence the aim was to look at the score of working memory tests that is considered to be responsible for assessing the performance of phonological loop and the central executive components of tripartite working memory. The assumption was that children with SLI would show a low trend in their performance compared to the group of children matched in chronological age and language abilities. In contrast, the hierarchical relationship would suggest a weakness in a slave component of working memory (the phonological loop) and resultantly would restrict performance of the central executive functions. This constraint would ultimately predict that children with SLI would perform poorly on working memory tests that tap the central executive compared to the scores of chronologically age-matched controls only. For this purpose, seven subtests of the Working Memory Test Battery for Children (Digit Recall, Word Recall, Non-Word Recall, Word Matching, Listening Recall, Backwards Digit Recall and Block Recall; Pickering and Gathercole 2001) were administered to 14 children with SLI as well as two control groups matched on chronological age and vocabulary level, respectively. The outcome of the research was in accordance with the assumption, since the group with SLI performed poorly when their functioning was compared to the control group. However, a difference was observed on tasks of spatial recall (Block Tapping) and Word (order) Matching only. In general both the groups performed similarly on tasks measuring STM. Furthermore, the SLI group performed significantly lower on tasks of serial recall of words and digits tasks which would tap into WM. Impairments of the SLI group on phonological loop tasks were apparent by virtue of their performance, even when the executive working memory scores were accounted for by using covariance.

Due to significant impairment of the group with SLI on the phonological tasks, the double-jeopardy evidence could not be ratified.

Marton (2008) examined executive functions and visuospatial processing working memory in children with SLI and typically developing children. The aim of the study was to explore the performance of SLI children on both verbal and visual spatial working memory. This research had two parts: In Experiment 1, 40 children participated in each group, i.e., SLI and typically developing children. They were assessed on three visual spatial processing tasks: space visualization, position in space, and design copying. In Experiment 2, 25 children were included in each group, i.e., SLI and typically developing children, and their performance was evaluated on the Wisconsin Card Sorting Test-64 (WCST-64) and the Tower of London test (TOL). In Experiment 1, children with SLI performed very poorly on all visual spatial working memory tasks compared to their age-matched peers. The experimenter also identified a subgroup within the SLI group performing poorly on the tasks related to Experiment 1. These children were reported as having difficulties with their attention by their parents and teachers as well. The experimenter concluded that the results substantiated the theoretical paradigm proposed by Engle (2002) describing attention as an important factor in successful completion of visual spatial working memory tasks. In Experiment 2, children with SLI produced more preservative errors and more rule violations than their peers on tasks measuring executive functions. This experiment proposed that executive functions have a great impact on children with SLI’s working memory performance, regardless of domain.

The school-age children’s performance, as mentioned already, on working memory measures show significant correlation with various intelligence and achievement measures, including reading recognition, and comprehension (Swanson, 1996) and with spoken language comprehension (Gaulin & Campbell, 1994; Swanson, 1996). Many researchers, who strongly supported the relationship of working memory with verbal abilities in adults, would prefer to include good vocabulary and understanding of complex literary paragraphs as a measure (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Carpenter, Miyake, & Just, 1994; Cochran & Davis, 1987; Daneman & Green, 1986; King & Just, 1991; Masson & Miller, 1983; Turner & Engle, 1989).

The previous section identified the factors which are likely to facilitate the capacity to process linguistic information. However, we still face a challenge in understanding why there are wide individual differences in vocabulary knowledge. The most obvious possibility is that all individuals share the same capacity for learning new words, and that individual differences in vocabulary knowledge are a consequence of unidentified exogenous factors such as the parents' vocabulary and exposure to vocabulary enhancing television programmes, books, and stories. However, it may warrant further investigation since the answer may not be as simple as it may appear to be with the age old argument between nurture's and nature's role. A possibility in the variation of vocabulary could be that children may differ in their cognitive skills that are of significance in learning new words. Recent neuropsychological research strongly supports the influence of the phonological component of working memory in learning new words.

A majority of the research with regards to the implications of WM in SLI have not used working memory specific assessment tools (Bishop, 1992; Ellis Weismer, 1996; Gathercole & Baddeley, 1990, 1993; Lahey, et al., 1994; Leonard, 1994; Montgomery, 1995, 1996). However, similar to many studies in the area of working memory, the differences in the outcome of these researches are mainly attributed to the nature of the tasks measuring the working memory and selection criterion used for SLI (Gathercole & Baddeley, 1995; Howard, & van der Lely, 1995).

1.9 Selection of instruments for the present research

The previous discussion has already alluded to the importance of careful selection of instruments for the purpose of measuring WM. Therefore, a concerted effort was made to select an instrument which could not only assess a wide range of memory components but would also measure what it is supposed to measure. Therefore, this process to select a standardized, valid and reliable tool, to measure different forms of memory, was quite challenging and time consuming. Many options were considered before arriving at a decision. Selection of an assessment instrument involves central consideration of the validity and reliability of the instrument to be used. As mentioned earlier, previous research in this field has either relied on tasks which are a part of a battery of a test or have used tasks mainly designed for measuring executive function. These instruments may not have had good statistical properties. In the initial stages of this research, significant time and effort were dedicated to designing a computerized set of memory tasks by the present researcher and the supervisor (details are available in the methodology section). However, piloting of these tests revealed difficulties; in particular it became apparent that it would be extremely important to select an instrument that the children found engaging and easy to use and that would not disadvantage any one of our neurodevelopmental groups based on their particular profile of deficits. Following extensive research and piloting of various measures, the Automated Working Memory Assessment (AWMA; Alloway, 2007) was identified as a suitable instrument. The AWMA is based on the dominant conceptualization of working memory as a system for the temporary storage and manipulation of information in a variety of domains (Alloway, Gathercole, Kirkwood, Elliot, 2008). The test has been normed on population from 4-22 years of age, which was considered to best suit the present sample, and it is deemed to be particularly useful for identifying those with WM difficulties. This assessment tool had many other advantages, such as:

- The AWMA was specifically designed to measure working memory;
- The test has both verbal and visual spatial WM tests, measuring both storage and simultaneous processing information;
- The test also measures verbal and visual spatial STM, with a focus on only short term storage;

- Each major domain, i.e. verbal and visual spatial WM/STM, has three subcomponent measures, so as to provide an insight into the performance of the sample at a micro level of memory functions;
- Since the test was normed on a UK population it would be considered valid for use with Irish population, as would be the case with other test batteries (e.g., Wechsler tests).

This multicomponent assessment tool was therefore selected, as it would support the present research study in finding a relationship between different domains of WM and STM.

To evaluate intellectual functioning, it was decided to use a test battery that not only had better reliability and validity in terms of its outcome but also had been used extensively with an Irish population and was seemingly very popular among clinicians. Therefore, the family of Wechsler tests was selected for the purpose. The Wechsler Intelligence Scale for Children (WISC-IV) and Wechsler Preschool Primary Scale of Intelligence (WPPSI-III) were used for older and younger children respectively. These are extensively used in different services in Ireland, and the WISC-IV is specially standardized for a UK population. There are very high correlations reported between WPPSI-III and WISC-IV, which is from .65 (PSI-PSQ) to .89 (for the FSIQ). The reliability coefficient for WISC-IV composite scales range from .88 (processing speed) to .97 (Full Scale IQ). The average reliability coefficients of the WPPSI-III subtests range from .83 to .89 (Wechsler, 2002). The present researcher has extensive experience in the use of these tests, which would be one of the requirements for administration of these tests.

1.10 Rationale for the Present Research

The existing research literature has not been very successful in answering some of the important questions regarding the implications of memory functioning within the neurodevelopmental disorders i.e., ASD, ID and SLI. It is still not very clear whether these groups have an impaired verbal/visual spatial WM and if so, then how much is accounted for by their intellectual functioning. Furthermore, there are very few studies that have compared these groups directly, using the same measure, and have considered the role of varied intellectual functioning in order to examine difference in performance based on level of IQ. The present study will make an attempt to answer some of these questions.

Besides, we know by now, from our previous discussion, that working memory plays a very important role in higher order cognition which includes executive function and intelligence. For example Unsworth (2010), as reported earlier, suggested that both WM and LTM are related to fluid Intelligence (Gf), but were related less so with crystallized Intelligence (Gc). The major influential intelligence tests have all included vocabulary as a compulsory component towards measuring the IQ. And it is also known that vocabulary is aimed towards measuring the crystallized intelligence component. Furthermore, vocabulary is an important measure of LTM as well. Therefore, based on this argument, crystallized intelligence may have some relationship at least with verbal working memory, which will be examined in the present research.

Keeping the above questions as a guideline, the main focus of the present investigation was to explore the profile of working memory among different groups with neurodevelopmental difficulties such as ID, ASD and SLI and to compare their performance with a group of typically developing children. A group of typically developing children was included here even though the measures are normed against a relatively local population (in the UK), in case there were any differences particular to the Irish context. The present study has some particular advantages over currently available studies. First, the use of a standardised instrument specifically designed for assessing short term and working memory has not been used in many studies. Second, no study to date has compared performance directly across groups with different neurodevelopmental disorders; the use of the same instruments here will allow such a comparison for the first time. Third, a more realistic performance would be expected due to the computerised nature of the WM assessment, especially from the sample comprising children with ASD on account of their deficits within social communication and interaction. Previous research indicates that children in this population perform better through use of a computer. They will therefore not be disadvantaged in the current study. Finally, standardized disability criteria following ICD-10 criterion will be followed here.

According to ICD-10, if an individual scores within the range 50-69 on a standardized IQ test, the person falls within the mild range of intellectual functioning disorder, while scores in the range from 70-79 are considered to be within the borderline range. A score from 35-49 is reported to be within the moderate range of intellectual functioning disorder. Scores from 80-110 are considered to be an average performance, and a score above 110 is considered to be high average, excellent and superior abilities.

1.11 The Present Research Questions

This research will assess the performance of children with ASD, ID and SLI on the verbal and visual spatial short term/working memory and their performance will be compared with typically developing children to explore the possible differences between and among the groups on these tasks. There are many research studies cited above that have alluded to a strong relationship between IQ and memory. Therefore this study will look at this relationship from a neurodevelopmental perspective in order to explore if the same relationship between IQ and memory is evident in the different neurodevelopmental groups.

Autism Spectrum Disorder (ASD) group

The following issues will be explored specifically with reference to children with ASD:

1. The performance of children with ASD with a varied range of intellectual abilities, (i.e., mild-moderate, borderline and average) will be compared on different memory tasks with the assumption that these children will perform differentially depending on the level of their intellectual functioning. This hypothesis was formulated based on the proposal that IQ is considered as contributing towards the enhancement of performance on the memory tasks as is suggested by various studies discussed earlier.
2. The performance of the low functioning children with ASD will be compared with children with ID to explore possible differences between the two groups on memory functioning when both groups are functioning within the same IQ range. If there is no difference observed between the performances on the memory tasks, this will further support a strong relationship of memory and cognitive abilities. This would mean that IQ is possibly determining the function of memory rather than the neurodevelopmental disorders per se.

3. In addition, children with ASD are reported to have difficulties on tasks requiring executive functioning, as a result of their deficits in this area. There is an assumption, that they have difficulties in taking another person's perspective, as is suggested by the theory of mind. This research will also indirectly assess this issue; if children perform poorly on tasks measuring the executive functions such as Digit Backward and Listening Recall of the verbal memory and Spatial Span and Mr-X subtest of the visual spatial memory, this would suggest problems with their executive functions. This could further lead us to assume that there is a possibility of linking theory of mind with the executive functioning, since theory of mind is based on the edifice of executive function paradigm.

4. This research will also look into the relationship between memory tasks and ability tests, to explore whether the outcome in some way may differ for the normal population and children with ASD.

Intellectual Disability (ID) group

The goal here was to examine working-memory function in children with moderate-mild-borderline intellectual disabilities with the following issues specific to the ID group:

1. It was hypothesised that children with intellectual disabilities would perform generally poorly on the memory tasks compared to the average ability control group. This hypothesis was based on previous studies indicating that memory function in general is impaired in children with intellectual disability compared to typically developing children (Borskowski, Peck, Damberg, 1991). They may also perform poorly on both the STM and WM tasks. (As suggested by Engle, 1999, a novel task, measuring STM, requires a certain amount of attention control.)

2. It was hypothesised that children with moderate-mild IQ range would perform poorly compared to the borderline IQ range children on the STM/WM tasks. This hypothesis is based on the research suggesting a strong relationship between IQ with memory. This hypothesis will look at the relationship from an ID perspective.

3. Based on previous research, it was also hypothesised that STM/WM will have a strong relationship with cognitive abilities. This relationship between IQ and memory tasks will be seen in the context of ID and will be explored further by comparing it with the performance of the ASD, SLI and typically developing children.

Specific Language Impairment (SLI) group

The third part of the research looks at the working memory performance of children with a diagnosis of speech and language impairment. There are many researchers who have made a concerted effort to understand the process of working memory within the group with SLI. Literature shows non-word tasks were mainly used as a rule of thumb for measuring phonological deficits in the group with SLI (Botting & Conti-Ramsden, 2001; Dollaghan & Campbell, 1998; Edwards & Lahey, 1998; Ellis-Weismer, Tomblin, Zhan, Buckwalter, Gaura Chynoweth, et al. 2000; Gathercole & Baddeley, 1990). Other tasks were designed and used to measure verbal short term memory (Archibald et al. 2006; Graham, 1980; Wiig & Semel, 1976). Notwithstanding the usefulness of these tasks, the majority of these researchers maintained an age appropriate performance by the SLI group on the visual storage tasks (Archibald & Gathercole, 2006), compared to their low performance on the verbal memory tasks (Archibald, et al. 2006; Bavin, Wilson, Maruff, & Sleeman, 2005). The present study will therefore examine the following:

1. Children with Specific Language Impairment are predicted to exhibit reduced verbal working memory compared to typically developing children while they may perform on a par with the typically developing children in other domains, as suggested by previous research.
2. The present research will examine variation in performance of children with specific language impairment on STM/WM tasks with a focus on different levels of IQ in order to see if IQ is a mediating factor in determining the performance of memory.
3. The relationship of the intelligence tests with the subcomponents of STM and WM tasks will also be examined, and compared with the typically developing children.

Chapter 2: Methodology

2.1 Overall approach

The aim of the present study was to explore the patterns of working memory dysfunction in children with neurodevelopmental difficulties compared to typically developing children. For this purpose, a cross sectional convenience sample of children with neurodevelopmental difficulties and typically developing children was assessed. The performance of these groups was evaluated on a number of memory measures for comparison, not only across different groups but also within groups. Another major objective of the study was to look at the relationship between IQ and memory and to look for unique patterns emerging in this relationship for the different groups.

A quantitative approach was used for this research. Statistical analysis was predominantly concerned with comparing the performance of children with different IQ levels and diagnoses on the memory tasks. To have a better understanding, each sample group was analyzed separately. However, results for the overall sample are also presented to compare the groups.

Statistical analysis, using SPSS, was used to compare the samples on working memory tasks. Correlations were carried out to examine the relationship of memory tasks with IQ. Comparative analysis was used to compare different groups.

2.2 Sample

Ninety-six children participated in this investigation. The sample consisted of 26 children with ASD; 15 children with SLI; 32 children with intellectual disabilities (ID); and 23 children with typical development (TD). The participants for the present study were mainly recruited from different schools within the Munster region. Different schools were approached via telephone or letter explaining the purpose of the present research. The criteria for the selection of ASD, SLI, ID and typically developing children were as reported in the following paragraphs. Once the school principal agreed to participation in the research they were requested to get verbal consent from the parents. Subsequently, the parents who volunteered to allow their children participate in the study were further requested for a written consent. The consent letter contained the information such as the aim and purpose of the study. The parents were also informed through the same letter about the confidentiality of the personal information and the steps involved in the research procedure. All children who participated in the study were English speaking and were residing in the Munster region. All the children were assessed for their intellectual functioning for the present study prior to their memory assessment.

While age ranges and average age differed somewhat across the four groups, especially with reference to the upper age range of the children with SLI, scores on these measures are standardized by age, allowing comparison. Table 2.1 presents a summary of the group characteristics.

Table 2.1 Summary of group characteristics and IQ ranges

	Gender		Chronological age (in months)		FSIQ		VCI		PRI		PSI	
Groups	Male	Female	M	SD	M	SD	M	SD	M	SD	M	SD
ASD	23	03	101	36.31	79	17.74	86	18.56	84	20.42	70	27.18
ID	21	11	117	35.96	65	10.39	70	12.14	68	10.09	75	19.94
SLI	10	05	98	25.98	85	6.39	87	10.00	93	9.15	91	`0.10
TD	12	11	123	46.93	100	11.20	100	12.46	99	11.91	102	11.01

Autism Spectrum Disorder (ASD) sample

The group with ASD consisted of children who had received a confirmed diagnosis of autism spectrum disorder from a clinical psychologist, and/or child and adolescent psychiatrist using standard diagnostic protocols such as the Diagnostic Interview for Social and Communication Disorder (DISCO) and Autistic Diagnostic Interview/Observation Schedule (ADI-R/ADOS) in accordance with the criteria laid down by the DSM-IV for ASD. These children were attending both special and mainstream schools. The IQ range of these children was from moderate to high average. The exclusion criterion was any additional diagnosis such as attention deficit hyperactivity disorder, and other co-morbid diagnoses, which was established from studying different reports available at the time of the present research especially the report of the child psychiatrist was very influential in decision making.

The ASD group had a mean chronological age (CA) of 101 months (range = 49.00 – 161.00 months) and consisted of 23 boys and 3 girls. The mean Full Scale IQ (FSIQ) for the ASD group was 79 (range = 47.00 - 120.00). The mean Verbal Comprehension Index (VCI) for the ASD group was 86.0 (range = 53 - 128). The mean Perceptual Reasoning Index (PRI) for the ASD group was 84.0 (range = 47-127). The mean Processing Speed Index (PSI) for the ASD group was 70 (range = 00-112).

Intellectual Disability (ID) sample

The ID group consisted of children who were either attending special schools or mainstream set up. These children were assessed for their intellectual functioning and children who scored less than 79 on Full Scale IQ (on WISC-IV or WPPSI-III) were selected for this sample. The Wechsler Primary Pre-school Scale of Intelligence (WPPSI-III) was used on children below 6 years of age. Children with a diagnosis other than mild learning disability, such as attention deficit hyperactivity or any other known medical condition were excluded from the study based on the available report provided by the parents and the school.

The ID group had a mean chronological age (CA) of 117 months (range = 56.00 – 192.00 months) and consisted of 21 boys and 11 girls. The mean FSIQ for the ID group was 65.0 (range = 40.00 - 79.00). The mean of VCI for the ID group was 70.0 (range = 50.00 - 99.00). The RRI mean for the ID group was 68.0 (range = 45.00 - 90.00). The PSI mean for the ID group was 75.03 (range = 00-103).

Specific Language Impairment (SLI) sample

Children in the SLI group were recruited from a community speech and language department. They were attending the special and language classes designed for children with language difficulties. The number of children per class is 7 and they typically stay there for two years. These children are referred to the special unit on the basis of their specific difficulties with speech and language. These children were assessed by the speech and language therapists to determine their linguistic abilities. Children who scored lower than 2 standard deviation from the mean on a standardized speech and language assessment were screened for the class. These children were further scrutinized by the admission board that consisted of the principal of the school, speech and language therapist, class room teacher, manager of speech and language therapy department and a psychologist. Only children with specific language disorder were screened for admission into the special class. Furthermore, the criteria for selection for these children were that they should perform within the average range on the performance tasks of an IQ test. Children were excluded from the study if they had an additional diagnosis of attention deficit hyperactivity, ASD, or motor co-ordination disorder which was determined by referring to the previous reports made available for the present research after parental consent. Furthermore, there were two children who obtained a score within the mild range of learning difficulties; they were excluded from the study.

The SLI group had a mean chronological age (CA) of 98 months (range = 73.00 – 154.00 months) and consisted of 10 boys and 5 girls. The mean FSIQ for the SLI group was 85.00 (range = 72.00 - 100.00). The mean VCI for the SLI group was 87.0 (range = 67.00 - 106.00). The mean PRI for the SLI group was 93.0 (range = 77.00 - 108.00). The mean PSI for the SLI group was 91.27 (range= 78-112).

Typically Developing (TD) sample

The Typically Developing (TD) children who participated in the study had average and above average intelligence. These children were selected from local schools and were reported as having no difficulties with their school work and were considered to be functioning at par with their normal developing peers. These children were assessed for their intellectual functioning for the present study prior to undertaking the memory assessment.

The TD group had a mean chronological age (CA) of 123 month (range = 48.00 – 190.00 months) and consisted of 12 boys and 11 girls. The mean FSIQ for the TD group was 100.0 (range = 80.00 - 122.00). The mean VCI for the TD group was 100.0 (range = 73.00 - 126.00). The PRI mean for the TD group was 99.0 (range = 79.00 - 127.00). The PSI mean for the TD group was 101.91 (range 73-121).

