Cognition in Children with Attentional Difficulties with particular reference to Working Memory

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Candidate's Statement

This is to certify that the research described in this thesis is solely my own work.

Signed: ______________________ Alison Scope

Acknowledgements

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Abstract

This research investigated cognitive function in children with observed and rated behavioural manifestations associated with inattention, hyperactivity and impulsivity. The aims were firstly to assess whether there were children in mainstream classrooms who displayed these behaviours, and secondly, to assess executive function and working memory in these children compared to a control group. It was anticipated that the findings could provide a basis for the development of a new model to explain cognitive function in children with attentional difficulties.

A group of children with attentional difficulties who were part of the normal population but who did have cognitive difficulties in comparison to controls were identified. It was concluded that these children constituted part of a normal continuum of attentional skills and were not diagnosable. Using the working memory model (Baddeley and Hitch, 1974, Baddeley, 2000) the nature of the cognitive difficulties in children with attentional difficulties was established. Specifically it was revealed that children with attentional difficulties had difficulties on spatial working memory tasks but not on visual working memory tasks. Central executive function was initially proposed to explain differences between the groups, however when this explanation was explored the Supervisory Attentional System (Norman and Shallice, 1980) emerged as a better model to explain the data. Limitations of Barkley's (1997) inhibition model were also identified.

It was hypothesised that children with attentional difficulties have difficulties associated with 'executive attentional control' mechanisms which impinge on their ability to complete central executive working memory tasks. Existing models were incorporated into a new model to more accurately explain these difficulties.

It is intended that these findings will be followed up longitudinally to assess the development of executive attentional control in children with attentional difficulties and to incorporate these findings into a developmental model.

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1.1 Background to the research programme

In recent years there has been considerable interest in the study of behavioural difficulties characterised by inattention, hyperactivity and impulsivity. This interest has been primarily focussed on the development of models to explain attention deficit / hyperactivity disorder (ADHD) (E.g. Barkley, 1997) as a result of cognitive dysfunction with a neurological cause. An issue of concern is that attentional difficulties in school-aged children may be limiting their potential for academic achievement (DuPaul et al., 2001), and this is a result of cognitive dysfunction.

The broad aim of the thesis, therefore, was to investigate cognitive function in children with observed and rated difficulties associated with inattention, hyperactivity and impulsivity, which will be referred to here as attentional difficulties. The goal is to identify and explain any differences between children with and without attentional difficulties in cognitive function. In order to achieve the aim of the thesis it was necessary to firstly, identify a group of children with observed and rated attentional difficulties (AD group) but not of such a severity as to warrant a diagnosis of ADHD and a control group of children without observed and rated attentional difficulties (NC group).

The purpose of this chapter is to provide a review and critical evaluation of the current literature relevant to the aim of the thesis. Section 2 will review the theoretical and empirical literature relating to children with attentional difficulties, describing the definitions, aetiology, symptoms and manifestations of attentional difficulties. As problems associated with inattention, hyperactivity and impulsivity are commonly reported in the typical population there is a suggestion that there may be a group of children with attentional difficulties at a lesser level of severity compared to those with a diagnosis of ADHD. Evidence to support this proposal will be presented in this section. The literature relating to attentional difficulties in the typical population and how this relates to a continuum theory of attentional difficulties will be reviewed. A final part of this section will review the literature regarding attentional difficulties and the education system. The first part of Section 3 will review the literature associated with the typical development of higher order cognitive processes and will then go on to review cognitive models of attentional difficulties, and cognitive models associated with attention and working memory more generally, to illustrate how these may be related. The chapter will conclude with the overall aims of the thesis.