2.3 Selection of instruments

The first goal of the study was to select an instrument which can reliably measure working memory. An intensive literature review was undertaken to find an assessment tool which could measure different aspects of memory along with some aspects of executive functions. As it is reported in the previous research that individuals with autism respond better to computerised assessment (Ozonoff & Stayer, 2001; Ozonoff, 1995; Pascualvaca, Fantie, Papgeorgiou & Mirsky, 1998), therefore, the aim was not only to look for a valid, reliable and standardized tool but also for a computerised assessment tool, which could increase the reliability of this research while working with children with ASD. Some of the steps involved in developing a standardized memory instrument were already reported in the previous section on selection of instruments. In the absence of a commercial, standardised, normed instrument at the outset of this research (2005-06), a computerised instrument devised by the supervisor and the present researcher, which had all the necessary components to measure working memory (WM) and executive functioning (EF), was piloted with a number of children to evaluate the efficacy of the tool. These tasks were computerized and children responded reasonably well to it. However, this test was abandoned as a commercial test, the AWMA, was introduced to the market shortly thereafter (2007). This had norms and had been developed specifically to address working memory difficulties and for use with varying groups. This was clearly a more valid and reliable instrument compared to the set of experimental measures. This new test had a computerised ceiling and basal point. The instructions were computerised which helps in administering the test with uniformity and standardizing the procedure. The test was piloted initially with 3 children from each group and they responded very well to the entire test, thus indicating no difficulties in following the instructions. Therefore despite the extensive preparation that had gone into developing the computerised but experimental measures, the AWMA was adopted as the measure of choice.

For the IQ test, the WISC-IV/WPPSI-III tests were used depending on the age of the child. The WISC-IV and WPPSI-III were selected for the purpose of this study as they are widely used in Ireland for IQ testing and they are both normed on the UK population.

2.4 Measures

The following measures were ultimately selected for the research: the Wechsler Intelligence Scale for Children (WISC-IV) (6-16 years); the Wechsler Primary Preschool Scale of Intelligence (WPPSI-III) (3-7 years); the Automated Working Memory Assessment (AWMA) - for age group from 4-22 (Alloway, 2007).

Wechsler Intelligence Scale for Children (WISC-IV) (6-16 years)

The WISC is the first intelligence test published by Wechsler (1949). There were four subsequent editions published. The latest version is the WISC-IV which was published in 2003. These tests were re-normed to compensate for the Flynn effect (1994), and questions have been refined to make them less biased against minorities and girls (Wechsler, 2003), and materials have been updated to facilitate administration of the test. The WISC was the first test to be standardized on children representing the total population of the United States, including ethnic minorities. The WISC-IV is based on UK norms.

The test comprises ten core subtests and five supplemental ones. The supplemental subtests are used to accommodate children in certain rare cases, or to make up for spoiled results which may occur from interruptions or other circumstances. No more than two substitutions are permitted in any FSIQ test, or no more than one per index. These subtests then generate a full scale score (FSIQ), as well as four composite scores known as indices: Verbal Comprehension (VCI), Perceptual Reasoning (PRI), Processing Speed (PSI) and Working Memory (WMI).

There is some overlap between the tests, with children aged 7 being able to complete the WPPSI or the WISC, and children aged 16 being able to complete the WISC or the Wechsler Adults Intelligence Scale (WAIS). Different floor and ceiling effects can be achieved using the different tests, allowing for a greater understanding of the child’s abilities or deficits. For the purpose of this research only core subtests, which were contributing towards, FSIQ, VCI, PRI, PSI, WMI, were administered.

Verbal Comprehension Index (VCI)

The VCI is considered as a measure of a child’s capacity with regards to verbal concept formation and verbal reasoning skill. This ability is regarded as an outcome of a child’s interaction with his environment and the learning that takes place as a result. The vocabulary and Information subtests could be considered measuring crystallized intelligence. The VCI’s subtests are:

Vocabulary: the examinee is presented with a word and the task is to define a word, for example, what is a cow, clock, hat, etc.

Similarities: the examinee is asked to report similarities between two concepts, for example, Red-Blue, Apple-Banana, etc.
Comprehension: the examinee is asked questions about social situations or common concepts of daily happenings, For example, ‘why do cars have seat belts’.

Perceptual Reasoning Index (PRI)

The PRI subtests are considered to be measuring fluid intelligence. Only core subtests were administered in this research. The PRI's core subtests are:
Block Design: the examinees are provided with blocks according to the model presented. They are supposed to reproduce the model according to a pattern either produced by the examiner or presented in the book. This test is timed, and a bonus score is awarded for some of the difficult designs depending on the completion time.
Picture Concepts: the examinees are provided with a series of pictures presented in rows (either two or three rows) and they are asked to determine which pictures go together, one from each row.
Matrix Reasoning: the examinees are shown an array of pictures with one missing square. They are then asked to select the picture that fits the array from five options.

Working Memory Index (WMI)

The WMI's subtests are:
Digit Span: There are two subtests in Digit Span, i.e., Digit Forward and Digit Backward. In these tasks children are orally presented with sequences of numbers. In the Digit Forward task, children are asked to repeat them in the same sequence, whereas in the Digit Backward subtest, the examinee needs to say the sequence in a backward order.
Letter-Number Sequencing: In this task, children are provided with a series of a numbers and letters. They are asked to say them back to the examiner with numbers before the letters. If there are more numbers and letters they have to arrange them in a proper sequence.

Processing Speed Index (PSI)

The PSI subtests are:
Coding: This test has two sets depending on the age of a child. For children under 8, the children are expected to insert different lines in a shape according to a code,

whereas children over 8 copy a digit-symbol code. This is a time-limited test and a bonus is given for speed.

Symbol Search: the examinees are given rows of symbols and target symbols, and asked to mark whether or not the target symbols appear in each row. For those under the age 8, children have to search for a single symbol and for children in the upper age range, above 8 years, they have to find two symbols. The maximum time limit for the test is 2 minutes and bonus points are given if the test is completed before time.

Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III)

The WPPSI-III is one of the newest editions of the Wechsler intelligence tests. Historically, the WPPSI series of tests has been held as the standard of measurement when comparing preschool intelligence tests (Kramer & Conoley, 1992). They are considered to be among the most reliable and valid intelligence tests designed for preschool children. The test is normed on a census based sample representative of US population, and is stratified with respect to age, gender, geographic region, ethnicity, and parental occupation and education. Similar to the WPPSI-R, the WPPSI-III was normed on population of 1,700 children, which is divided into nine age groups (Dumont/Willis, 2001 and Wechsler, 2003). This new edition also includes the processing speed quotient for older children, which will be equivalent to PSI of the WISC-IV, with an expanded age bracket and with improved floors and ceilings. The average reliability coefficient of the WPPSI-III subtests range from .83-.95. The reliability coefficients for WPPSI-III composite scales range from .89 to .96 (Wechsler, 2003).

On each subtest of the WPPSI-III, a child is provided enough teaching examples before the start of the actual subtest to improve his/her understanding. The child is also provided with a second chance (querying) to ensure that the child performs at the best of his or her abilities. This latest version has the advantage of being colourful which can help in developing the interest of children in the task. The respondents' choice of answers are scored on a scale of 0, 1 or 2 as proposed in the examiners' manual and guide taking into account the quality of the knowledge about the subject matter.

The WPPSI-III is widely used in Ireland for assessing children to establish their intellectual functioning. The publisher highly recommends that the test should be administered by an experienced psychologist and the administrator should thoroughly familiarize his/herself with the subtest administration instructions. The administrator should also be aware of the unique baseline and ceiling rules for each subtest.

The WPPSI-III contains the following 14 subtests: Block Design, Information, Matrix Reasoning, Vocabulary, Picture Concepts, Symbol Search, Word Reasoning, Coding, Comprehension, Picture Completion, Similarities, Receptive Vocabulary, Object Assembly, and Picture Naming (Wechsler, 2003). The subtests can be combined to measure Verbal (crystallized) IQ, Performance (fluid) IQ, Processing Speed Quotient (PSQ), General Language (GL) composite and a Full Scale IQ (Dumont/Willis, 2001). The Verbal IQ, Performance IQ and Full Scale IQ are taken from the core subtests. The other scores, involving optional or supplemental subtests, do not contribute towards the calculation of an IQ score (Wechsler, 2002). The test is divided into two age bands, 2:6-3:11 and 4:0-7:3, with different subtest batteries for each age band. For the younger groups, the VIQ consists of Receptive vocabulary and Information subtests, and for the PIQ, the subtests consist of Block Design and Object Assembly. For the older age band the VIQ consists of Information, Vocabulary and Word Reasoning. The PIQ consists of Block Design, Matrix Reasoning, and Picture Concepts subtests. The Processing Speed Quotient (PSQ) consists of Coding and Symbol Search subtests. The General Language (optional) consists of Receptive Vocabulary and Picture Naming subsets. The FSIQ, for the younger group, is obtained from the four core subtests as mentioned above. For the older group, the FSIQ consists of subtests of VIQ, subtests of PIQ and Coding subtest of the PSQ. Only core subtests of the WPPSI-III are used for the current research.

The Automated Working Memory Assessment (AWMA)

The AWMA (Alloway, 2007) battery consists of 4 sets of measures of memory which includes the measures and sub-measures shown in Table 2.2. These measures are described in more detail below.

Table 2.2 Components of the AWMA and sub-tests

AWMA composite Test	Subtests
Verbal Short Term Memory	a. Digit Recall. b. Word Recall. c. Non-Word Recall.
Visual Spatial Short Term Memory	a. Block Recall. b. Mazes Memory. c. Dot Matrix.
Verbal Working Memory	a. Backward Digit Recall. b. Listening Recall. c. Counting Recall.
Visuospatial Working Memory	a. Odd-one-out. b. Mr.-X. c. Spatial Span.

The AWMA provides standardized scores, with a mean value of 100 and standard deviation of 15, for 4 to 22 year-olds (AWMA: Alloway, 2007). The test-retest reliability for this test in a normally-distributed sample is reported to be .64 (Alloway et al., 2006). The research has also established good diagnostic validity of the test (Alloway et al. 2008). Prior to the commencement of each task, the child is presented with examples and practice items to familiarize him/her with the task. In addition, the child was also given further explanation of the task by the present researcher if he or she appeared to need further clarification in order to fully understand the instructions. A description of each subtest follows.

Verbal Short-Term Memory (VSTM)

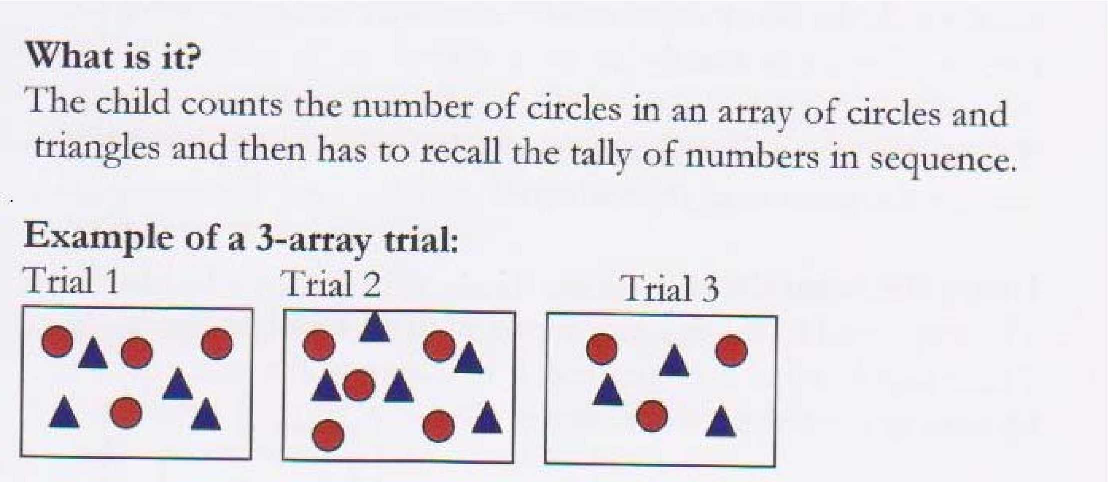
The verbal short term memory tasks include Digit Recall, Word Recall, and Non Word Recall. The child is presented with a sequence of digits, words, or non words and the child is required to recall them in the correct serial order. Digit lists consist of digits randomly constructed ranging from 1-9, which are spoken at a rate of one digit per second.

The word lists are monosyllabic words with a consonant-vowel-consonant structure. The words are presented as a single trial. The nonwords were developed from the same pool of phonemes as was used in the word recall subtest. The words and non-words are verbalised at a rate of one syllable per second. The participants are expected to verbally repeat the words in a correct serial order as per the manual. Credit was only given when children could substitute a phoneme due to their habitual articulation pattern for that phoneme.

Verbal Working Memory (VWM)

This includes backward Digit Recall, Listening Recall and Counting Recall. In the Backward Digit Recall test, a child is required to recall a sequence of spoken digits presented to him or her, in reverse order. A number is added after a correct recall of blocks of digits until the child is unable to recall four correct trials at a particular block.

In the Listening Recall task, a child is presented with a series of spoken sentences such as, “Lions have four legs,” “Pineapples play football”. The child is expected to confirm whether the sentence is right or wrong by stating “true” or “false” and she or he is also to recall the final word for each sentence in sequence. The task begins with one sentence and other sentences are added in each block until the child is unable to recall three correct trials at a block.



What is it?

The child counts the number of circles in an array of circles and triangles and then has to recall the tally of numbers in sequence.

Example of a 3-array trial:

Fig 2.1 Sample, with explanation, of the counting recall task from the AWMA

In the Counting Recall test, a child is presented with a visual array of red circles and blue triangles and the child is expected to count only the circles by putting his or her finger on each circle and when the presentation disappears, the child has to call out the number of circles he or she has counted. The test begins with one visual array and it increases by an additional visual array in each block until the child is unable to correctly recall four trials. Each visual array stays on the computer screen until the child indicates that he or she has completely counted all the circles. The number of correct trials is scored for each child.

Visual Spatial Short Term Memory (Vs-Sp STM)

This includes Block Recall, Mazes Memory, and Dot Matrix. In the Block Recall test, there are nine randomly located cubes on a specially designed board. The presenter taps a sequence of cubes with a finger on a specifically designed board. The child's task is to watch and repeat the sequence in the same order as the presenter has demonstrated. Testing begins with a single block tap and increases by one additional block.

In the Maze Memory test, the child observes a two-dimensional line maze with a path drawn through the maze for 3 seconds. The same maze appears on the screen without the path, and the child is asked to recall the same path by tracing it with his fingers following the same direction on the maze. The complexity of the maze increases by adding additional walls to the maze.

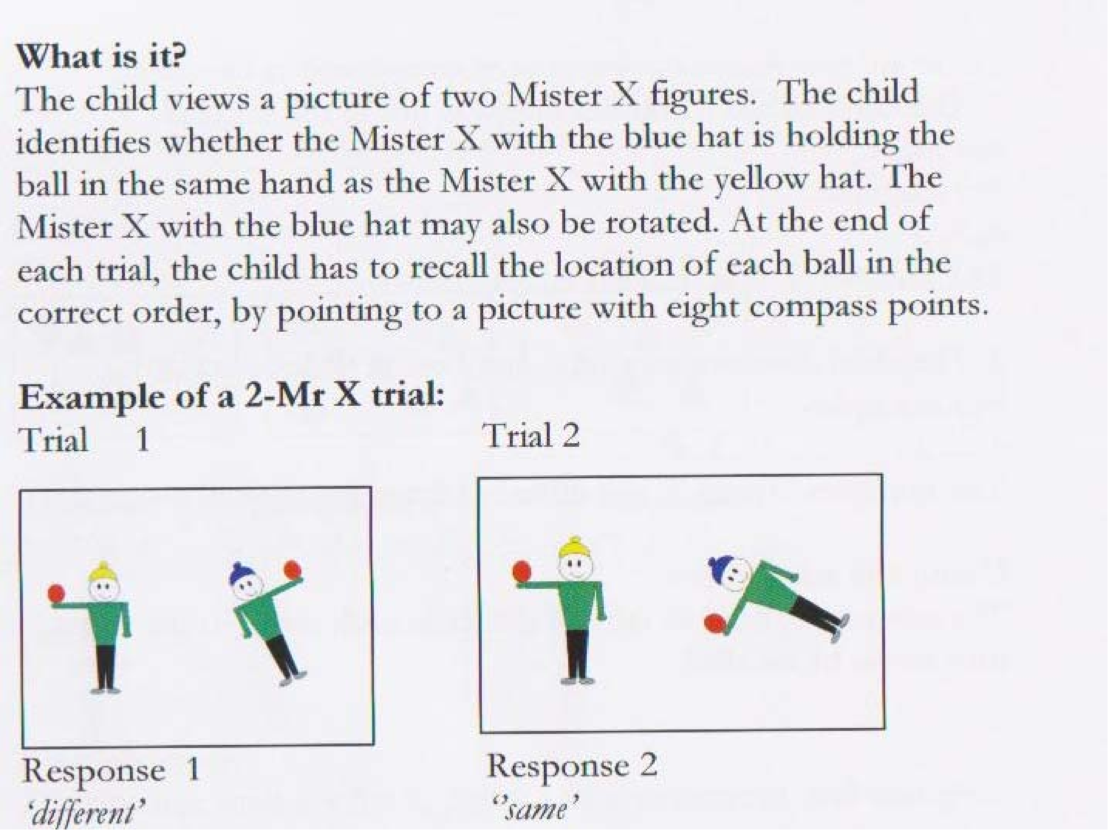
In the Dot Matrix task, a sequence of red dots is presented on a 4 x 4 grid, and the child is required to point to the positions of each dot that appeared for 2 seconds. The sequences are random, with no location being highlighted more than once within a trial.

Visual Spatial Working Memory (Vs-Sp WM)

In the odd one out task, a child is presented with a horizontal row of three boxes with three shapes, one in each box. The child needs to identify the shape that does not match the other two shapes and also to remember its location. The child is then presented with a blank set of three boxes on the screen and the child needs to point to the location of the odd one shaped where it had appeared in the correct order. The boxes always appear centred horizontally on the screen, but at different positions along the vertical axis to eliminate visual traces.

In the Mr X task, a child is presented with a picture of two Mr X figures, one with a yellow hat and the other one with a blue hat. The Mr X can be rotated to change the position of his hand as well. The child needs to identify whether Mr. X with the blue hat is holding the ball in the same hand as Mr. X with the yellow hat.

Both the Mr X figures and the compass points stay on the computer screen until the child provides a response. Once the child provides a response the figures disappear and the child has to recall the location of each ball in Mr. X's hand in sequence, by pointing to a picture with compass points.



What is it?
The child views a picture of two Mister X figures. The child identifies whether the Mister X with the blue hat is holding the ball in the same hand as the Mister X with the yellow hat. The Mister X with the blue hat may also be rotated. At the end of each trial, the child has to recall the location of each ball in the correct order, by pointing to a picture with eight compass points.

Example of a 2-Mr X trial:

Trial 1

Response 1
'different'

Trial 2

Response 2
''same'

Fig 2.2 Sample, with explanation, of the Mister X task from the AWMA

In the Spatial Span task, a child views a picture of two identical shapes except that the shape on the right side of the screen has a red dot on it. The child identifies whether the shape on the right is the same or opposite of the shape on the left. The shape with the red dot may also be rotated. At the end of each trial, the child has to recall the location of each red dot on the shape in sequence, by pointing to a picture with three compass points. Both the shapes and the compass points stay on the computer screen until the child provides a response.

2.5 Procedure

Ethical Approval

In the initial stages of the planning of the present research, ethical approval for this study was sought and granted by both the Southern Health Services Executive (HSE) Ethics Committee and the National University of Ireland Maynooth Ethics Committee. All possible measures were considered to ensure care was taken in relation to ethical issues. Parents were duly informed about the purpose and aim of the research in writing. They were given specific information about the manner and the time involved in the administration of the tests. They were informed that the study would consist of administration of two psychological tests which are specifically designed to measure the intellectual functioning and memory functions of children. They were informed that these tests are widely used with children in the Republic of Ireland and UK and that the tests are administered individually. They were also told that these tests would involve participation over 4-5 hours that may consist of 2 to 3 sessions. In order to preserve privacy and confidentiality, the parents were duly informed verbally prior to the commencement of the assessment about the processes of privacy and confidentiality in the course of the assessment and the steps involved. They were also given information about the storage of the record sheets and that they would be kept under lock and key. The scores of the memory assessment could only be retained in the computer with a password access and which could only be known to the present examiner. Furthermore, the parents were assured that subsequent to the publication of the study, the records would be destroyed after 6 years. The parents were also informed that they had the right to withdraw their child from the assessment process at any stage. However, all the parents and children cooperated very well and no parent requested withdrawal from the assessment process.

A number of children who participated in the present research were also attending the Early Intervention services where the author is working as a senior clinical psychologist. The parents of these children were also offered feedback, as was required by the service, pertaining to their level of disability after the assessment process was over. The parents were informed about specific strengths and weaknesses of the child as was depicted on these tests. The parents were given recommendations on the basis of the outcome of the ability and memory tests. The recommendations were mainly related to early intervention. Since all of these children were already accessing different disability services, and given that the researcher (the present author) is a senior clinical psychologist within the same service, this was deemed appropriate. This could be one of the reasons that there was no reported or observed instance of stress on parents' part and the present researcher remained professional and sensitive to parents' level of expectation. The participants in the study did not indicate that the test in any way proved stressful as the researcher was able to maintain and sustain rapport with the children prior to the start and during the test administration. However, it was agreed with the parents prior to the session that in case a situation arose whereby the child became significantly anxious or stressed the session would be postponed for another date or she/he would be given some intermittent breaks. The present researcher remained sensitive to the level of interest and motivation of the participants throughout the assessment process. When the participants would indicate any sign of boredom or tiredness either by their sudden drop in their performance or the participant, especially the younger ones, asking about the finishing time of the test, the assessment was postponed for a later date. Moreover, children in the older age group who appeared to follow and understand the purpose of the testing procedure were provided with the rationale and information as regards the research; it was only after receiving verbal and written consent from their parents that the study was proceeded with. The typically developing children performed within the average range on the Full Scale IQ and no instance of stress was reported either by the participants or by their parents. Any issues raised in assessing the typically developing children were discussed with the parents.

Assessment process

The assessments were completed over two- to -three sessions in a quiet room mostly on one to one, following the typical procedures used in this particular service. However, in some cases, parents were requested to join the session where it was considered that the performance of the very young children would be affected by their absence. (This also followed standard practice within the service.) Each assessment lasted for approximately four to five hours (conducted over two to three sessions, with breaks as appropriate). A standardized procedure was adopted in the order of administration of tests. The intelligence test was always used first in the sequence of administration, followed by a memory assessment with a gap of at least one day. The rationale for this order is embedded within the design of this research as it was important to determine the intellectual functioning of the children first. For example, in the case of ID group, only children who scored within the ID range were tested further. There were 3 children who scored above the cut off point of the ID range who were subsequently not included in the study. There were also 2 children in the SLI group who scored within the ID range; they were also not included in the study. This occurred even though recruitment had targeted these specific groups.

The children were encouraged and given positive feedback as and when it was considered appropriate, such as during moments when there was an indication of a child's boredom, low attention, frustration or tiredness, etc. Again, this follows typical assessment practices.

In addition to the assessments carried out for the purpose of the present research, children with speech and language difficulties were also assessed by the community speech and language therapist to determine their placement for the speech and language class.

The group of children presenting with ASD had undergone a comprehensive and intense assessment of their social and communication deficits in order to receive a diagnosis of autism spectrum disorder. This assessment of ASD diagnosis was in line with the approved guidelines involving the use of appropriate diagnostic protocols.

The intelligence tests were used following the standard subtest order as recommended by the publishers and scoring was carried out following the publisher manual. A predetermined computerized sequence of AWMA subtests, as set by the author, was followed. The AWMA scoring was automatic except that the researcher had to press a right or left arrow key. The left arrow was for a correct answer and right arrow for the wrong answer. A test would progress from basal (start items) to ceiling points until the child would fail on the three consecutive tasks, which was determined by the computerised programme.

Chapter 3 Results

3. 1 Overview

Each answer book of the ability tests were scored following the examiner's manual. Raw scores were converted to standardized scores, following the test procedures. The AWMA scores were automated for conversion from raw to standardized scores by the computer.

To recapitulate the key measures, the AWMA tasks consisted of four subdomains i.e. verbal STM, verbal WM, visual spatial STM and visual spatial WM. Both verbal and visual spatial STM tasks are considered to measure capacity to store information for a short period, whereas the verbal and visual spatial WM tasks require the capacity to store and process information for a short period of time. The majority of the tasks employed to measure WM in the present research were traditionally used for assessing the executive functions e.g., digit backward, listening recall and odd-one-out. However, as these tasks do not require planning *per se* except to process them mentally, these tasks were considered to be more relevant to assess working memory.

The WISC-IV consisted of four major indexes – Verbal Comprehension index (Crystallized intelligence), Perceptual Reasoning Index (Fluid intelligence), Processing Speed Index (PSI), Working Memory Index (WMI) along with Full Scale IQ (FSIQ). WPPSI-III consisted of Verbal IQ (VIQ; crystallized intelligence), Performance IQ (PIQ; fluid intelligence) and Processing Speed Quotient (PSQ).

Table 3.1 presents the mean scores and the ranges for all four groups. The typically developing group score within a narrow range on the memory tasks. There appears to be some overlap in the scoring patterns observed for the groups with ASD and ID. The score for the group with SLI on the memory tasks are similar to those produced by the Typically Developing group.

The scores of the group with ASD on the intelligence test show considerable variation, ranging from moderate to high average. This variation allows an examination of performance of children with ASD with a range of abilities and a comparison of their performances on the memory tasks. The range of scores for the group with ASD on the memory tests appears to be small, except on verbal working memory, where we see a very high score in the maximum of the range (maximum 140; M=83). This would suggest that some of the children in the ASD group are performing at a near-normal level on the verbal working memory tasks, in contrast to the ID and SLI groups.

The scores of the group with ID on the intelligence test are from the moderate to borderline range of intellectual functioning. This wide range of scoring by the group with ID will also allow performances to be examined as a function of IQ level. The scoring pattern of the sample appears to be within quite a narrow range on the memory tasks with an exception on the verbal STM composite score, where there was a somewhat high maximum score of 120 (M=78).

The scores of the group with SLI ranged from borderline to average on the intelligence test. The sample seems to have performed well on the visual spatial WM and STM memory, as is indicated by the maximum scores and means (see Table 3.1).

The group characteristics (see Table 3.1) shows comparable age ranges across groups except for the group with SLI. Children with SLI are usually referred very early to the speech and language class; typically, they are referred when they are in the Junior Infants class and a majority of them stay in the speech and language class for 2 years, after which the children generally leave the service. Therefore for practical reasons, it was not possible to test a group of children with SLI with exact age-matching to the other groups. However, given that the tests used are age-normed, this difference between the groups should not carry implications for data analysis.

Table 3.1 Descriptive statistics of standard scores for measures of Memory, IQ and demographic variables (n=96)

	TD (n=23) (m:12; f: 11)				**ASD (n = 26) (m: 23; f: 3)**				**ID (n=32) (m: 21; f: 11)**				**SLI (n=15) (m: 10; f: 5)**			
	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD
Age (in months)	48	190	123.97	46.93	49	161	101.35	36.31	56	192	117.06	35.96	73	154	98.20	25.98
VCI Score	73	126	100.22	12.46	53	128	86.00	18.56	50	99	70.19	12.14	67	106	87.20	10.00
PRI Score	79	127	99.22	11.91	47	127	83.65	20.42	45	90	67.50	10.09	77	108	92.93	9.15
PSI Score	73	121	101.91	11.01	0	112	69.60	27.18	00	103	75.03	19.94	78	112	91.27	10.10
Full Scale IQ	80	122	99.83	11.20	47	120	79.12	17.74	40	79	64.66	10.39	72	100	85.00	6.39
Verbal STM CS	65	127	100.57	18.44	61	110	84.73	14.62	59	120	78.16	14.57	64	103	84.60	13.09
Digit recall	74	131	102.48	13.68	47	122	87.62	17.93	63	109	81.00	11.21	58	122	81.27	16.80
Word Recall	64	128	99.61	19.81	59	110	84.38	14.18	58	131	81.97	17.44	66	129	86.13	16.80
Non word recall	66	135	99.96	20.95	59	123	89.69	17.76	58	132	81.00	17.99	61	118	93.00	15.71
Verbal WM CS	72	131	103.48	16.85	60	140	83.15	19.78	58	93	72.16	7.42	61	107	83.53	13.20
Listening recall	63	135	105.43	16.69	55	117	83.11	17.52	55	117	75.81	12.52	58	122	81.27	16.81
Counting recall	63	125	96.96	16.11	67	142	84.65	17.00	62	103	77.06	10.33	66	129	86.13	16.80
Digit recall	65	130	103.91	17.36	58	133	87.58	20.91	58	101	77.75	8.50	61	118	93.00	15.71
Vs-Spatial STM CS	64	129	94.83	17.31	61	126	82.31	17.12	57	99	77.28	12.35	72	128	101.27	17.54
Dot Matrix	66	128	96.91	15.73	57	124	83.42	15.32	58	107	78.25	14.37	75	126	97.40	13.10
Mazes Memory	64	137	94.43	18.43	48	120	85.15	18.92	48	120	84.84	16.95	61	135	101.53	23.38
Block recall	61	123	97.96	16.47	61	123	87.04	15.76	59	108	78.91	13.15	77	125	103.86	14.09
Vs-Spatial WM CS	63	132	102.17	17.51	59	121	86.96	16.68	59	97	74.38	10.89	59	136	90.00	18.30
Odd-one-out	71	131	100.30	16.98	63	119	85.73	14.02	59	105	77.28	13.60	67	126	92.47	17.62
Mister X	71	131	102.43	15.51	66	119	90.77	15.27	60	105	76.81	12.18	70	130	92.80	17.75
Spatial Recall	64	135	101.43	16.43	0	123	89.50	24.80	59	118	78.72	16.80	57	129	87.00	20.61

VCI= Verbal Comprehension Index; PRI = Perceptual Reasoning Index; CS = Composite Score; STM = Short Term Memory; WM = Working Memory; Vs = Visual; TD= Typically Developing Children, ASD = Autism Spectrum Disorder; ID = Intellectually Disabled; Sp & Lang impairment = SLI.

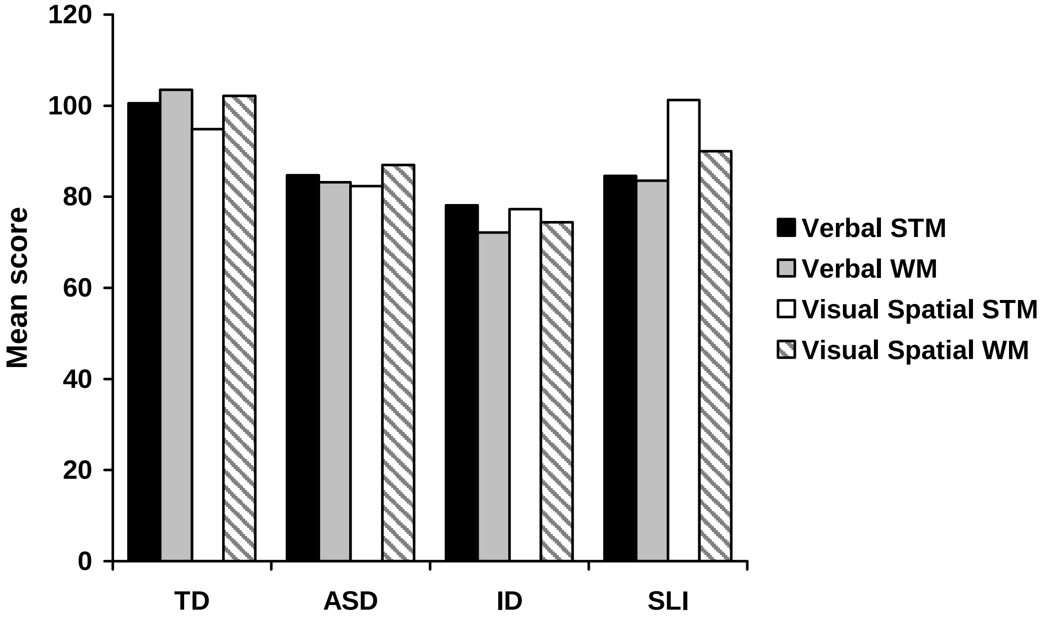


Fig 3.1 Mean scores of the four groups on the four composite memory components (AWMA)

The summary of the results (see Fig 3.1) shows normal performance by the typically developing children, with ASD and SLI performing almost similarly on all the components of the memory tasks, except the visual spatial STM. The group with SLI seems to have performed much better than the group with ASD and produces similar performance to the typically developing children on visual spatial STM. The group with ID seems to have consistent low performance on all the components of memory compared to the other three groups. These results seem to be in line with the hypotheses, as children with ID have shown difficulties across the board on all the components of memory. The groups with SLI and ASD, while scoring moderately lower compared to the typically developing children on the verbal STM and visual spatial WM, are still producing scores within the average range. The only area where the two groups, ASD and SLI, have performed particularly poorly is on verbal WM.

A multivariate analysis of variance was carried out on the four memory composite standard scores to compare the performances of the four groups. This analysis was carried out to look for any unique strengths and specific deficits according to neurodevelopmental group. The probability value associated with Hotelling's t-test is reported here. The overall group term was significant, ($F = 8.39$, $p<.001$, $n^2_p=.30$). Significant differences were observed on all the memory components ($p<.001$). F values and effects sizes are reported in Table 3.2. Post hoc pairwise comparisons found significant differences between the following groups (p<.001, Bonferroni adjustment for multiple comparisons). The typically developing children performed better on the verbal STM and WM compared to the remaining three groups, and children with ASD performed better than children with ID on the verbal WM. This would suggest that children with ASD, as a group, may produce low scores on the verbal WM compared to typically developing children, but they outperform the children with ID.

On the Visuospatial STM, typically developing children performed better than children with ID and ASD and there is no difference between the performance of children with SLI and the typically developing children in this domain. The same pattern emerges for visual spatial WM. The poor performance of the group with ID is noticeable and in stark contrast to the other three groups.

The results indicate that the typically developing children performed better than both the groups with ID and ASD on all the subcomponents of memory. There was no significant difference between the SLI and typically developing children on the visual spatial tasks, while predictable differences appear on the verbal components. These results confirm the hypotheses that children with ID and ASD would generally perform poorly across the memory tasks, while the group with ASD outperform the group with ID on some memory components (see Table 3.2).

The first hypothesis in relation to children with ID was also supported, as children with ID not only performed poorly, as evident on all the composite scores, compared to the typically developing children but they also showed significant impairment on verbal working memory compared to the group with ASD and they also showed significant impairment on visual spatial STM compared to the group with SLI. Furthermore, they also performed poorly compared to both the groups with SLI and ASD along with the typically developing group on the visual spatial WM. These results are consistent with previous research showing a generalised detriment affecting the memory sub-components within the population with ID (Hulme & Machenzie, 1992; Jarold & Baddeley, 1997; Jarold, Baddeley, Hewes, 1999, 2000; Russell, et all. 1996). These results also provide strong support for the limited capacity of the phonological loop in children with ID, as has been noted in previous research (Henry 2001; Henry & Maclean, 2002; Jarold & Baddeley, 1997; Numminen, Service, Ahonen & Ruoppila, 2001, 2002; Russell et al., 1996). These results also point to differing profiles for the groups, as the group with ID produced significantly poorer performance than the group with ASD on the tests of working memory (both verbal and visual spatial) while performance on the STM tests are comparable. The children with SLI performed poorly when compared to typically developing children on the verbal STM/WM only, as their performance was on a par with the typically developing children on the visual spatial STM/WM. This pattern would again confirm the assumption of the present research: that children with SLI would perform poorly on the verbal memory tasks compared to visual spatial tasks. These outcomes are in support of previous results obtained by Gathercole et al. (1990) and Montgomery (1995). These results would provide strong evidence in support of reduced capacity for processing phonological information, which may be contributing towards the language impairment.

In addition to supporting the hypotheses of the present research, these results suggest that it is important to break down the components of WM so that STM and WM components can be examined separately, as it would appear that the deficits affecting children in these groups manifest differently when we consider the storage (STM) versus processing (WM) aspects of memory.

Table 3.2 The performance of the four groups of children on the memory tests as a function of developmental disorder (n=96)

MANOVA			
Measure	F	N^2_p	Pairwise comparison
Verbal STM	9.72	.24	TD* > all 3 disability groups
Verbal WM	20.10	.40	TD > all 3 disability groups; ASD > ID
Visuospatial STM	10.74	.26	TD > ID, ASD; SLI > ID, ASD
Visuospatial WM	14.64	.32	TD > ID, ASD; ID<all 3 groups

*TD = Typically Developing Children.

A MANCOVA was performed (Table 3.3) on the four composite memory subscales to find out whether the three major components of intelligence i.e., PSI/PSQ, VIQ/VCI, and PIQ/PRI (for convenience these IQs will be referred as PSI, VCI and PRI respectively), as a covariate would have an effect on the memory performance of the four groups. The overall group term was observed to be significant, (F = 8.38, p <.001, n^2_P =.28), with variation specific to each group.

Table 3.3 The performance of the four groups of children on memory test as a function of developmental disorder and cognitive test (n=96)

MANCOVA									
	PRI as covariate			VCI as a covariate			PSI as a covariate		
Measure	F	n^2_p	Pairwise comparison	F	n^2_p	Pairwise comparison	F	n^2_p	Pairwise comparison
Verbal STM	2.82	.09	TD > SLI	2.43	.07	NS	5.49	.17	TD > all 3 groups
Verbal WM	5.77	.16	TD > all 3 groups	5.41	.15	TD > all three groups	14.23	.35	TD > ID, SLI; ASD > ID
Vis-sp STM	3.15	.09	SLI > ASD	5.61	.16	SLI > ID; ASD	5.07	.16	TD > SLI > ID
Vis-sp WM	2.03	.06	NS	3.22	.10	TD > ID	10.09	.27	TD > ID; ASD > ID

Processing Speed Index (PSI) as a Covariate

When PSI was a covariate, there were significant differences observed among the groups, (F=8.36, p < .001), and there were variations among the profiles for each group which are indicated by the post-hoc comparisons. The post-hoc pairwise comparisons identified significant differences between the groups (using Bonferroni adjustment for multiple comparisons). For example, the typically developing children performed better than all the three neurodevelopmental groups on verbal STM, when PSI is statistically controlled, which would be according to our primary hypothesis regarding each group (Table 3.3). This would also suggest that processing speed could not be considered as a mediating factor for the three groups on tasks of verbal STM as despite controlling this factor the typically developing children performed better than the participants with neurodevelopmental disorders.

On the other hand, a significant variation is observed on the verbal WM (Table 3.3) among the groups. For example, the group of typically developing children outperformed the groups with SLI and ID on verbal WM, while the group with ID produced significantly lower scores than the ASD group on that measure. This pattern of performance would suggest that for the group with ASD the processing speed component could have been a mediating factor influencing their performance on the verbal WM, as there was no difference observed between the performance of the typically developing and the children with ASD, while the children with ASD outperform the group with ID.

On the visual spatial STM, (Table 3.3) the typically developing children have performed better than the group with SLI and the children with SLI have shown a better performance than the group with ID. Here no significant difference is observed for ASD group, again suggesting the importance of the role of processing speed for this group. Controlling for processing speed reveals a deficit for the SLI group affecting visual spatial STM, although they do outperform the ID group on this measure. This contrasts with research suggesting that visual spatial memory is normal in SLI and supports the approach adopted in this research, that is, fractionating the components of WM into STM and WM capacities and considering the role of intelligence and related constructs.

On the visual spatial WM component, the typically developing and the group with ASD outperform the group with ID, with no other differences emerging (Table 3.3).

This would mean that when processing speed, which we understand is vital for carrying out a WM task, is controlled, there are no differences observed between the children with ASD and the typically developing children except on the verbal STM. Therefore, it is probably the processing speed which is mainly influencing the performance of the group with ASD on the memory tasks. These results could also be considered in conjunction with the difficulties children with ASD experience, as there are a large number of children with ASD diagnosed with developmental coordination disorder. Children with developmental coordination disorder are considered to experience significant difficulties in the area of visual spatial processing. Motor impairments in individuals with ASD have been categorized as “associated symptoms” (Ming, Brimacombe, & Wagner, 2007). These authors note the high prevalence of hypotonia, motor apraxia, reduced ankle mobility, history of gross motor delay, and toe-walking in children with ASD. Mayes and Calhoun (2008) suggest that children with high-functioning autism have attention, graphomotor, and processing speed weaknesses, in contrast to strengths in verbal and visual reasoning.

The performance of the group with ID was consistently poor across the memory tasks when processing speed was controlled, with scores significantly below those of the typically developing children on all the four sub-tests as they invariably performed poorly compared to each group on each memory task.

The group with SLI performed on a par with the typically developing children only on the visual spatial WM measure, and they showed poor performance on all three other domains, which included not only the verbal domains but also visual spatial STM.

Verbal Comprehension Index (VCI) as a covariate

When the VCI was a covariate, there were significant differences observed among the groups ($F=7.15$, $p < .001$). The post-hoc pairwise comparison indicated significant differences among the groups except for verbal STM, where there was no significant difference observed between the groups (see Table 3.3). This outcome would be predicted, as VCI would be expected to show a close relationship with verbal STM, and this is reflected in the lack of differences between the groups on this measure. This also points towards the importance of crystallized intelligence (VCI) in determining the verbal STM.

Compared to the performance of the typically developing group, all the remaining three groups performed poorly on verbal WM when VCI was controlled. These results would point to the important factor of processing capacity which is additionally required for WM tasks compared to STM tasks, as there was no difference observed on the verbal STM when VCI was controlled.

On the visual spatial STM measure, the group with SLI outperformed both the children with ID and ASD, but there was no difference observed among the children with typical development, ID and ASD (Table 3.3). In the visual spatial WM the typically developing group performed better than the group with ID, with no difference observed between the typically developing children and the groups with SLI and ASD. This would suggest that VCI is not a critical factor when performance on visual spatial WM is considered. On this task, there seems to be a lesser demand on language processing, apart from following the directions of the test. The only factor that may be common between VCI and visual spatial WM is the processing of information.

These results would indicate that even if verbal reasoning abilities are controlled, the three groups still performed lower than the typically developing children on the verbal WM. These results may be useful to consider in the context of previous research, as here all three groups have shown impairment in this area despite the control of VCI; that is the performance on verbal WM is not as would be predicted from the children's verbal IQ scores. Another important outcome of the result of the present analysis is that children with ID did not show significantly poorer performance compared to the typically developing children on either verbal or visual spatial STM, when the VCI is a covariate. These results may have implications in terms of intervention for the group with ID and future research; for example, it may be worth exploring whether training to improve STM would have positive effects in terms of overall functioning.

The group with SLI produced significantly poorer performance compared to the typically developing children on the measure of verbal WM, but not on verbal STM, when VCI is a covariate. These results again support an approach that separates STM from WM components, and suggests that storage capacity should be considered independently from processing capacity.

Perceptual Reasoning Index (PRI) as a covariate

When the PRI was a covariate, there were overall groups differences (F=11.19, p < .001); however, the pattern here was slightly different (see Table 3.3). Here, when controlling for performance/non-verbal ability there are no group differences on the measure of visual spatial working memory. However, the group with SLI emerge as having significantly poorer performance than the typically developing children on both the verbal STM and verbal WM measures. This would support the hypothesis of the present study, as it was proposed that children with SLI would perform lower than the typically developing children on the verbal memory measures. The outcome would also support the significant impairment of group with SLI in this domain. However, the group with ASD and ID performed similarly to the typically developing children suggesting the importance of PRI for these groups.

On verbal WM, all three groups performed lower than the typically developing group; again this is in support of the hypothesis of the present study. This would suggest the limited role of PRI in the memory performance of the three neurodevelopmental groups, as despite its control performance is lower than that of the typically developing children. This effect is similar to that seen when VCI is controlled (see Table 3.3).

On visual spatial STM, the group with SLI performed better than the group with ASD. This means that the performance of the groups with ASD, TD and ID were in line with each other on the visual spatial STM, which suggests the importance of PRI (fluid intelligence) in determining the efficiency of visual spatial STM. There was no significant difference between the four groups on the visual spatial WM, supporting the importance of PRI as a major factor in influencing visual spatial WM.

These results suggest that fluid intelligence makes a significant contribution towards the efficiency of three major components of memory, the exception being verbal WM, with some of the groups affected more so than others. Overall, these results show impairment of the three groups on the verbal WM, with no additional effect on verbal or visual spatial STM and visual spatial WM, when PRI is controlled.

These findings indicate that the three neurodevelopmental groups share some similarities in their performance on the memory tasks but there are areas of memory impairment that are specific to these groups. Especially when the PRI, VCI, and PSI, were statistically controlled, all the three groups performed poorly on the verbal working memory tasks, whereas their performance on the other components of the memory differs by group. The performance of the group with ASD is of particular interest as this group has shown lower deficits on memory components such as the verbal STM and visual spatial STM/WM while controlling the three indexes of the IQ. The group with ID also show less deficient memory in their performance on the verbal and visual spatial STM. Furthermore, IQ appears to be playing a crucial role in determining the pattern of memory performance and that of its subsidiary subcomponents.

The next sections examine the performance of each group, before a comparison of group profiles is presented.

3.2 Typically Developing Children

The Pearson product correlation was conducted (Table 3.4) on the typically developing children’s data to see not only the relationship among different subcomponents of AWMA but also with different domains of IQ. This analysis was also carried out to look for a normal scoring pattern so that it can be cross-checked with the performance of children with neurodevelopmental disorders. The analysis indicates a high correlation among almost all the subcomponents of AWMA and FISQ with the exception of the Digit Recall, Non Word Recall, Dot Matrix and Mister-X within the AWMA, which may suggest that Digit Recall, Non-Word Recall, Dot Matrix and Mister-X can differentially measure memory (independent of IQ).

The correlation between the subcomponents of AWMA and PRI again are very high except for Digit Recall, and Non-Word Recall. The PRI is considered to be measuring fluid intelligence. The correlation for PRI and memory components ranged from .51 to 73. The highest correlation of PRI was obtained with visual spatial WM (.73). The PRI also was highly correlated with all the memory composite scores (verbal STM=.51; verbal WM=.67; and visual spatial STM =.56). It was only the Mazes subtest of the visual spatial STM which did not show a significant correlation with PRI. These results support earlier studies, suggesting a strong relationship between fluid intelligence and memory.

By contrast, correlation with VCI was observed with comparatively fewer sub-components of memory. The correlation of VCI with memory components ranged from .47 to .63. The highest correlation of VCI was obtained with verbal WM composite score (.63). The VCI is considered to measure crystallized intelligence. However, there was no significant correlation observed between PSI and the memory tasks. The PSI is a measure of the speed with which an individual can process simple visual material quickly. It also taps visual memory to some extent. It was presumed that PSI may also be related to the memory tasks, at least for the visual spatial STM. However, the absence of a relationship here could be due to differences in the format of the measures used here; the PSI involves carrying out a task manually, while the WM tasks require mental processing using a computer-based task. The child in the processing speed tasks has to copy or scan the visually presented symbol and either make the shape or tick the correct box.

In order to look at the relationship of individual subtests of the IQ test with the Composite Scores (CS) of the memory test, a correlational matrix was constructed (Table 3.5). The results indicated that all the memory composite scores were highly related with Picture Concept, Matrix Reasoning (fluid intelligence) subtests and Vocabulary (crystallized intelligence) subtest, whereas there was no correlation observed between the Block Design subtest (fluid intelligence) and with both subcomponents of Processing Speed Index (Symbol Search and Coding subtests). These results show a relationship of Vocabulary subtest with the memory, which is considered to be relying heavily on crystallized intelligence. However, the result of the Block Design subtest is somewhat surprising (and may also reflect differences in response format) as this is a test which would tap into fluid intelligence and there is an element of planning involved which would also measure, to an extent, executive functioning.

Table 3.4. Pearson's correlations between memory components and intelligence test for the Typically Developing children (N=23).

	Word Recall	Non-word Recall	Verbal STM CS	Listening Recall	Counting Recall	Digit Recall	Verbal WM CS	Dot Matrix	Mazes	Block Recall	Vs-Sp STM CS	Odd-one-Out	Mister X	Spatial Recall	Vs-SP WM CS	VCI	PSI	PRI	FSIQ
Digit Recall	.61(**)	.36	.76(**)	.59(**)	.42(*)	.67(**)	.64(**)	.59(**)	.59(**)	.64(**)	.69(**)	.52(*)	.38	.52(*)	.56(**)	.36	.10	.36	.37
Word Recall		.51(*)	.87(**)	.74(**)	.59(**)	.73(**)	.76(**)	.39	.63(**)	.50(*)	.63(**)	.53(**)	.66(**)	.53(**)	.63(**)	.47(*)	-.15	.53(**)	.43(*)
Non Word Recall			.805(**)	.41	.46(*)	.48(*)	.49(*)	.27	.29	.35	.34	.32	.57(**)	.42(*)	.51(*)	.15	.07	.35	.27
Verbal STM CS				.69(**)	.61(**)	.76(**)	.76(**)	.48(*)	.60(**)	.59(**)	.66(**)	.55(**)	.67(**)	.60(**)	.69(**)	.39	-.01	.51(*)	.43(*)
Listening Recall					.64(**)	.74(**)	.85(**)	.57(**)	.69(**)	.55(**)	.74(**)	.65(**)	.53(**)	.61(**)	.67(**)	.65(**)	.04	.64(**)	.70(**)
Counting Recall						.71(**)	.85(**)	.52(*)	.75(**)	.72(**)	.83(**)	.81(**)	.70(**)	.85(**)	.89(**)	.38	-.18	.65(**)	.47(*)
Digit recall							.92(**)	.57(**)	.66(**)	.76(**)	.78(**)	.63(**)	.64(**)	.63(**)	.74(**)	.60(**)	-.31	.67(**)	.55(**)
Verbal WM CS								.65(**)	.79(**)	.79(**)	.88(**)	.79(**)	.69(**)	.76(**)	.86(**)	.63(**)	-.24	.73(**)	.64(**)
Dot Matrix									.49(*)	.64(**)	.81(**)	.56(**)	.27	.49(*)	.52(*)	.36	-.11	.51(*)	.36
Mazes Memory										.60(**)	.85(**)	.87(**)	.42(*)	.75(**)	.80(**)	.52(*)	-.02	.55(**)	.57(**)
Block Recall											.83(**)	.69(**)	.52(*)	.66(**)	.76(**)	.54(**)	-.33	.56(**)	.44(*)
Vis-Sp STM CS												.83(**)	.49(*)	.77(**)	.81(**)	.57(**)	-.13	.66(**)	.57(**)
Odd-one -out													.45(*)	.76(**)	.87(**)	.50(*)	-.14	.67(**)	.53(**)
Mister X														.64(**)	.77(**)	.31	-.10	.55(**)	.41
Spatial Recall															.92(**)	.33	-.13	.71(**)	.55(**)
Vis-Sp WM CS																.43(*)	-.20	.73(**)	.54

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 3.5. Pearson’s correlations between memory components and individual subtests of the IQ tests for typically developing children (N=23).

	Block Design	Picture Concept	Coding	Vocabulary	Matrix Reasoning	Symbol Search
Verbal STM CS	.23	.53(*)	.03	.69(**)	.44(*)	-.02
Verbal WM CS	.24	.62(**)	-.17	.70(**)	.72(**)	-.21
Vs-Sp STM CS	.07	.68(**)	-.10	.71(**)	.64(**)	-.10
Vs-Sp WM CS	.30	.60(**)	-.07	.59(**)	.65(**)	-.21

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

3.3 Autism Spectrum Disorder Group (ASD)

An independent samples t-test analysis (Table 3.6) was conducted to compare the children with ASD and typically developing children irrespective of their age and IQ level in order to compare the two groups on all the subcomponents of the memory and significant differences were observed on almost all the subcomponents of AWMA.

Verbal Short Term Memory (Verbal STM)

The results show that the typically developing children performed much better on almost all the subcomponents of memory tasks of the verbal STM except on the nonword recall subtest. The results for the verbal STM Composite Score show better performance by the typically developing children compared to children with ASD: (the scores for the group with ASD: M= 84.73, SD = 14.62 and for the typically developing group: M= 100.57, SD = 18.44); t (47) = 3.49, p = .002 (see Table 3.6). The results were significant for the subcomponents of the verbal STM. On Digit Recall, the group with ASD (M=87.61, SD = 17.89) performed significantly lower that the typically developing group (102.48, SD 13.68); t (47) =3.23, p = .002. The difference was also significant for the Word Recall subcomponent: (the score for the groups with ASD: M=84.38, SD 14.18; and for the typically developing group:

M=99.61, SD = 19.81); t (47) = 3.12, p = .003. The result was, however, not significant for the Non Word Recall: (the score for the group with ASD: M=89.69, SD = 17.77 and for the normal group: M= 99.96, SD = 20.95); t (47) = 1.86, p = .07. These results would support the hypothesis of the present research suggesting difficulties of children with ASD as a group on verbal STM. The Non Word measure is the only area where there were no significant difference observed between the two groups. The Non Word subtest has been criticised by various researchers as previously noted in the introduction section of this thesis (Dollaghan, et al., 1993, 1995; Gathercole, 1995; Snowing, et al., 1991).

Verbal Working Memory (Verbal WM)

Significant differences were found on all the verbal WM components (Table 3.6). The difference in the verbal WM Composite Score (for the group with ASD, M=83.15, SD=19.78; and for the typically developing group: M=103.48, SD=16.85); was highly significant, t(47) =3.85, p=.000. The same pattern emerges on the Listening Recall test, as there was a significant difference between the group with ASD and typically developing children (the score for the group with ASD: M = 83.12, SD=17.53 and for the typically developing group: M=105.43, SD = 16.69), t (47) = 4.55, p = .000. On Counting Recall, the typically developing children performed significantly better than the group with ASD (the score for the group with ASD: M=84.65, SD=17.00; and for the typically developing group: M=96.96, SD, 16.12), t (47) = 2.60, p = .013. The results also differed on the Digit Backward Recall as the typically developing children performed much better than the group with ASD (the scores for the group with ASD: M=87.58, SD = 20.91; and for the typically developing group: 103.91, SD=17.36), t (47) = 2.95; p=.005).

These outcomes are in line with the hypothesis that children with ASD have difficulties on tasks of verbal working memory. Furthermore, some of the subtests of the present verbal WM test have previously been used for measuring executive functioning (for example, Digit Backward and Listening Recall), and therefore the present results may also be important in terms of the implications for executive functioning in children with ASD.

Visual Spatial Short Term Memory (Vis-Sp STM)

Except for the Mazes subtest of the visual spatial STM, the typically developing children outperformed the children with ASD on all the tasks within this domain. The scores on the visual spatial STM Composite Score show a significant difference in favour of the typically developing children: (the scores for the group with ASD: M=82.30, SD=17.17.12; and for the typically developing children: M=94.83, SD=17.13); t (47) = 2.54, p=0.14. The typically developing children performed better than the children with ASD on the Dot Matrix subtest: (the scores for the group with ASD: M=83.42, SD=15.32 and for the typically developing children: M=94-83, SD=17.31); t(47)=3.04, p=.004. There were no significant differences observed on the Mazes Memory: (the scores for the group with ASD: M=85.15, SD=18.92, and for the typically developing group: M=94.43, SD=18.43); t (47) =1.74, p=.089. This level of performance by the children with ASD would be in line with their special preference for remembering routes, directions, etc.

On the Block Recall subtest, the group with ASD performed lower than the typically developing children: (the scores for the group with ASD: M=87.04, SD=15.76, and for the typically developing children: M=97.96, SD=16.47); t (47) = 2.37, p=.022. These results would be in agreement with the present research hypothesis, suggesting that children with ASD present with difficulties with visual spatial STM. Mazes Memory was the only subtest which could not significantly differentiate the two groups.

Visual Spatial Working Memory (Vis-Sp WM)

The results are significant on all the domains of the visual spatial WM as the typically developing children performed better than the group with ASD (see Table 3.6). The typically developing children performed better than the group with ASD on the visual spatial WM Composite Score: (the scores for the group with ASD: M=86.96, SD=16.68, and for the typically developing group: M=102.17, SD=17.51); t(47)=3.11, p=.003. The typically developing children performed better on the Odd-One-Out subtest: (the scores for the group with ASD: M=85.73, SD=14.02 and for the typically developing children: M=100.30, SD=16.98); t(47)=3.29, p=.002. The performance of the group with ASD is significantly lower than the typically developing children on the Mister-X task (the scores for the group with ASD: M=90.77, SD=15.27, and for the typically developing children: M=102.43, SD=15.51); t (47) = 2.65, p=.011. The performance on the Spatial Recall for the group with ASD is significantly lower than the typically developing children: (the score for the ASD: M=89.50, SD=24.80 and for the typically developing children: M=101.43, SD=16.43); t(47)=1.96), p=.056. These data support the hypothesis proposed by the current study – that children with ASD would present difficulties on visual spatial WM.

Table 3.6. Comparison of children with ASD and TD on the sub-components of AWMA and the level of significance (N=49)

	ASD N= 26		TD N= 23			
	M	SD	M	SD	t	p
Verbal STM CS	84.73	14.62	100.57	18.44	3.35	.002
Digit Recall	87.61	17.93	102.48	13.68	3.23	.002
Word Recall	84.38	14.18	99.61	19.81	3.12	.003
Non word recall	89.69	17.77	99.96	20.95	1.86	.070
Verbal WM CS	83.15	19.78	103.48	16.85	3.85	.000
Listening recall	83.12	17.53	105.43	16.69	4.55	.000
Counting recall	84.65	17.00	96.96	16.12	2.60	.013
Digit recall	87.58	20.91	103.91	17.36	2.95	.005
Visual Spatial STM CS	82.30	17.12	94.83	17.31	2.54	.014
Dot Matrix	83.42	15.32	96.91	15.73	3.04	.004
Mazes Memory	85.15	18.92	94.43	18.43	1.74	.089
Block recall	87.04	15.76	97.96	16.47	2.37	.022
Visual Spatial WM CS	86.96	16.68	102.17	17.51	3.12	.003
Odd-one-out	85.73	14.02	100.30	16.98	3.30	.002
Mister X	90.77	15.27	102.43	15.51	2.65	.011
Spatial Recall	89.50	24.80	101.43	16.43	1.96	.056

These results appear to be very convincing, supporting the previous studies regarding memory impairment within the population with ASD. However, it needs to be kept in mind that these analyses were conducted on children representing a wide spectrum of abilities, from moderate to average IQ. In previous paragraphs it was emphasized that IQ is a major moderator in determining the performance of WM; therefore it may prove interesting to consider the performance of high functioning children with ASD and compare their performance with the typically developing children on memory components.

High Functioning ASD and Typically developing children

An independent samples t-test (Table 3.7) was carried out to find out differences between the performance of children with ASD and typically developing children on the memory tasks when they were matched on age and IQ. Only children who had obtained a FSIQ score of 80 and with an age below 161 months were considered for this analysis in order to match a sub-group of children with ASD with typically developing group on age and ability. The previous results as presented in the preceding paragraphs showed poor performance by the children with ASD compared to typically developing group, when the entire group was analysed without considering their level of IQ and age. Therefore, this analysis was carried out with the aim of looking at the role of IQ, since previous research has suggested a strong relationship of IQ with memory. Therefore, there is a possibility that the low performance by the group with ASD in previous studies could be due to lack of control over their IQ. Hence, the assumption was that if children with ASD had WM impairment, then they would perform poorly on these tasks irrespective of their cognitive abilities on the IQ test.

No significant results were obtained on any of the memory subcomponents except the Listening Recall of verbal WM: (the scores for the group with ASD: $M=89.44$, $SD=20.13$ and for the typically developing group: $M=104.94$, $SD = 16.68$); $t(26) = 2.13$, $p=0.044$ (see Table 3.7). This outcome supports the contention of the present research that average ability children with ASD would perform similarly on the AWMA subtests compared to the typically developing children. This would subsequently suggest an intact memory performance, including both verbal and visual spatial STM/WM of high functioning children with ASD. This would also suggest the importance of the relationship of intelligence with memory within the population with ASD. The only exception was on the Listening Recall, which as mentioned earlier is a test used by many previous researchers in measuring executive functioning. This would therefore point towards implications for executive function within the population with ASD, which needs to be explored by future research with specially designed tasks developed exclusively to measure executive functions. The present results would, in general, support the previous results showing intact memory of high functioning children with ASD (Russell, et. al., 1996; Griffith, et. al., 1999; Williams, et. al., 2005).

Table 3.7 Comparison of high functioning* and chronologically matched age* children with ASD and TD children and the levels of significance on the subcomponents of AWMA (N=27).

	ASD n=9		TD n=18			
	M	SD	M	SD	t	P
Verbal STM CS	91.44	16.42	104.33	18.05	1.799	.084
Digit Recall	94.00	18.75	104.56	13.44	1.685	.104
Word Recall	87.89	11.78	100.83	19.62	1.812	.082
Non word recall	98.11	18.02	105.39	19.19	.947	.353
Verbal WM CS	97.56	23.64	105.39	16.54	1.005	.325
Listening recall	89.44	20.13	104.94	16.68	2.127	.044
Counting recall	96.11	20.10	99.39	16.37	.447	.659
Digit recall	107.33	19.44	105.72	17.51	.217	.830
Visual Spatial STM CS	95.11	15.22	97.89	17.20	.410	.685
STM Dot Matrix	91.56	15.00	99.50	15.79	1.252	.222
Mazes Memory	101.89	13.65	96.78	18.05	.747	.462
Block recall	94.78	11.55	101.28	14.27	1.183	.248
Visual Spatial WM CS	101.89	12.95	105.22	17.63	.502	.620
Odd-one-out	96.78	13.14	103.28	15.39	1.082	.289
WM Mister X	100.89	15.37	103.72	15.64	.446	.659
WM Spatial Recall	106.44	9.36	104.17	17.40	.365	.718

*FSIQ above 80 and age below 161 months.

Performance of ASD children as a function of IQ

After finding that there was no difference in the performance of the high functioning children with ASD and the typically developing children on the memory functioning, it would be interesting to explore the possibility of differences among children with ASD with different abilities. If the high functioning children with ASD perform better than the low functioning children with ASD, it would again support the earlier stance taken by this research that there is a strong relationship between IQ and memory. For this purpose, the children with ASD were divided into three groups based on their scores on the intelligence tests, i.e. mild-moderate (IQ score between 40 - 69), borderline (IQ score between 70-79)) and average-above (IQ score between 80-120) (Table 3.8). These groups were created following ICD-10 and DSM-IV criteria based on their scores. A one-way ANOVA was conducted to examine differences between these groups of children with ASD on the memory tests. The following were the outcomes.

Verbal Short Term Memory (Verbal STM)

There were significant differences on the two subscales and the composite scale of verbal STM: The score for the verbal STM Digit Recall [F(2, 23) = 5.501, p =.01], for verbal STM Word recall, [F(2, 23) = 3.45, p = .049] for verbal STM Composite Score, [F (2, 23) = 4.7, p = .019] (see Table 3.8). There was no significant difference on the verbal STM Non Word Recall task [F(2, 23) = 2.03, p = .15]. Tukey post hoc technique was used for comparison between the groups, which showed that children with ASD with low IQ has performed low on the verbal STM Digit Recall compared to the other two groups of children with higher IQ. On the verbal STM Composite Score, average group has performed better only than children in the mild-moderate group. This would mean that the difference in IQ needs to be quite large in order to produce a meaningful difference as there was no significant difference observed between the average and borderline groups.

Verbal Working Memory (Verbal WM)

On verbal WM, there were significant differences obtained on the verbal WM Counting Recall: [F(2, 23) = 4.6, p = .02; on the verbal WM Digit Recall [F(2, 23) = 11.96, p = 000]; and the verbal WM Composite Score [F(2, 23) = 5.32, p = .013]. There was no significant difference for verbal WM Listening Recall [F(2, 23)= 1.83, p

= .183]. The Tukey post hoc technique was used to see the differences among the groups (Table 3.8). On the verbal Working Memory tasks, the average group has performed better than the mild-moderate group on Counting Recall subtest and verbal WM Composite Scores and better than the mild-moderate and borderline groups on verbal WM Digit Recall. The Listening Recall is the only subtest, which remains unchanged with variation in IQ. Again the difference in IQ needs to be quite significant for a large difference to be observed.

As there was significant differences observed on both the verbal WM/STM Composite Scores; the average group has performed better than the group with ASD, this would suggest a strong link of IQ with memory and also between the STM and WM for the group with ASD.

Visual Spatial Short Term Memory (Vis-Sp STM)

On visual spatial STM, there were significant differences observed between the groups: for visual spatial STM Dot Matrix [F (2, 23) = 5.24, p = .013]; for visual spatial STM Mazes [F(2, 23) = 15.65, p = 000]; for visual spatial STM Block Recall [F(2, 23) = 4.737, p = .019]; for visual spatial STM Composite Score [F(2, 23) = 11.16, p = 000]. The Tukey post hoc technique showed the average group performed better than the mild-moderate on the Dot Matrix, Block Recall and Composite Scores and better than the mild-moderate and borderline on the Mazes memory of visual spatial STM (Table 3.8). These results would emphasise the relationship between intelligence and visual spatial STM as the average group has performed better than the lower group.

Visual Spatial Working Memory (Vis-Sp WM)

On all the subscales of the visual spatial Working Memory, there were significant differences: [F(2, 23) = 7.75, p = .003] for visual spatial Working Memory Odd One Out; [F(2, 23) = 5.32, p = .01] for visual spatial Mister-X; [F(2, 23) = 7.64, p = .003] for visual spatial WM Spatial Recall; [F(2, 23) = 13.30, p = .000] for visual spatial Composite Score. The Tukey post hoc technique indicated the average group performed better than the mild-moderate group on the Odd One Out, Spatial Recall subtests of the visual spatial WM (Table 3.8). Whereas the average group has performed better than both groups, i.e., mild-moderate and borderline, on the Spatial Recall subtest, and the Composite Scores of the visual spatial WM. These results strongly support the role of IQ in memory since a parallel relationship is witnessed between the level of IQ and memory functioning. Hence, this will support the hypothesis of the present research with regards to the increment in memory performance with increase in IQ level of children with ASD, as the average group has performed better than the groups with low IQ on all the Composite Scores of memory.

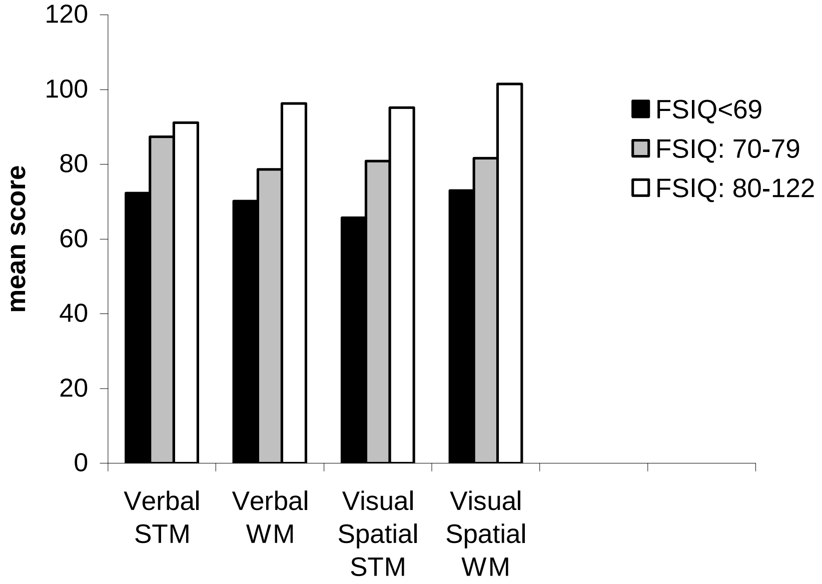


Fig 3.2 Mean scores of the group with ASD on the four memory components as a function of IQ

Table 3.8 Comparison of children with ASD with different range of IQ and the levels of significance on the AWMA test (N=26).

	FSIQ<69 n = 7		FSIQ: 70-79 n= 9		FSIQ: 80-122 n = 10			
	M	SD	M	SD	M	SD	F	P
Verbal STM CS	72.29	11.69	87.33	10.05	91.10	15.52	4.700	.019
Digit Recall	71.14	14.15	93.56	13.31	93.80	17.69	5.501	.011
Word Recall	73.43	17.58	89.22	10.60	87.70	11.13	3.452	.049
Non word recall	80.86	10.70	87.89	20.58	97.50	17.10	2.033	.154
Verbal WM CS	70.14	5.64	78.67	15.35	96.30	22.64	5.322	.013
Listening recall	73.43	10.49	83.67	18.45	89.40	18.98	1.830	.183
Counting recall	72.86	6.23	82.44	12.58	94.90	20.16	4.611	.021
Digit recall	72.57	8.68	79.00	14.51	105.80	18.95	11.906	.000
Visual Spatial STM CS	65.71	4.57	80.89	14.74	95.20	14.35	11.159	.000
Dot Matrix	71.43	9.86	82.67	13.99	92.50	14.45	5.239	.013
Mazes Memory	70.14	8.28	77.44	15.17	102.60	13.07	15.647	.000
Block recall	73.43	8.46	90.56	18.48	93.40	11.73	4.737	.019
Visual Spatial WM CS	73.00	9.76	81.67	12.75	101.50	12.27	13.296	.000
Odd-one-out	74.29	9.30	83.44	10.89	95.80	12.77	7.749	.003
Mister X	84.86	10.30	83.56	13.39	101.40	14.58	5.318	.013
Spatial Recall	67.57	31.10	88.11	18.47	106.10	8.89	7.639	.003

Performance of Low IQ ASD children and ID

Having analyzed different groups of ASD with different abilities, comparing the low functioning groups with ASD and ID would give further insight into the role of IQ role in determining the memory. For this purpose, the children with ID were compared with low functioning children with ASD with an IQ score <69 (see Table 3.9). They were also matched on age (56-161 months). This analysis was carried out in order to see whether participants with ASD with different range of IQ would perform differently, which would support the earlier stance taken by this research of high relationship of IQ with memory. An independent t-test indicated no significant differences when low-functioning children with ASD were compared with children with ID of the same age group except on the Mazes Memory subtest, a subcomponent of visual spatial STM: (the scores for the ID group: M=85.11, SD=16.40 and for the group with ASD: M=74.25, SD=12.81); t (42) = 2.28, p=.028, suggesting better performance by the group with ASD on the Mazes subtest. This would be in accordance with the hypothesis of the role of IQ in determining the performance on memory tasks as there were no differences observed between the two groups.

Table 3.9 Comparison of children with ID and ASD matched on the basis of IQ & chronological Age and their levels of significance on the AWMA test (N=44).

	ID n=28		ASD n= 16			
	M	SD	M	SD	t	P
Verbal STM CS	79.50	14.97	80.75	12.96	.279	.781
Digit Recall	81.54	11.46	83.75	17.51	.507	.615
Word Recall	82.50	18.09	82.31	15.78	.035	.973
Non word recall	84.07	17.12	84.81	16.87	.139	.890
Verbal WM CS	72.39	7.67	74.94	12.55	.837	.407
Listening recall	76.93	12.75	79.19	15.91	.516	.608
Counting recall	77.50	10.96	78.25	11.14	.217	.829
Digit recall	77.11	8.46	76.19	12.38	.292	.771
Vs-Spatial STM CS	77.43	12.93	74.25	13.59	.770	.446
Dot Matrix	78.46	14.71	77.75	13.28	.160	.873
Mazes Memory	85.11	16.40	74.25	12.81	2.277	.028
Block recall	79.64	13.56	83.06	16.96	.734	.467
Vs-Spatial WM CS	75.04	11.31	77.88	12.02	.783	.438
Odd-one-out	79.36	13.05	79.44	10.95	.021	.984
Mister X	76.50	12.57	84.13	11.77	1.979	.054
Spatial Recall	77.29	16.89	79.13	26.07	.284	.778

Table 3.10 Pearson's Correlation of AWMA test with the intelligence test for children with ASD (N=26).

	Word Recall	Non word	Verbal STM CS	Listening recall	Counting recall	Digit recall	Verbal WM CS	Dot Matrix	Mazes	Block recall	Vis-sp-STM CS	Odd-one-out	Mister X	Spatial Recall	Vis-sp-WM CS	VCI	PRI	FSIQ	PSI
Digit Recall	.44*	.28	.73**	.62**	.63**	.51**	.67**	.42(*)	.32	.44*	.49*	.59**	.37	.37	.56**	.37	.49*	.61**	.49(*)
Word Recall		.53**	.78**	.16	.11	.15	.12	.34	.41*	.56**	.51**	.17	.14	.21	.21	.36	.33	.46*	.41
Non word			.81**	.22	.42*	.41*	.40*	.56**	.60**	.58**	.66**	.213	.31	.18	.29	.35	.45*	.55**	.35
Verbal STM CS				.46*	.53**	.48*	.55**	.56**	.58**	.67**	.72**	.42*	.37	.33	.46*	.44*	.52**	.68**	.47(*)
Listening recall					.74**	.73**	.88**	.26	.38	.34	.42*	.61**	.58**	.61**	.74**	.21	.37	.40*	.15
Counting recall						.73**	.92**	.48*	.48*	.52**	.60**	.75**	.63**	.54**	.79**	.40*	.59**	.65**	.45(*)
Digit recall							.90**	.46*	.60**	.44*	.61**	.65**	.65**	.65**	.80**	.49*	.70**	.70**	.43
Verbal WM CS								.46*	.52**	.48*	.60**	.71**	.68**	.58**	.82**	.40*	.63**	.66**	.42
Dot Matrix									.63**	.71**	.88**	.40*	.41*	.36	.49*	.41*	.54**	.63**	.64(**)
Mazes										.54**	.85**	.65**	.59**	.45*	.69**	.58**	.64**	.76**	.48(*)
Block recall											.86**	.44*	.18	.38	.43*	.32	.44*	.58**	.53(*)
Vis-Sp-STM CS												.62**	.47*	.49*	.65**	.51**	.63**	.78**	.60(**)
Odd-one-out													.57**	.57**	.84**	.41*	.52**	.63**	.50(*)
Mister X														.41*	.85**	.47*	.46*	.58**	.02
Spatial Recall															.73**	.29	.50**	.49*	20
Vis-Sp-WM CS																.56**	.61**	.72**	.44

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Correlation matrix

Table 3.10 presents correlation coefficients between the AWMA subscales scores and the FSIQ, VCI , PRI and PSI of children with ASD. There seems to be significantly high correlation between FSIQ scores and all the subcomponents of AWMA. The range of correlation of the FSIQ with the memory subcomponents is from .40 to .78. The highest correlation was obtained with the visual spatial STM composite scores. PRI and VCI showed high correlations with all the Composite Scores of AWMA. The range for the correlations for the VCI with the memory sub-tasks was from .40 to .58. The highest correlation was obtained with the Mazes (.58) followed by visual spatial WM (.56). The range for the correlation for the PRI and memory components was from .44 to .70. The highest correlation for the PRI was with the Digit Recall (.70). There was also a significant correlation observed between PSI and a large number of memory components which would present a completely different profile compared to the typically developing children, for whom there was no relationship between processing speed and memory (see Table 3.4). The range of correlation for the PSI with memory components was from .45 to .64. The highest correlation was obtained on the Dot Matrix with the PSI.

These high correlations would suggest a strong link between memory components and intelligence and support the analysis reported above comparing children with ASD as a function of their IQ: as the IQ of the children with ASD approaches a normal range, working memory deficits disappear, across the set of working memory sub-tasks.

Table 3.11 Pearson's Correlation of AWMA with the Intelligence subtests for children with ASD (N=26).

	Block Design	Picture Concept	Coding	Vocabulary	Matrix Reasoning	Symbol Search
Verbal STM CS	.39	.56(**)	.27	.57(**)	.57(**)	.44(*)
Verbal WM CS	.54(*)	.69(**)	.39	.59(**)	.49(*)	.52(*)
Vs-Sp STM CS	.70(**)	.70(**)	.50(*)	.72(**)	.50(*)	.78(**)
Vs-Sp WM CS	.58(**)	.73(**)	.51(*)	.60(**)	.32	.63(**)

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The Pearson correlation indicates (Table 3.11) high correlation of the individual subtests of the IQ test with a majority of the Composite Scores (CS) of the AWMA. Unlike the TD children, the CS of memory also indicated a significant relationship with the Block Design (BD) Coding and Symbol Search subtests. The only lack of relationship of BD subtest was observed with verbal STM. Verbal STM/WM did not show any relationship with Coding.

3.4 Intellectual Disability (ID) group

Table 3.12 presents the t-test results for the two groups i.e., ID and typically developing children. Results indicate high performance of typically developing children on almost all the tasks of AWMA, which include verbal/visual subcomponents of STM/WM, compared to children with ID approving the assumptions presented by this research.

Verbal Short Term Memory (Verbal STM)

There are significant differences observed between the group with ID and the typically developing children on the verbal STM composite score, as typically developing children have performed much better: (the scores for the group with ID: M= 78.16, SD = 14.57 and for the typically developing children group: M= 100.57, SD = 18.44); t (53) = 5.03, p = .000 (table 3.12). The typically developing children have performed much better than the group with ID on the Digit Recall: (the scores for the group with ID: 81.00, SD =11.21 and for the typically developing children: M = 102.48, SD=13.68), t (53) = 6.39, p= 000. There are significant differences observed between the children with ID and the typically developing children on the Word Recall subtest: (the scores for the group with ID: M=81.97, SD = 17.44 and for the typically developing children group: M = 99.61, SD =19.81) t(53) = 3.50, p= .001. The typically developing children have performed much better on the Non-Word Recall subtest than the group with ID (the scores for the group with ID: M=81.00, SD =17.99 and for the typically developing children: M = 99.96, SD = 20.95), t (53) = 3.60, p = .001. This performance would indicate significant difficulties by children with ID on tasks involving verbal STM and which would be according to the hypothesis of the present research.

Verbal Working Memory (Verbal WM)

There were significant differences observed on all the subcomponents of verbal WM in favour of the typically developing children (Table 3.12). The typically developing children performed much better as evident by the verbal WM Composite Score compared to their performance with the group with ID: (the scores for the group with ID: M = 72.16, SD = 7.42 and for the typically developing children: M =103.48, SD= 16.85), t(53) =9.35, p =.000. The performance of the group with ID is much lower than the typically developing children for the Listening Recall subtest: (the scores for the group with ID: M= = 75.81, SD = 12.52 and for the typically developing children: M =105.43, SD =16.69), t (53) = 7.53, p =.000. The Counting Recall subtest also differentiated the two groups as the typically developing children have performed much better: (the scores for the Counting Recall subtest for the group with ID: M= 77.06, SD=10.33 and for the typically developing: M= 96.96, SD=16.11), t (53) = 5.59, p = .000. The group with ID performed very poorly on the Digit Backward Recall subtest compared to the typically developing children: (the scores for the group with ID: M= 77.75, SD=8.50 and for the typically developing children: M=103.91, SD=17.36), t (53) = 7.40, p=.000. These scores show that children with ID have poor performance on all the subcomponents of the verbal WM suggesting significant difficulties in this area. This performance is in line with the assumption of the present research that children with ID would perform low on verbal WM.

Visual Spatial Short Term Memory (Vis-Sp STM)

The group with ID has also shown poor performance on visual spatial STM compared to the typically developing children (Table 3.12). There is a significant difference between the children with ID and the typically developing children in favour of the typically developing group on the visual spatial STM Composite Score: (the scores for the group with ID: M= 77.28, SD=12.35 and for the typically developing group: M = 94.83, SD=17.31), t (53) = 4.33, p =.000. The typically developing children have performed much better on the Dot Matrix compared to the performance of the group with ID: (the scores for the group with ID: M=78.25, SD=14.37 and for the typically developing children: M= 96.91, SD = 15.73), t (53) = 4.57, p=.000. The typically developing children have performed better than the group with ID on the Mazes Memory: (the scores for the group with ID: M= 84.84, SD=16.95 and for the typically developing children: M=94.43, SD =18.43), t(53) = 1.10, p=.051. The performance is quite significant on the Block Recall as the typically developing children have performed much better than the children with ID: (the scores for the group with ID: M = 78.91, SD =13.15, and for the typically developing children: M= 97.96, SD=16.47), t(53)=4.77, p=.000. The group with ID showed significantly poorer performance on the visual spatial STM compared to the typically developing children, which would be in line with the assumption of the present research.

Visual Spatial Working Memory (Vis-Sp WM)

There are significant differences observed on all the subcomponents of visual spatial WM as the group with ID has performed very low compared to the typically developing children (see Table 3.12). The typically developing children have performed better than the group with ID on the visual spatial WM Composite Score: (the scores for the group with ID: M= 74.38, SD=10.89 and for the typically developing children: M= 102.17, SD=17.51), t (53)=7.252, p=.000. The group with ID has performed low on the Odd-One-Out subtest compared to their performance with the typically developing children: (the scores for the group with ID: M= 77.28, SD = 13.600 and for the typically developing children: M=100.30, SD=16.98), t (53) = 5.579, p=.000. The performance of children with ID is quite low compared to the typically developing children on the Mister-X subtest: (the scores for the group with ID: M= 76.81, SD =12.18 and for the typically developing children: M= 102.43, SD=15.51), t (53) = 6.863, p =.000. The typically developing children have performed significantly better on the Spatial Recall subtest compared to the group with ID: (the scores for the group with ID: M= 78.72, SD = 16.80 and for the typically developing children: M=101.43;, SD=16.43), t(53)=4.991, p=.000. Children with ID have performed very poorly compared to the typically developing children, supporting the assumption of the present research.

In general, these results would substantiate previous research which has suggested the difficulties of with children ID on memory tasks. This research has further established that the children ID not only have difficulties with WM but also with STM both in verbal and visual spatial domains. In the introduction section, it was suggested that any new task could be considered as tapping both the storage and processing capacity. This could be the reason for the low performance by children with ID on each of the subcomponents including STM. These results reflect the significant difficulties of children with ID on both visual spatial sketchpad and phonological articulatory loop.

Table 3.12 Comparison of children with ID and TD children and their significance level on the AWMA test. (N= 55)

	ID n= 32		TD n=23			
Scales	*M*	*SD*	*M*	*SD*	*t*	*P*
Verbal STM CS	78.16	14.57	100.57	18.44	5.03	.000
Digit Recall	81.00	11.21	102.48	13.68	6.39	.000
Word Recall	81.97	17.44	99.61	19.81	3.50	.001
Non word recall	81.00	17.99	99.96	20.95	3.60	.001
Verbal WM CS	72.16	7.42	103.48	16.85	9.35	.000
Listening recall	75.81	12.52	105.43	16.69	7.53	.000
Counting recall	77.06	10.33	96.96	16.11	5.59	.000
Digit recall	77.75	8.50	103.91	17.36	7.40	.000
Vis-Sp STM CS	77.28	12.35	94.83	17.31	4.33	.000
Dot Matrix	78.25	14.37	96.91	15.73	4.57	.000
Mazes Memory	84.84	16.95	94.43	18.43	1.10	.051
Block recall	78.91	13.15	97.96	16.47	4.77	.000
Vis-Sp WM CS	74.38	10.89	102.17	17.51	7.252	.000
WM Odd-one-out	77.28	13.60	100.30	16.98	5.579	.000
WM Mister X	76.81	12.18	102.43	15.51	6.863	.000
WM Spatial Recall	78.72	16.80	101.43	16.43	4.991	.000

Performance of chronologically age-matched children

The previous analysis has supported the contention that children with ID would have difficulties on the memory tasks. In order to see whether chronological age could be a factor in contributing towards the outcome of the lower performance by the group with ID, the two groups, ID and typically developing children, were matched on age (Table 3.13) and only children within the age range from 56-190 months were selected. However, the results still indicate low performance by the ID children on almost all the tasks of AWMA compared to typically developing children. These results in general are in line with the outcome of the assumptions of the present study as children with ID performed very poorly on almost all the tasks of memory, suggesting that both IQ and memory complement each other. These results would also confirm that the performance of children with ID cannot reach the performance of the typically developing children even when they are matched on chronological age.

Table 3.13 Comparison of the chronologically age-matched children with ID and TD and the levels of significance on the AWMA test (N= 51).

	ID group n=32		TD group n=19			
	M	SD	M	SD	t	P
Verbal STM CS	78.16	14.57	104.21	17.55	5.718	.000
Digit Recall	81.00	11.21	103.84	13.43	6.533	.000
Word Recall	81.97	17.44	102.05	19.80	3.780	.000
Non word recall	81.00	17.99	104.84	18.80	4.501	.000
Verbal WM CS	72.16	7.42	106.16	16.42	10.146	.000
Listening recall	75.81	12.52	106.53	17.61	7.265	.000
Counting recall	77.06	10.33	99.74	15.98	6.165	.000
Digit recall	77.75	8.50	106.05	17.07	7.905	.000
Vis-Sp STM CS	77.28	12.35	97.95	16.71	5.058	.000
Dot Matrix	78.25	14.37	98.89	15.57	4.810	.000
Mazes Memory	84.84	16.95	97.89	18.20	2.587	.013
Block recall	78.91	13.15	100.89	13.96	5.644	.000
Vis-Sp WM CS	74.38	10.89	105.37	17.14	7.913	.000
Odd-one-out	77.28	13.60	104.21	15.50	6.490	.000
Mister X	76.81	12.18	103.79	15.20	6.968	.000
Spatial Recall	78.72	16.80	103.63	17.07	5.089	.000

Performance of Low-High Functioning ID children

After comparing the group with ID with the typically developing children and the very low performance on the memory tasks across the board by the group with ID, a further analysis was conducted to compare the two groups of children with ID with a range of IQ levels. For this purpose the group with ID was divided into two groups based on their obtained scores on the ability tests (Table 3.14). One group consisted of children who obtained a FSIQ score between the range of 40-65 (mild to moderate range) and the other group consisted of children whose scores were ranging from 66-79 (Mild to borderline range). This divide was created not only to have an equal number of cases but also to have a clear difference in scores between the groups, and the mean and standard deviation of the group (which was 64.66 and 10.39

respectively) was considered. The aim of this analysis was to see if the two groups would perform differently on the memory tasks.

An independent t-test was conducted to compare performance on the different components of AWMA. There were significant differences obtained only on three subcomponents and one composite score of the AWMA.

The significant difference was observed between the scores on the subcomponents of verbal WM Listening Recall: (the scores for the low functioning group: M= 69.80, SD = 9.00 and for the high functioning group: M= 81.12, SD = 12.99); t (30) = 2.83, p = .008. There was a significant difference between the scores on the subcomponents of Mazes of the visual spatial STM: (the scores for the low functioning group: M= 75.87, SD = 16.42 and for the high functioning group: M= 92.76, SD = 13.36); t (30) = 3.21, p = .003. There was a significant difference between the scores on the subcomponents of visual spatial WM for Odd-One-Out: (the scores for the low functioning group: M= 72.20, SD = 12.57 and for the high functioning group: M= 81.76, SD = 13.21); t (30) = 2.09, p = .045. The only significant difference observed on the Composite Scores was on the visual spatial STM Composite Score: (the scores for the low functioning group: M= 72.67, SD = 14.55 and for the high functioning group: M= 81.34, SD = 8.5); t (30) = 2.09, p = .045.

These results are according to expectations as the group as a whole represents children with ID and their overall low cognitive functioning is probably playing a major part in determining their performance on the memory tasks. These results have further established that children with ID (low/high score) present almost similar difficulties with the exception of their performance on some of the memory tasks, such as listening recall, odd-one-out, etc. Albeit performance was low by both the groups, there seem to be intact areas of memory of children with high functioning ID, which could prove very useful from the point of intervention. These results are also in support of the very recent research in this area (Schuchardt et al., 2010; Henry, 2010).

Table 3.14. Comparison of children with low and high ID and the levels of significance on the AWMA test (N= 32).

	FSIQ < 65 n = 15		FSIQ: 66-79 n = 17			
	M	SD	M	SD	t	P
Verbal STM CS	77.47	15.72	78.76	13.95	.248	.806
Digit Recall	80.33	10.24	81.59	12.28	.311	.758
Word Recall	82.40	19.55	81.59	15.96	.129	.898
Non word recall	79.73	20.45	82.12	16.06	.369	.715
Verbal WM CS	70.40	7.40	73.71	7.30	1.270	.214
Listening recall	69.80	9.01	81.12	12.99	2.825	.008
Counting recall	79.40	11.95	75.00	8.49	1.212	.235
Digit recall	76.67	8.23	78.71	8.87	.671	.507
Visual Spatial STM CS	72.67	14.55	81.35	8.51	2.092	.045
Dot Matrix	74.87	17.07	81.24	11.16	1.263	.216
Mazes Memory	75.87	16.42	92.76	13.36	3.208	.003
Block recall	76.33	14.07	81.18	12.24	1.041	.306
Visual Spatial WM CS	72.73	11.87	75.82	10.08	.797	.432
Odd-one-out	72.20	12.57	81.76	13.21	2.091	.045
Mister X	77.53	14.57	76.18	10.03	.310	.759
Spatial Recall	77.13	18.10	80.12	15.10	.495	.624

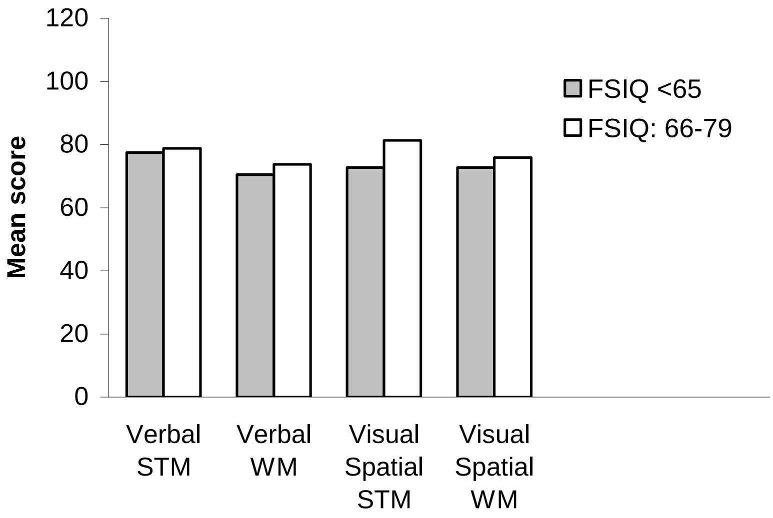


Fig 3.3 Mean scores of children with ID on four memory components as a function of IQ.

Table 3.15 Pearson Correlation between AWMA subtests and intelligence tests for children with ID (N =32).

	Word Recall	Non Word	Verbal STM CS	Listen Recall	Count Recall	Digit Recall	Verbal WM CS	Dot Matrix	Mazes	Block recall	Vis-sp-STM CS	Odd-one-out	Mister - X	Spatial Recall	Vis-sp-WM CS	VCI	PRI	FSIQ	PSI
Dig R	.42*	.25	.58**	.14	.41*	.35	.37*	.22	.17	.21	.20	.01	.15	.12	.16	.35	.04	.35	.02
Word-R		.60**	.86**	.15	.04	.16	.16	.05	-.04	.07	-.01	-.08	.06	.19	.15	.21	.12	.13	.01
Non word-R			.84**	.28	-.11	-.27	-.01	-.04	-.08	.02	-.07	-.01	-.14	-.05	.05	.08	.10	.05	-.00
VWM-CS				.24	.10	.00	.18	.05	-.01	.09	.01	-.06	-.02	.06	.09	.22	.14	.17	-.02
Listen-R					.04	.04	.69**	-.02	.21	.10	.11	.13	.06	.05	.08	.47**	.36*	.46**	.01
Count-R						.17	.59**	.28	.06	.46**	.31	.24	.49**	.13	.29	-.03	.05	.13	-.13
Digit –R							.52**	.16	.15	.20	.17	.13	.16	.53**	.41*	.29	.05	.36*	.18
Verbal WM CS								.12	.15	.35	.23	.23	.32	.28	.33	.35	.21	.42*	-.06
Dot Matrix									.57**	.48**	.84**	.44*	.71**	.72**	.78**	.14	.31	.40*	.13
Mazes										.35*	.79**	.19	.40*	.39*	.34	.36*	.64**	.67**	.42(*)
Block R											.69**	.36*	.47**	.43*	.55**	.27	.10	.38*	.13
Vis- Sp STM CS												.36*	.73**	.65**	.69**	.25	.42*	.53**	.23
Odd-One-Out													.32	.30	.67**	.10	.30	.37*	.24
Mist X														.52**	.68**	-.06	.13	.15	-.10
Spatial R															.82**	.11	.22	.32	.09
Vs-sp-WCS																.07	.22	.32	.05

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Correlation of IQ scores with STM/WM of ID children

Table 3.15 presents correlation coefficient between the AWMA subscales, the FSIQ, VCI and PRI for the group with ID. There seems to be striking correlation between FSIQ scores and verbal WM and visual spatial STM Composite Scores with a range from .42 and .53. However, there is no significant correlation between verbal STM and visual spatial WM Composite scores and FSIQ. There is also no significant correlation of VCI, PRI and PSI with any of the composite scores. However, VCI, PRI and FSIQ are all correlated with the subcomponents of verbal WM Listening Recall and visual spatial STM Mazes Memory recall of AWMA. The FSIQ is also correlated with verbal WM Digit-Recall, visual spatial STM Dot Matrix, visual spatial STM Block Recall, and visual spatial WM Odd-One-Out. Visual spatial STM Composite Scores are correlated with PRI. Moreover, there was no significant correlation observed between memory components and the PSI except for the Dot Matrix. If the contents of Dot Matrix and the PSI are compared they appear to be the same and maybe they are measuring the same function as in this task, one need to remember a visual image in the memory and respond to it accordingly.

The correlations among the memory composite scores are also non existent except between the visual spatial STM and visual spatial WM which is .69. This may suggest an interrelationship between visual spatial STM and WM especially for the children with ID.

These results are a contrast to the correlational matrix of children with ASD and typically developing children as for the group with ID there were few significant correlations observed between memory components and the different indexes of IQ. Furthermore, these results would also suggest that both fluid and crystallized intelligence are not related with the memory composite scores and hence these constructs are functioning independently in the case of children with ID.

Table 3.16 Pearson correlation of memory composite scores and IQ subtests for children with ID (N=32)

	Block Design	Picture Concept	Coding	Vocabulary	Matrix Reasoning	Symbol Search
Verbal STM CS	.24	.18	.00	.30	.19	.02
Verbal WM CS	-.13	.29	.19	.18	.03	.40(*)
Vs-Sp STM CS	.19	.18	.59(**)	.11	.52(**)	.56(**)
Vs-Sp WM CS	.11	.15	.43(*)	.05	.24	.37(*)

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Unlike children with ASD and the typically developing children, the correlation matrix (Table 3.16) shows less correlation with the individual subtests of the IQ test with the memory Composite Scores (CS) for the group with ID. Overall only the Processing Speed Index (PSI) in this group shows significant correlation; the Symbol Search subtest has high correlation with verbal WM and both the Coding and Symbol Search subtests have high correlation with visual spatial STM/WM. There is no correlation observed with the subtests contributing towards crystallized and fluid intelligence, except that Matrix Reasoning subtest was related with only visual spatial STM.

3.5 Speech and Language Impairment (SLI)

In order to examine performance of the group with SLI on all the subtests of AWMA, a t-test was conducted to compare them with the typically developing children (Table 3.17). The results show differences on three composite scores for the group with SLI, i.e., verbal STM/WM and visual spatial WM. These results would suggest that the group with SLI is performing on a par with the typically developing children only on the visual spatial STM measure.

Verbal Short Term Memory (Verbal STM)

The verbal STM Composite Score shows a significant difference between the group with SLI and the typically developing children: (the scores for the group with SLI: M= 84.60, SD = 13.10 and for the typically developing children group (M= 100.57, SD = 18.44); t (36) = 2.13, p = .006 (see table 3.17). The group with SLI performed lower than the typically developing children on Digit Recall: (the scores for the group with SLI: M = 85.53, SD = 10.32 and for the typically developing children group (M=102.48, SD=13.68); t (36) = .78, p= 000. The group with SLI has performed low on the Word Recall subtest compared to the typically developing children: (the scores for the group with SLI: M=86.87, SD = 12.53 and for the typically developing children: M = 99.61, SD =19.81); t (36) = 4.17, p= .033. There was no significant difference observed between the group with SLI and the typically developing children's performance on the Non Word recall: (the scores for the group with SLI: M=90.47, SD =19.51 and for the typically developing children: M = 99.96, SD = 20.95), t (36) = .07, p = .17. This would seem to indicate that on Non-Word tasks, children with SLI and typically developing children performed comparatively. However, caution must be exercised in interpreting this result, as considerable scepticism has been expressed by previous researchers about the Non Word test, as was discussed in the introduction section. Alternatively, the phonics training that these children would have experienced as part of their intervention may be influencing the results here.

Verbal Working Memory (Verbal WM)

The performance of the group with SLI again presents a similar pattern on this domain as was seen on the verbal STM. The group with SLI performed significantly lower on the verbal WM Composite Score: (The scores for the group with SLI: M = 83.53, SD = 13.20 and for the typically developing children: M =103.48, SD = 16.85), t(36) =1.67, p =.000 (see Table 3.17). The scores indicate significant difference in favour of the typically developing children. The group with SLI has performed low on the Listening Recall: (M = 81.27, SD = 16.81) compared to the typically developing children (M =105.43, SD =16.69), t (36) = .00, p =.000. The group with SLI has performed somewhat low on the Counting Recall: (the scores for the group with SLI: M= 86.13, SD=16.80 and for the typically developing children: M= 96.96, SD=16.11), t (36) = .054, p = .054. The group with SLI has performed somewhat low on the Digit Recall compared to the typically developing children (the scores for the Digit Recall for the group with SLI: (M= 93.00, SD=15.70 and for the typically developing children: M=103.91, SD=17.36), t (36) = .42, p=.057). This pattern would suggest difficulties on all the subdomains of the verbal WM; however, the group with

SLI has performed much lower on the Listening Recall, as compared to the Digit and Counting Recall. This result would be according to expectation as the Digit Recall and Counting Recall tasks consist of numerics/digits while the Listening Recall relies mostly on Word Recall.

Visual Spatial Short Term Memory (Vis-Sp STM)

There are no significant differences observed on any of the subcomponents of the visual spatial STM suggesting intact performance in this area. The overall score did not show any difference between the group with SLI and typically developing children on the visual spatial STM Composite Score (see Table 3.17). This scoring pattern is in line with the assumption of the present research which has proposed intact visual spatial STM for the group with SLI.

Visual Spatial Working Memory (Vis-Sp WM)

The performance of the group with SLI on this domain is somewhat variable as they have performed better on some of the subcomponents. The group with SLI has performed lower on the visual spatial WM Composite Score compared to the typically developing children but the difference is not statistically significant, at p=.05: (the score of the group with SLI: M= 90.00, SD=18.30 and for the typically developing children: M= 102.17, SD=17.51), t (36) =.002, p=.05. There is no significant difference observed on the Odd-One-Out subtest: (the score of the group with SLI: M= 92.47, SD = 17.62 and for the typically developing children: M=100.30, SD=16.98), t (36) = .001, P=.179. There is no difference observed between the two groups on the Mister X: (the score for the group with SLI: M= 92.80, SD =17.75 and for the typically developing children: M= 102.43, SD=15.51), t (36) = .019, p =.085. There is a significant difference observed on the domain of the Spatial Recall: (the score for the group with SLI: M= 87.00, SD = 20.61 and for the typically developing children: M=101.43, SD=16.43), t(36)=1.205, p=.02. Here again the difference in performance is not as significant as appeared on the verbal STM/WM. The difference is obtained on the Spatial Recall in this domain which has probably affected the score on the composite score of visual spatial WM. This would point towards difficulties of children with SLI on tasks of Spatial Recall.

Table 3.17 Comparison of children with SLI and TD children and significance level on the AMWA test (N = 38)

	SLI n=15		TD n=23			
	M	SD	M	SD	t	p
Verbal STM CS	84.60	13.10	100.57	18.44	2.13	.006
Digit Recall	85.53	10.33	102.48	13.68	.78	.000
Word Recall	86.87	12.53	99.61	19.81	4.17	.033
Non word recall	90.47	19.51	99.96	20.95	.07	.170
Verbal WM CS	83.53	13.20	103.48	16.85	1.66	.000
Listening recall	81.27	16.81	105.43	16.69	.00	.000
Counting recall	86.13	16.80	96.96	16.11	.05	.054
Digit recall	93.00	15.71	103.91	17.36	.42	.057
Visual Spatial STM CS	101.27	17.54	94.83	17.31	.18	.272
Dot Matrix	97.40	13.10	96.91	15.73	1.07	.921
Mazes Memory	101.53	23.38	94.43	18.43	1.30	.304
Block recall	103.87	14.10	97.96	16.47	.32	.261
Visual Spatial WM CS	90.00	18.30	102.17	17.51	.00	.047
Odd-one-out	92.47	17.62	100.30	16.98	.00	.179
Mister X	92.80	17.75	102.43	15.51	.01	.085
Spatial Recall	87.00	20.61	101.43	16.43	1.20	.022

Performance of children with Speech & Language Impairment (SLI) and Typically Developing (TD) children with matched IQ

An independent t-test analysis (Table 3.18) was conducted on children with SLI and the typically developing children while matching them on their IQ level. Children with the range of FSIQ 80-100 were included for this analysis, a score considered to be within the average range. A significant difference was observed on the verbal STM Digit Recall subcomponent as typically developing children performed better on the Digit Recall than the group with SLI (the scores for the Digit Recall for the group with SLI: M= 87.00, SD = 10.21 and for the typically developing children: M= 99.46, SD = 13.11); t (24) = 2.70, p = .01. There was a significant difference observed on the Listening Recall of the verbal WM subcomponent (the scores for the SLI: M= 81.54, SD= 17.38 and for the typically developing children (M=95.54, SD = 12.47) t (24) = 2.33, p = .03. There is significant difference observed on the Block Recall, a subcomponent of the visual spatial STM. Children with SLI performed better than the typically developing children with the following scores: the scores for the children with SLI: M= 106.92, SD = 12.15 and for the typically developing children: M= 92.77, SD = 19.32, t (24), p = .04. There was also significant difference observed on the visual spatial STM Composite Score in favour of the children with SLI, which may have been due to the high score on the Block Recall (the scores for the children with SLI: M= 104.15, SD=16.52 and for the typically developing children (M= 88.69, SD=16.67), t (24), p = .03. There were no significant differences observed on any of the components of visual spatial WM between the group with SLI and the typically developing children. These results suggest that children with SLI have very specific difficulties related to particular aspects of verbal memory which is consistent with previous research and also supporting the present research hypotheses. The better performance by the group with SLI over the typically developing children on the visual spatial memory could be due to intervention that these children were availing of from their respective agencies. Majority of these children with SLI, prior to attending the SLI special class, had received intensive intervention which mostly focuses on their memory processing abilities. These factors may have contributed to their better performance over the typically developing children.

Table 3.18. Comparison of the IQ matched children with SLI and TD children and the level of significance on the AWMA tests (N=26; FSIQ= 80-100)

	SLI n=13		TD n=13			
	M	SD	M	SD	t	P
Verbal STM CS	87.69	11.06	94.77	19.49	1.14	.27
Digit Recall	87.00	10.21	99.46	13.11	2.70	.01
Word Recall	90.46	8.85	91.46	18.98	.17	.86
Non word recall	93.08	19.59	96.77	21.47	.46	.65
Verbal WM CS	84.85	13.70	95.15	15.20	1.82	.08
Listening recall	81.69	17.38	95.54	12.47	2.33	.03
Counting recall	86.54	17.25	91.30	17.74	.70	.49
Digit recall	95.31	15.29	97.69	18.20	.36	.72
Visual Spatial STM CS	104.15	16.52	88.69	16.67	2.38	.03
Dot Matrix	99.77	12.10	94.38	13.73	1.06	.30
Mazes Memory	103.15	24.25	87.77	17.35	1.86	.08
Block recall	106.92	12.15	92.77	19.32	2.24	.04
Visual Spatial WM CS	91.00	19.37	95.23	18.66	.57	.58
Odd-one-out	93.85	18.29	94.08	16.76	.03	.97
Mister X	93.69	18.90	97.46	15.21	.56	.58
Spatial Recall	86.69	21.78	94.62	16.49	1.05	.31

Performance of children with Speech & Language Impairment (SLI) as a function of IQ

There was no significant difference observed between the two IQ sub-groups of SLI (group 1 = 72-84, group 2 = 85-100) on any of the components of AWMA (Table 3.19). This would suggest that children with SLI present similar difficulties across the board, mainly in the area of phonological loop, irrespective of IQ level.

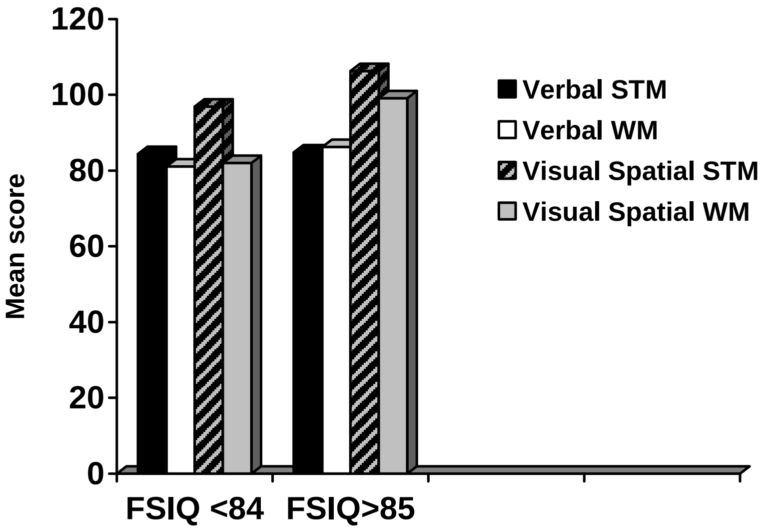


Figure 3.4. The mean scores of the group with SLI on the four memory components as a function of IQ.

Table 3.19 Comparison of low/high IQ children with SLI difficulties and the level of significance on the AWMA tests (N=15)

	FSIQ<84 n=8		FSIQ>85 n=7			
	M	SD	M	SD	t	P
Verbal STM CS	84.38	14.10	84.86	12.97	.07	.95
Digit Recall	85.63	12.60	85.43	7.98	.04	.97
Word Recall	82.63	14.84	91.71	7.63	1.5	.17
Non word recall	94.00	17.00	86.43	22.70	.74	.47
Verbal WM CS	81.13	10.40	86.29	16.25	.74	.47
Listening recall	78.13	11.21	84.86	22.01	.76	.46
Counting recall	85.38	21.95	87.00	9.75	.18	.86
Digit recall	91.38	12.98	94.86	19.27	.42	.69
Vis-Sp STM CS	96.88	19.62	106.29	14.61	1.04	.32
Dot Matrix	92.88	8.10	102.57	15.74	1.49	.16
Mazes Memory	98.63	28.25	104.86	17.89	.50	.63
Block recall	100.63	15.21	107.57	12.78	.95	.36
Vis-Sp WM CS	82.00	12.38	99.14	20.48	1.99	.07
Odd-one-out	91.38	14.63	93.71	21.71	.25	.81
Mister X	85.38	9.56	101.29	21.71	1.88	.08
Spatial Recall	80.00	14.38	95.00	24.69	1.46	.17

Table 3.20. Pearson's Correlation between memory subtests and the intelligence tests for the group with SLI (N=15)

	V-STM Word Recall	V-STM Non word recall	V-STM Composite Score	V-WM Listening recall	V-WM Counting recall	V-WM Digit recall	V-WM CS	Vis-Sp STM Dot Matrix	Vis- Sp STM Mazes	Vis-Sp STM Block recall	Vis-Sp STM CS	Vis-Sp WM Odd-one-out	Vis-Sp WM Mister X	Vis-Sp WM Spatial Recall	Visual Spatial Working Memory Composite Score	VCI	PRI	WMI	PSI	FSIQ	BD	Sim	DS	PC	Cd	Voc	L-No-S	MR	Comp	SS
V-STM Digit Recall	.13	.11	.45	.41	-.14	.63(*)	.47	.42	.41	.45	.50	.28	.33	.32	.40	.23	-.02	.41	-.33	.08	-.84(*)	.38	.45	.31	-.42	.26	.36	-.66	.41	.16
V-STM Word Recall		.59(*)	.80(**)	-.09	.34	.19	.22	.41	.46	.69(**)	.62(*)	.28	.14	.07	.24	.46	.46	.26	.02	.56(*)	.08	.38	.80	-.32	.34	-.08	.68	-.18	.09	.61
V-STM Non word recall			.88(**)	-.01	.206	-.17	.02	.10	.34	.21	.31	.35	-.21	-.24	-.08	.06	.31	-.13	.01	.14	.47	.26	.82	.15	-.05	-.30	.05	-.14	-.55	.75
V-STM CS				.10	.20	.19	.26	.37	.54(*)	.56(*)	.61(*)	.42	.04	-.01	.18	.29	.37	.14	-.10	.32	.05	.43	.80	.03	-.03	-.11	.39	-.38	-.07	.64
V-WM Listening recall					-.09	.39	.68(**)	.45	.41	.31	.46	-.16	.28	.37	.29	.43	-.04	-.11	.26	.33	-.82(*)	-.10	-.11	-.41	.19	-.25	.24	-.83	.59	.32
V-WM Counting recall						.05	.51	.270	.48	.28	.45	.31	.41	.426	.53(*)	-.07	-.03	.17	.24	.10	.09	-.58	.65	-.40	.58	-.53	.10	.43	-.75	.77
V-WM Digit recall							.73(**)	.74(**)	.42	.58(*)	.63(*)	.27	.41	.398	.42	.44	-.11	.29	-.00	.27	-.83(*)	.54	.26	-.19	.05	.27	.69	-.54	.76	.06
V-WM CS								.76(**)	.70(**)	.59(*)	.81(**)	.24	.58(*)	.63(*)	.65(**)	.41	-.08	.17	.27	.37	-.72	-.20	.54	-.59	.54	-.35	.56	-.35	.14	.72
Vis-Sp STM Dot Matrix									.48	.58(*)	.76(**)	.45	.338	.36	.55(*)	.62(*)	.11	-.03	.21	.45	-.80	.50	.24	-.13	-.03	.17	.56	-.67	.69	.15
Vis-Sp STM Mazes										.549(*)	.89(**)	.43	.318	.43	.48	.26	.18	.02	.25	.37	-.36	-.69	-.20	-.87	.74	-.81	-.05	-.39	-.01	.66
Vis- Sp STM Block recall											.82(**)	.01	.278	.35	.42	.44	.06	.40	-.25	.31	-.12	.20	.37	-.66	.57	-.25	.63	-.39	.37	.55
Vis-Sp STM CS												.3	.367	.46	.58(*)	.48	.17	.14	.11	.44	-.50	-.25	.10	-.76	.63	-.50	.36	-.52	.30	.62
Vis-Sp WM Odd-one-out													.114	.16	.40	.02	-.04	-.02	.29	.05	-.92(**)	-.01	.05	-.50	.33	.02	.61	-.55	.74	.16
Vis- Sp WM Mister X														.91(**)	.87(**)	.26	.22	.23	.05	.35	-.48	-.13	.89(*)	.33	-.20	-.05	.13	.03	-.52	.55
Vis- Sp WM Spatial Recall															.92(**)	.11	-.03	.09	.08	.13	-.44	-.60	-.15	-.61	.46	-.86	-.24	-.65	-.09	.76
Vis-Sp WM CS																.23	.07	.14	.06	.22	-.68	-.36	.17	-.57	.42	-.60	.16	-.68	.13	.75

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

The correlation matrix for the group with SLI (Table 3.19) shows no significant correlation with the majority of the IQ scores. The correlation between VCI was obtained with only Dot Matrix of the visual spatial STM (.62). There was no significant correlation observed between PRI and memory components, which contrasts with the pattern of correlation observed with typically developing children, children with ASD and ID. The FSIQ was only related to word recall with a correlation of .56. There was no correlation obtained between PSI and memory components.

The relationship of visual spatial STM Composite Score was observed with verbal STM/ WM and Visual Spatial WM, whereas verbal WM was also related to visual spatial WM.

Chapter 4 Discussion

The present study attempted to explore the profile of memory dysfunction in children with ID, ASD, and SLI and to compare the profiles with the typically developing children. The study also proposed to explore a relationship not only within the varied memory components but also to seek a link with the intelligence batteries and to examine how this link differed in a range of neurodevelopmental disorders. For this purpose, a broad battery of computerised Working/Short Term memory (AWMA) measures was used to assess verbal and visual spatial WM/STM, and WISC-IV/WPPSI-III were selected to measure intellectual functioning of the children.

The findings of previous research have been mixed. The present research aimed at a comparison of children with neurodevelopmental disorders within a single study design that aimed to explore the distinct pattern of working memory deficits within this population and address some of the methodological shortcomings of previous research. The analysis indicated that the four groups have divergent working memory profiles, as they have performed differentially on the four dimensions of working memory. Therefore, the patterns of memory impairments in the neurodevelopmental disorders are distinctive, since contrasting strengths and weaknesses are apparent on these tasks. This research also points in the direction of the important role of intellectual functioning and its strong relationship with memory as a construct. However, there are other factors that could also significantly influence not only memory but also the outcome of the cognitive measures such as attention, concentration, linguistic skills, etc. This is based on the observation while evaluating children with numerous developmental delays. There appears to be a high risk of obtaining skewed results if a child presents problems in these areas. This view could be substantiated by the earlier stand that a core impairment associated with particular developmental disorder can have cascading effect on other cognitive skills (Frith & Happe, 1998). The implications of the unique working memory patterns in the different developmental disorders is discussed in the following paragraphs.

4.1 Working Memory and Intelligence

The correlation matrix of the four groups of the present study presents unique profiles. For example, the results of the typically developing children and children with ASD show a significant relationship between memory components and intelligence, which provides strong support to the hypothesis that memory and higher cognitive functioning are closely related concepts. This is one of the grounds for the inclusion of memory tests, specially STM and WM, in almost all the available intelligence tests currently in use. The results of the present study also support this hypothesis as the four composite scores of memory, i.e. verbal STM/WM, visual spatial STM/WM, are highly correlated with both crystallized and fluid intelligence for both the children with ASD and typically developing children. Furthermore, this outcome is in line with previous research supporting a relationship of memory, especially the WM, with fluid intelligence. This strong relationship evident in the data between IQ and memory, in particular for those with ASD and the typically developing group, very emphatically suggests that if children with ASD present with difficulties on memory, this could possibly be due to their low IQ and not because of their ASD symptoms. This result would indicate that both STM and WM are important constructs in the context of intelligence. This would also suggest that both STM and WM can predict higher cognitive mental abilities within children with ASD and in typically developing children. These results would be consistent with the outcome obtained by Tillman, Nyberg, & Bohlin, (2008), as they found a strong relationship between both STM and WM with IQ. However, the present research was also able to support the notion that memory functioning is also somewhat related to crystallized intelligence. In contrast with the claim presented by Engle et al., (1999), that only the executive processes could predict intelligence, the results of the present research also point to the relationship of STM with IQ. The STM is traditionally considered to be a basic storage unit, which holds information for a short length of time, and therefore it would not be required to engage in higher cognitive processes. However, the present results may not be entirely irreconcilable with the contention of Engle (1999). As discussed before, any new task at the initial stages taps fluid intelligence until the task is learned and is engrained into LTM. It is at this point, probably, that these tasks become part of crystallized intelligence. Notwithstanding the relationship between memory and cognitive functioning, the relationship between VCI and memory components, however, was not very high as compared to PRI.

Furthermore, the same level of high correlation was lacking in the results of children with ID and in the group with SLI. The correlation matrix for the group with ID identified relationships on some of the subcomponents of the AWMA with the IQ;

these include Listening recall, Digit Recall of the verbal WM. Of the visual spatial STM, the correlation was high on the Dot Matrix, Mazes, and Block Recall. The correlation was within a range from .36 to .67, although not as high as obtained by Henry (2001), which was between .67 to .73 for working memory and mental age. Secondly, there was not a very significant correlation observed between the AWMA tasks and the two major indexes of the IQ, i.e., VCI and PRI, except for Mazes, which was found to be highly correlated with PRI (.64). This outcome would suggest that there are some components of the AWMA test that would be able to identify children with ID. Hence, this finding may prove helpful in designing and formulating interventions as this research has identified some overlapping and common areas between the subcomponents of memory and IQ. These areas may be targeted through intervention in a way that may help in transferring the positive effects in the other related areas, while areas not related to each other could be approached independently.

The correlation matrix of the groups with SLI and ID did not show any significant relationship between the memory subcomponents and any of the indexes of the IQ test which would strongly support not only the uniqueness of performance and the cognitive style of each group, but would also propose an argument in favour of AWMA as a differential instrument in profiling SLI and ID.

Recent research by Unsworth (2010) suggested that both WM and LTM are related to intelligence and, specifically, concluded that all three memory constructs were substantially related to fluid Intelligence (Gf), but were related less so with crystallized Intelligence (Gc). However, this argument can vary based on the development of a child as can be confirmed by the present research. The groups with SLI and ID appear to have responded in different ways to processing higher order cognitive information.

If research with a focus on the findings of relationship of memory and intelligence is examined, it would appear to support the results of present research. For example, researchers have previously proposed high level of reliance of short-term storage and executive processes in WM in intelligence (Tillman, et al., 2008; Abad et. al., 2005; Shah & Miyake, 1996). If this was the case, that intelligence is a factor in determining the functions of short-term storage and executive processes or vice versa, then in neurodevelopmental difficulties where intelligence is relatively unaffected, performance on memory tasks may be spared. Colom, Shih, Carmenm and

Quiroga (2006) have reported that WM/STM share many of the factors, similar to the idea of the WM system based on both domain-general and domain-specific components as proposed by Engle et al. (1999). However, this high relationship was not seen among the memory composite scores for the children with ID and SLI, except the high relationship observed between the visual spatial STM and visual spatial WM for the group with ID.

Looking at the unique characteristics of the relationship, the results of the typically developing children and children with ID did not show significant correlation of working memory with the Block Design subtest. This outcome appears somewhat confusing, as Block Design (BD) is considered to be measuring fluid intelligence, along with visual spatial awareness. However, this lack of relationship could be due to the additional demand posed by the BD tasks such as the use of planning and organizing abilities within the visual spatial domain, which was not measured by the memory tasks for these particular groups. The results obtained by the group with ASD showed a strong relationship between BD and memory composite scores except for verbal STM. The data of the group with SLI, on the other hand, showed a negative correlation between BD and a majority of the subcomponents of memory.

Furthermore, the results of the groups with ASD and ID showed a positive relationship between memory composite scores and the Processing Speed Index (PSI) tasks as opposed to the typically developing group which indicated negative correlation. The subtests of PSI, i.e., Coding and Symbol Search, are assumed to measure Short-Term visual memory, cognitive flexibility, and concentration (Kaufman, 1994). The Non-Word test appears to be the only subtest, having the very least amount of correlation with other subtests for the typically developing children, and Word Recall would be for the group with ASD, suggesting that these are the only two subtests, that can differentiate these groups only on their memory performance. However, as mentioned in the previous paragraphs, there were serious reservations reported about the non-word test as a measure of working memory. There was not very high correlation observed among the subtests of the memory with the IQ tests of the group with ID.

Looking at Table 3.3, all three clinical groups seem to have performed poorly on verbal working memory when VCI and PRI are statistically accounted for individually. This trend would make an argument in support of the lack of influence of VCI and PRI on verbal WM and also in favour of the independent status of the memory components. However, an important factor worth considering here is that these factors were controlled individually and the chances are that the other indexes could still influence the outcome. For example, if one factor (for example VCI) was controlled then the other factors (PRI & PSI) may still have an effect over these memory tasks. Notwithstanding this argument, these outcomes still point towards difficulties of children with neurodevelopmental problems on verbal working memory. The typically developing children performed better on verbal STM compared to the group with SLI only when PRI was controlled statistically, whereas the visual spatial skills of the group with SLI were on a par with the typically developing children even when PRI was taken into consideration. The results obtained by children with SLI, performing poorly on the verbal STM/WM, appear to confirm the previous research. For example Alloway, Rajendran and Archibald (2009) also found that children with SLI performing poorly when non-verbal IQ was taken into account. This again points towards the difficulties of the SLI group with both storing and processing information, which could be contributing towards their low scores in these areas. However, the group with SLI did not show any problem on the visual spatial tasks, and this group performed better than the children with ASD when PRI was taken into consideration. Their performance was also better than children with ID and ASD when VCI was taken into account on the visual spatial domain. This suggests the importance of fluid and crystallized intelligence when performance of the group with SLI on tasks requiring visual spatial skills is looked at. Besides, the performance of children with ASD and ID also showed improvement on visual spatial tasks, when PRI is taken into account. However, the VCI seems to have no significant impact on the visual spatial WM, with reference to the group with ID, as they performed poorly when VCI is taken into account. However, VCI seems to be effective and may influence the verbal STM for all the groups as there was no difference observed between the groups on the verbal STM when the VCI was accounted for.

Although there are distinctive characteristics on the memory profiles of the different neurodevelopmental disorders, a cursory look at the trends would point towards a common factor between these three neurodevelopmental disorder groups when VCI and PRI is controlled. The three groups have produced a low performance on verbal working memory compared to the typically developing group. This would indicate the significance of the processing component of memory, which seems to be operating independently with no influence from the higher cognitive functioning such as VCI and PRI. However, the effect of the VCI and PRI were noted on the performance of verbal STM and visual spatial WM, where there is no significant difference observed between the groups. These results would support the assumptions of the relationship of PRI (fluid intelligence) and visual spatial WM, as both measures share common underpinnings of a visual spatial-perceptual nature. On the other hand, VCI (crystallized intelligence) is considered to be measuring verbal reasoning abilities and does not have an explicit processing component, therefore its impact on verbal STM may also make sense.

However, a somewhat different picture emerged when PSI was taken into account. The three groups performed poorly on verbal STM compared to the typically developing children (when PSI was taken into account), suggesting the limited impact of processing speed on verbal STM. This would support the view that there seems to be very little in common between the two constructs i.e., the PSI and verbal STM. The PSI subtests are considered to rely mainly on non-verbal skills, and therefore would not require the use of language for attempting and performing on tasks in this domain. On the verbal WM, with the control of PSI, there is no major difference and ID and SLI group performed poorly in this area, suggesting the limited role of processing speed for these two groups. However, as regards the performance of children with ASD, an improvement is seen in the performance since there was no significant difference observed between the groups with ASD and typically developing children when processing speed was taken into account on the verbal WM. On visual spatial STM, the typically developing group has performed better than the group with SLI. This would again suggest the limited control of PSI on the performance of children with SLI in this area. On the visual spatial WM, the typically developing children and children with ASD have performed better than ID.

These results would in short emphasise the importance of VCI and PRI over the PSI, since a very limited influence of PSI is observed on the performance of memory for these groups. VCI and PRI seem to be responsible for generating much of the variation among the four groups.

4.2 The relationship of STM/WM

The results also showed a very high correlation between the four major memory composite scores for both the typically developing and children with ASD. A strong relationship was obtained between visual spatial STM composite score (CS) and visual spatial WM (CS) for the group with ID. The data obtained for the group with SLI showed a strong correlation between the verbal STM and visual spatial STM composite scores, and verbal WM showed a strong relationship with visual spatial STM and visual spatial WM. Visual spatial STM has a high correlation with the visual spatial WM for the SLI group. However, this relationship, perhaps, depends on the neurodevelopmental disorder and their IQ level as there are variations among these relationship for different neurodevelopmental groups and the typically developing children.

These relationships of memory subcomponents would reiterate the point presented by Unsworth (2010), who proposed that WM tasks cannot be considered as measuring only a specific construct, as these tasks could be measuring other similar constructs. Therefore, he proposed that all memory components, i.e., WM, STM, and LTM, require the same basic component to process a task. This means that a task could measure multiple components at the same time and this could be one of the major reasons for a high relationship between these tasks. This argument is partly supportive of the present research, as only typically developing children and children with ASD have obtained a very high correlation in their performance on almost all the memory tasks, however, children with ID and SLI have performed differentially. Johnson (2005) has commented that “If experimental approaches stay alert to commonalities across tasks (and are not satisfied with local theories of very specific tasks), and individual differences approaches stay alert to components that may be represented in their latent variables (and are not satisfied with global explanatory constructs like episodic memory and executive function), these approaches should converge on a cumulative and cohesive picture of cognitive function” (p. 530).

Baddeley (2007) also suggested that the episodic buffer maintains an interaction between the WM and LTM which could be a major factor in contributing towards this overlapping between the components. However, he attributed the unique variance to specific WM processes. Although the present research did not address these issues which need to be looked at in future research. However, as mentioned earlier, any new or novel task requires mental control to retain and process it, which is supposedly a task for WM, which also relies on LTM and STM. There is a need for future research which can focus on differentiating between different models of memory.

4.3 Autism Spectrum Disorder and Working Memory

The findings of the present research indicate that, as a group, children with ASD performed poorly compared to the typically developing children. However, when high functioning children with ASD were compared with the typically developing children having the same level of IQ and age, no significant differences were found on the majority of the components of the STM/WM. Earlier researches on autism has obtained contradictory results, since some researchers have demonstrated impairment on verbal and visual spatial working memory (these studies have been examined in the introduction section). The present research also obtained results suggesting no difference between high functioning children with ASD and typically developing children as they have performed similarly on almost all the memory tasks except the Listening Recall subtest of the verbal WM. This was the only subtest which was able to differentiate children with ASD from the typically developing children. As mentioned earlier the Listening Recall subtest is the only test which has a component of reasoning as the child has to listen to a sentence and then decide whether the sentence is right or wrong. Therefore, the present author considers this as a test suitable for measuring the Executive Functioning as opposed to verbal working memory. These findings, however, seem to be quite significant as children with ASD with low abilities performed poorly on almost all the subtests of the WM/STM tasks suggesting memory impairment for this group. This outcome also supports the observation that individuals with ASD are quite diverse in their abilities, as predicted by their level of IQ functioning.

Furthermore, there were no differences observed when the performance of low functioning children with ASD was compared with children with ID on memory components. This would in itself suggest the dominant role of IQ in memory functioning especially in these groups of children. Significant differences were noted in the performance on the memory tasks of ASD with different ability groups, i.e., mild-moderate, borderline and average, as the performance on memory tasks show upward trend with the increase in the level of IQ. Does this outcome suggest that memory may be considered as a function of ability as opposed to features related to ASD, which were suggested by some of the previous studies? This current study provides strong evidence in favour of the relationship of IQ and memory with reference to the group with ASD.

There were some concerns expressed earlier that individuals with autism have impairment in shifting attention rapidly from one stimulus or modality to another (Courchesne, Townsend, Akshoomoff, Yeung-Courchesne, Press et al., 1994), which could have affected their performance on the memory tasks used in this study. For example, Listening Recall, the Mr-X and Spatial Recall tasks, were quite intense as regards attention and concentration, although the children with ASD performed on a par with the typically developing children in the present research. This would point towards the fact that IQ and attention also share common factors, as discussed previously, that without providing sustained attention to a task, it may not be possible to solve a problem. Nonetheless, these findings provide strong evidence in favour of intact memory functioning within the high functioning group with ASD and indicate the importance of further examination of possible subcomponents of executive function within these groups. For example, the performance of children with low IQ was invariably low across all the subcomponents of memory. High functioning children with ASD performed better than low functioning and there was no difference observed in the performance of the low-functioning ASD and ID children.

4.4 Autism Spectrum Disorder (ASD) and Social Deficits

The most common deficits of ASD are in the domains of social interaction and communication (Baron-Cohen, Tager-Flusberg, & Cohen, 1993) and research has attempted to establish links to impairment of central cognitive processing as a basis for these difficulties (Courchesne, Chisum, & Townsend, 1994; Frith & Happe, 1994; Hughes et al., 1994). Frye, Zelazo and Palfai (1992) demonstrated similar age related changes in both theory of mind and cognitive tasks, where each shared a common logical structure. They suggest that a developmental change in cognitive complexity underlies the developmental shift in children's capabilities, regardless of the task content. Russell, Mauthner, Sharpe and Tidswell (1991) have shown that children with autism are unable to pass strategic deception tasks not because they are unable to represent another person’s mental state, but because they have less executive control over their behaviour and are unable to inhibit inappropriate responding. In addition, executive function and working memory tasks have been shown to be related to other areas of social ability in autism. McEvoy et al. (1993) have shown a relationship between executive function tasks and joint attention behaviour in preschoolers with autism.

These studies support the implication of EF/WM within the individuals with ASD which subsequently affects social communication and interaction. In order to carry out effective social interaction, we require a constant processing and retention of information both in visual and verbal fields. In fact, operating in a social situation would place a very high demand on WM and EF. Based on this assumption, a very strong case for WM implications within the individuals with ASD was reported by these researchers. However, if this is a possibility, then we need to look at this claim from a perspective of IQ levels, since these deficits could not be explained in isolation by EF or WM/STM only, as is demonstrated through the results of the present research involving the high functioning group with ASD. In the present study, the high functioning children with ASD did as well on the memory tests as the typically developing children. Matson, Dempsey, Lovullo, and Wlkins (2008) supported the idea of IQ as an important moderator of symptoms of ASD in the intellectually disabled population, as they found higher rates of ASD symptoms with low IQ. In their study, individuals with autism displayed the greatest impairment in the domain of repetitive behaviours, which was followed by social interaction and then communication. Controls not only had far fewer symptoms of ASD across the board, but symptoms were more affected by level of intellectual functioning. The IQ factor was, therefore, a major moderator for this group. For the entire sample, lower IQ was related to a greater presentation of ASD symptoms, regardless of group classification. However, the only area where children with ASD performed low across the board i.e., low-high functioning, was on Listening Recall subtest and as already mentioned, this test may be considered as a measure of Executive Functioning. Therefore, could this low performance on a single subtest be enough to link it with the impairment of Central Executive and then further with the theory of mind? Future studies may resolve this issue.

Summary

As ASD is considered to be a lifelong disability, early intervention can improve affected individuals' lifestyle but will not completely ameliorate their performance. Furthermore, research has suggested that the more severe the IQ deficits, the more resistant the person is to treatment (Ben-Itzchak & Zachor, 2007; Woley & Garfinkle, 2002). The problem gets further complicated as a substantial number of people with ASD also have ID, which is estimated as 40 to 63% of ASD population (Baird, Charman, Baron-Cohen, Cox, Swettenham, et al., 2000; Bertrand, Mars, Boyle, et al., 2001). Thus, understanding the relationships of ID and ASD would appear to be an important clinical issue for intervention and therefore future researches may focus their direction on these topics.

The current study did not examine social deficits in autism; thus it can only be speculated based on the relationship between general cognitive processes, such as IQ, WM and social interaction. Further research is necessary to determine whether IQ or EF tasks which include WM is particularly involved in the types of social cognition tasks that children with autism fail on.

4.5 Working Memory and Intellectual Disability (ID)

The study also explored the role of different components of short term and working memory among children with intellectual disabilities (ID). The results obtained support our first assumption regarding cognitive memory deficits of children with ID: they performed poorly on different facets of STM and WM irrespective of their age and IQ level functioning. This result replicates findings from numerous empirical studies that have been reported with regards to working memory deficits in children with ID (Gathercole & Baddeley, 1990; Ceci, 1984; Kirchner & Klatzky, 1985; Schuchardt, Maehler, & Hasselhorn, 2008; Lewis, Hitch, & Walker, 1994; Rutter, Caspi, Ferguson, Horwood, Goodman, Maughan, et al, 2004). The outcome of the present research also supports the earlier studies suggesting a general memory deficit in participants with ID, a deficit that is independent of modality (visual or auditory) and memory components (STM or WM; Isaki & Plante, 1997; Swanson, 1994). The children with ID, when matched on chronological age with the typically developing children, showed significantly lower performance on all the memory tasks. This result is also in line with the recent research conducted by Henry (2010a). This finding reflects the difficulties children with ID have compared to their chronological age matched children.

One of the noteworthy outcomes of this research is that the children with ID performed poorly on the STM as well as WM tasks. This outcome supports the model presented by Engles et al. (1999) who proposes a role of attentional control for STM, in that any new task, depending on the complexity level, requires a corresponding amount of attention for processing. This has been reiterated by Case (1985, p. 351) who proposed that the operating space for a given class of tasks decreases as the processing efficiency increases, allowing more space for storage. In the case of children with ID, who struggle with learning due to their limitations with retention and processing of information, they may have limited space available for storing new information for a short period of time. This could be the reason for the poor performance by the group with ID on the STM tasks. This account corresponds with Atkinson and Shiffrin's (1968) model which was promoted by Newell and Simon (1972), which proposes that short term memory constitutes a temporary working memory. In Swanson's (1994) study, the STM and WM loaded on different factors, suggesting that both areas of deficit were independent, but co-occurring, in his subjects. However, in the present study, we did not observe any difference in performance between STM and WM since the participants with ID performed poorly on both constructs. Therefore, it could not be suggested on the basis of the present study that children with ID have deficits both in visual spatial sketchpad and phonological storage system which is feeding into STM/WM, as this limitation could occur due to poor attentional control of the executive system. Based on the outcome of this analysis, it is possible that both STM and WM abilities could be considered as relevant to the understanding of long term cognitive deficits. Gathercole et al. (1990) also suggested that phonological processing ability is directly related to the capacity to hold information. Their theoretical framework would suggest that poor phonological encoding or storage within STM and WM systems may have contributed to poor performance on the WM tasks especially in the case of children with ID.

4.6 Memory functioning and low/high ID children

The second assumption was partially supported as both high functioning and low functioning children with ID performed almost equally with very little distinction in their performance, on the tasks of the AWMA. The differences between the two groups were only observed on the Listening Recall, Mazes, and Odd-one-Out subtests of the AWMA. These were the only subtests where children with borderline ID performed better than the mild-moderate children. The Listening Recall task, which is a subcomponent of verbal WM, appears to be quite difficult compared to Digit Recall and Counting Recall tasks within verbal WM. The Listening Recall tends to be highly demanding not only on the phonological loop, it also requires an element of reasoning ability (as mentioned before). The child on the Listening Recall subtest has to decide whether the sentence is right or wrong. In the area of visual spatial domain, the performance of the group with ID was better on tasks such as Mazes and Odd-One-Out.

These results suggest that children with ID may have deficits on verbal STM and verbal WM, possibly related to lack of attentional control and storage capacity but there seems to be segments of intact visual spatial STM/WM in children with borderline learning disability. This result is in line with other studies (Gathercole, Pickering, Ambridge, Wearing, 2004). Henry (2001) found children with borderline learning disabilities obtaining high scores on visual spatial memory span compared to mild and moderate learning disabilities. However, upon further analyses of the results of the present study, the outcome was not in line with Henry's research. In the present study high functioning children with ID performed better on only two sub-components out of six components of visual spatial STM/WM tasks. Thus, it could be outlined from this result that the capacity to store and process information for both the verbal and visual spatial tasks is much lower for children with ID than the typically developing children. This outcome may once again point to the fact that children with ID present difficulties both in verbal and visual spatial STM and WM tasks across the board, which can possibly be attributed to central attentional control for both verbal and visual spatial domains. This central attentional control and IQ as suggested by Engle (2002) seems to play a major role in determining the capacities of phonological and visual spatial sketchpad.

Henry (2010b) in her recent study, compared children with ID with different levels of IQ. She found significant impairment across the board as she observed working memory to be markedly lower in children with mild and moderate learning disability and somewhat lower in children with borderline learning disabilities. This result would be in agreement with the present research with regards to children with borderline disability who performed somewhat better on some of the tasks of AWMA. Furthermore, if we compare the mean scores of the two groups with ID, i.e. mild and borderline IQ, it certainly would indicate an upward trend on some of the subcomponents corresponding to the level of ability, indicating the importance of IQ. This would in turn suggest that the degree of memory impairment has a direct relationship with intelligence as when the IQ level decreases it has a direct bearing on the memory performance.

These findings have implications for children with ID in terms of their academic achievement and designing individualized educational plans, as the phonological memory impairment will have implications for further language development and the difficulties on visual spatial memory tasks are thought to have implications for reading, numeracy, and abstract reasoning skills.

Summary

In summary, it was found that a child's learning disability has implications across the range of STM and WM tasks. All the children with ID showed impairment on all the tasks irrespective of their IQ level. There were some pockets of abilities indicated (on some of the subcomponents of visual spatial tasks) by high functioning children with ID, such as odd-one-out and Mazes, where they performed somewhat better than the low functioning group with ID.

4.7 Memory and Speech and Language Impairment (SLI)

The results of the analysis for children with SLI indicate significantly low performance on both the verbal STM and WM composite scores when compared to the typically developing children, while there were no differences observed on the visual spatial STM and WM tasks. These results are consistent with the previous findings where the group with SLI were in general found to have impaired performance on the verbal memory tasks compared to visual spatial memory tasks (Gathercole et al., 1990; Baddeley, 1998). Baddeley et al. suggested that short-term memory plays an important role in learning new words by generating a phonological representation of brief and novel speech events thereby allowing a phonological entry to be made within the long-term lexical store. These results support the hypothesis that children with SLI would perform poorly on the verbal memory tasks but at par on the visual spatial memory tasks compared to typically developing children.

However, when children were matched on IQ and age, the difference between the performance of groups with SLI and typically developing was restricted to a few memory subcomponents such as Digit Recall of the verbal STM, Listening Recall of the verbal WM and Block Recall of the visual spatial STM. Significant differences were also observed on the visual spatial Composite Score. No significant difference was observed on any of the other subcomponents and Composite Scores of the memory test. These results suggest that children with SLI present with very specific difficulties related to particular aspects of the verbal memory rather than a general difficulty as reported in the earlier research. Of note is the better performance of the group with SLI on the Word and Non-Word tasks which is contrary to the outcome of that of Gathercole and Baddeley (1990) study and supports the study of Van der Lely and Howard (1993). In Gathercole and Baddeley's (1990) study, it was concluded that children with SLI necessarily have an impaired capacity for phonological storage as reflected by recall of nonwords. On the other hand, we find researchers who consider Non-Word tasks as not being a true measure of working memory (Edwards & Lahey, 1998). In the present study, despite the fact that a standardized assessment tool was used for the purpose , the Word and Non-Word repetition tasks may not have been sensitive in tapping the deficits of SLI compared to Digit and Counting Recall. One of the other reasons could be that children in the age range of the present study had been in receipt of a significant amount of intervention with a focus on enhancing their vocabulary growth to their optimum level. A look at some other factors which may have also contributed to word/non word repetition including input and output phonological process, (Gathercole, 1995; Snowling et al. 1991,), and pre-existing lexical knowledge (Gathercole, Willis, Baddeley, 1991, Gathercole, 1995), and that may have improved with the intervention. Van der Lely (1993) argued, in support of their work, that Gathercole et al. (1991) may have used an insensitive instrument for matching the groups, since a short version of the test was used at the time. However, this argument seems to have no basis, since for the present research as for that of Van der Lely, children were comprehensively assessed for their difficulties with linguistic skills.

A further look at the outcome of the present study would indicate that children's performance was mainly affected on the Digit Recall of the STM and

Listening Recall of the WM. Both of these tasks have been widely tested with the aim of measuring working memory. The Listening Recall subtest creates an additional load on memory, as one has to remember the last word of a sentence while also processing the content of it. Numbers can be considered to be much more abstract carrying no similarity to each other and therefore can be considered as a very reliable instrument of measuring an aspect of memory. However, if we analyse these two tasks further, they are not putting any extra demand on word production per se. There were many other tasks in the memory test which were highly demanding on word production such as Word Recall, Non-Word Recall, and as such the children did not show any significant difference on these tasks.

On the basis of these findings, it seems likely that the poor short term memory and working memory function in this group reflects a parallel underlying disorder as the group performed poorly on both the verbal STM and WM. This outcome is in agreement with earlier research (Swanson, 2004, Gathercole, et al., 2005), and suggests parallel systems of WM and STM. In one study, it was found that children with a history of very poor STM that extended between 4 and 8 years of age and WM skills in the low average range had age-appropriate language abilities four years later (Gathercole et al., 2005), suggesting the importance of the WM in developing linguistic skills.

The data of this research, however, supports our hypothesis that children with SLI would perform equally well on the visual spatial memory tasks. The performance of the children with age and IQ matched SLI and typically developing children showed no significant difference except their low performance on the Block Recall, which is a subcomponent of the visual-spatial STM, and on the visual spatial STM Composite Score. This result on the Block Recall could be an outcome of their difficulties with attention and concentration. The group with SLI may have found this task highly demanding on the attention and concentration. This finding supports Engle's (2002) attention control theory to some extent since this was not the only task which required attention and concentration. Other tasks within the same domain, such as Mazes and Dot Matrix, are also equally demanding of attention and concentration skills. While none of the children with SLI met the criterion for ADHD/ADD, a number of these children were noted to have difficulties with sustained attention and concentration. However, many children with neurodevelopmental difficulties show clinically significant levels of attention and concentration difficulties.

There was no difference observed between the two groups of children with high and low IQ on any of the component of the AWMA. This means that children with average abilities perform similarly on tasks of memory irrespective of their level of IQ. However, the IQ range within this sample was quite small, (FSIQ ranging from 72-100). If this IQ range was extended upwards, perhaps there may have been some variations observed between the two groups.

There was no significant correlation observed between PRI, VCI, and PSI with any of the Composite Scales of AWMA. This research, despite the use of a reliable and standardized instrument, measuring different subcomponents of memory could not find significant differences between children with SLI and typically developing children, when they were matched on IQ and age. The only difference was observed on Digit and Counting Recall. This outcome vindicates the earlier stand regarding the importance of IQ in memory functioning. Children with SLI in this sample were all functioning within the average range on the IQ tests, which has, in the author's opinion, certainly helped these children improve their performance.

Another reason for this outcome could be that majority of the children in this study were attending the specific special speech and language class. These classes comprise of approximately 7 children per group who get intervention from a speech and language therapist on a daily basis, that lays an emphasizes on their listening and attention alongside a focus on their linguistics/including pragmatic skills. The curriculum also embraces word production and vocabulary building, therefore the possibility of an enhanced performance of this group on the tasks involving words may make sense. However, this group still presents with difficulties on tasks requiring memory skills such as Digit Recall and Counting Recall.

Another important consideration for the present outcome is the heterogeneity of the SLI sample, which could have accounted for the difference. With increasing research it is becoming evident that children with SLI are inherently diverse. Some subgroups have clearly differing linguistic characteristics, for example, "semantic-pragmatic SLI" children who have relatively fluent speech and good grammatical comprehension (Bishop & Adams, 1989) versus children who exhibit grammatical deficits in both their comprehension (van der Lely & Harris, 1990) and expression of language (van der Lely, 1990). However, other children from the SLI population share some but not all linguistic characteristics (e.g., Gopnik & Crago's [1991] group characterised by familial aggregation). The possibility that different groups of children with SLI may have different characteristics affecting memory and language abilities, which may have important implications for identifying the underlying cause of SLI. It would appear unlikely that a single underlying cause could account for the wide range of deficits found, especially on the verbal memory tasks.

4.8 Summary and Conclusion

Although much research is available in this field, the advantage of the present research is that it studied children with different neurodevelopmental disorders and compared their performance on a number of memory tasks within a single design. The major aim of the present research was to explore the implications of memory performance within the neurodevelopmental disorders and to relate it with their performance on the intelligence test. There are studies that have assumed a very strong relationship between memory and IQ. However, the present research was undertaken to look at this relationship from a neurodevelopmental perspective. The IQ may be considered as a main body of a system, with memory a subsidiary mechanism feeding into the main body, via the central executive. The IQ can only function in the normal range when all the peripheral systems (memory and central executive) feed proper information into it. Another major aim was to explore the relationship of different memory systems such as STM/WM. All these constructs are very crucial for supporting children in developing not only their academic skills but also their social skills. WM is considered to be very crucial in carrying out even every day social conversations, which relies heavily on storing and processing of information on a continuous basis.

This research has indicated that children with different disabilities have distinct memory profiles. Therefore these children manifest their own particular strengths and needs that highly depend on the cognitive systems, and most importantly on the psycho-social factors which contribute towards their level of specific abilities.

This research has also highlighted the importance of the relationship of IQ with memory. We know that a Full Scale IQ consists of two major constructs, crystallized and fluid intelligence. We also know that crystallized intelligence has its basis in learned material. Hence, this would subsequently make a strong case for improvement of memory with a stimulating environment. This makes a strong case for provision of support to children who function at a lower level of intellect as this may help improve their deficits.

Many previous studies have suggested that children with ASD have difficulties with WM. If we go back into the history, it started off initially with the theory of amnesia which suggested that individuals with ASD have difficulties with remembering. With new advancement and researches the focus was narrowed i.e., from a very general impairment to the very specific area of memory deficits, such as deficits in either verbal or visual spatial WM or both. However, even these studies produced contradictory results by supporting or disputing the concept of an intact verbal/visual spatial WM. However, many of these studies were conducted without taking into account the IQ construct, which seems to play a crucial role, as is indicated by the present study, as a factor in determining the level of memory function. This research has shown that children with autism perform poorly when compared to the typically developing children, in general; however, if they are matched on IQ, then the difference in their memory performance appears to be non-existent. Furthermore, not only does FSIQ plays an important role, the different indexes on the IQ measures which contribute towards FSIQ were also shown to be a major factor in determining the memory functioning for the group with ASD. And the PSI, for which not much research exists, also seems to be a major contributing factor for verbal STM, and visual spatial STM/WM especially for the group with ASD. The only difference obtained between the children with high functioning ASD and typically developing children was on the Listening Recall test, indicating a specific discrimination power of this particular task between the two groups. These outcomes appear to have significant importance for early intervention and later in supporting these children in their school life. While devising individual educational plan for these children, these factors need to be considered.

Regarding the participants with ID, the findings demonstrated that children with ID indicated problems on memory tasks across the board. These impairments would strongly support the assumption of difficulties of children with ID on both the slave systems i.e., visual spatial sketchpad and phonological loop. However, these difficulties could mainly be due to central executive problems, which deals with the attentional control as suggested by Engle (2002) or by its equivalent SAS system proposed by Norman and Shallice (1986) rather than the individual slave system as Baddeley suggested.

The group with SLI has indicated significant difficulties with phonological loop function whereas their performance suggested an intact visual spatial sketchpad. However, their performance showed improvement on the verbal STM when VCI was taken into account showing the importance of crystallized intelligence and ultimately of learning.

Based on the outcome of the results, the present research would emphasize the uniqueness of the memory profile for each memory component of the group, which, to a larger extent, depends on intelligence. When the different indexes of the IQ were taken into account, even children with ID showed better performance on a number of memory scales.

The correlation matrixes also indicated variations in the relationship of memory components with intelligence for different groups. Notwithstanding this dissimilar performance, some similarities could still be identified between the profiles. For example the profile of the children with ASD and the typically developing children shows some resemblance in their correlational matrix suggesting significant similarities between these two groups as compared to the groups with SLI and ID. Does this mean that children with ASD use their intelligence to support their memory compared to the other two groups, i.e., ID and SLI? If this is the case then the intervention strategies for these children should be based on differential mechanisms. For children with ASD, it can be assumed that if memory is targeted that may have a corresponding improvement in intelligence, whereas this might not by expected for the ID and SLI groups. For children with ID and SLI, both memory and IQ need to be independently targeted to maximize their potentials. It can also be assumed from the outcome of the present research that children with low functioning intellect find it difficult to update information in WM, which is very important to carry out a task of WM and which probably differentiates them from typically developing children. Therefore, these children need to be given short tasks, supporting them by teaching different mnemonic strategies, which can help them update information on a regular basis. The major focus should also be in developing their STM as a first step and subsequently exposing them to tasks requiring simple processing and storage as is required by the WM. The STM, therefore, should be a stepping stone to build their WM skills.

To conclude, this research has provided sufficient food for thought in understanding the memory profiles of children with neurodevelopmental disorders by not only comparing their performance between each other but also with the typically developing children. The use of an extensive computerized memory instrument specifically designed for the purpose was an added advantage over other research, in allowing the different groups to be tested using a standardized procedure that could be completed readily by children with the different disorders.

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