1.2 Attentional Difficulties

1.2.1 Definitions

Attention Deficit/Hyperactivity Disorder (ADHD) (APA, 1994; 2000) is a condition reported to affect a small, but increasing, number of children from birth or infancy. Recently it has been reported as characterised by deficits in executive functioning (Barkley, 1997). A number of theories to account for the development of ADHD have been presented in the literature and the current theory views ADHD as a biopsychosocial disorder (Cooper, 1997). This theory implicates biological, psychological and environmental factors in the aetiology of the disorder. Assumptions have been made that brain abnormalities, whether caused by differences in brain structure (Castellanos et al., 1996; Filipek, 1997), genetic transmission (Cantwell, 1975; Biederman et al., 1995) or environmental factors, such as diet (see Schnoll et al., 2003) or parenting styles (Durkin, 1995), go on to cause cognitive deficits and subsequent inappropriate or atypical behaviour which are the symptoms of ADHD. Thus, ADHD is thought of as a biological predisposition triggered by environmental factors. The symptoms of ADHD are behavioural in nature and are characterised as indicating inattention, hyperactivity and impulsivity. According to the American Psychiatric Association (APA), Attention Deficit/Hyperactivity Disorder (ADHD) is characterised by 'a persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequent and severe than is typically observed in individuals at a comparable level of development' (DSM-IV) (APA, 1994; p.78). They suggest that the diagnosis of ADHD should be based on these behavioural symptoms and they should be persistent for at least 6 months. Some of these symptoms should have been present before the age of seven, and should be persistent in at least two settings. There should also be clear evidence of a clinical impairment. Symptoms of inattention include inattention to schoolwork, difficulty maintaining sustained attention, not listening when spoken to, not following instructions, disorganisation, avoidance of sustained mental effort, losing items, being easily distracted by extraneous stimuli, and forgetfulness. Symptoms of hyperactivity include fidgeting, running and climbing excessively, difficulty in engaging in activities quietly, and talking excessively, and symptoms of impulsivity would include, shouting out, interrupting others, and finding difficulty in waiting turn. There are also three subtypes of ADHD dependent on the type of symptoms displayed (APA, 1994; 2000). These are combined type (ADHD-CT), predominantly inattentive type (ADHD-PI), and predominantly hyperactive-impulsive type (ADHD-HI). The ratio of boys to girls diagnosed with ADHD is reported as lying somewhere between 4:1 and 8:1(Barkley, 1998), and this sex difference is explained by varying theories such as differing personality traits of boys in comparison to girls (Barkley, 1998), and sex differences in dopamine receptor density (Anderson and Teicher, 2000).

1.2.2 Diagnosis of Attentional Difficulties

Although the term ADHD is widely used throughout the world, the British definitions of the disorder have, until relatively recently, often been based on the International Classifications of Diseases 10th edition (ICD 10) (WHO, 1990), and is known as Hyperkinetic Disorder (HKD). The definition of HKD is severe and pervasive inattentiveness, overactivity and impulsiveness with an onset prior to the age of 6 years. According to Taylor and Hemsley (1995) the prevalence rate, in Britain, of HKD in the whole population of prepubertal children is likely to be around 0.5%-1%. More recent figures are difficult to come by due to the different diagnostic systems applied in Britain, however it is widely held that prevalence rates are much lower in Britain compared to the United states. The prevalence rate of ADHD in America according to a more recent study (Brown et al., 2001) ranges from between 4% to 12% in the general population of 6 to 12 year olds. It is argued (Kewley, 1998) that ADHD is under diagnosed in Britain, which may account for the difference in prevalence rates between Britain and America.

Differing prevalence of ADHD between countries, in the large part, is not attributed to cultural differences in behaviour (Swanson et al., 1998). Instead, differences in the criteria used to diagnose attentional disorders are said to account for variations in prevalence. The definition of HKD is more restrictive, as it focuses more on extreme hyperactive behaviours, implying that HKD is a more severe version of ADHD. Kewley (1998) asserts that the view of ADHD as less severe is inaccurate, and posits that hyperactivity, which is emphasised in descriptions of HKD, is just one problem associated with ADHD. It is possible that HKD is analogous to predominantly hyperactive type ADHD. Like Britain, Australia uses both DSM and ICD definitions to diagnose attentional disorders and the prevalence rate of 1% (Atkinson et al., 1997) based on the number of school-aged children prescribed stimulant medication is more comparable to the British prevalence rate.

The difference in prevalence rates suggests a difference in the way attentional difficulties are viewed between countries. The United States are more likely to take a medical-disease standpoint when discussing ADHD (Reid and Maag, 1997), whereas the 1997 British Psychological Society Working Party Report, viewed ADHD as 'an evolving concept', and suggested that very few children described as having ADHD demonstrate any neurological aetiology (Reason and Sharp, 1997).

The literature illustrates the anomalies in the diagnosis of the disorder and supports the contention that otherwise typically developing school children may have difficulties associated with inattention and hyperactivity-impulsivity, yet at a lower level of severity than those children diagnosed with ADHD or HKD. Further this may illustrate that the category of ADHD itself may include greater or lesser attentional difficulties.

1.2.3 The Continuum Theory of Attentional Difficulties

Minor attentional lapses have been reported to be common in the normal population (Manly et al., 1999), and it has been suggested that these lapses vary between individuals depending on personality and propensity to absentmindedness, and as a result of differences in functional brain activation (Hester et al., 2004). An individual differences explanation for attentional lapses is supported by studies on ADHD and personality. Extraversion has been found to be a significant predictor of hyperactive-impulsive symptoms, neuroticism was significantly related to both inattention and hyperactivity-impulsivity, and agreeableness and conscientiousness were both negatively related to ADHD (Parker et al., 2004).

The results of these investigations are consistent with the idea that attentional difficulties are variable and support the theory of an attentional skills continuum (Connor, 1997). As Connor (1997) states, '...attentional skills may fall on a continuum wherein the average range is broad, and are influenced by a range of factors both intrinsic to the child and extrinsic (linked to the classroom organisation, teaching style, etc.).' (p. 15).

Findings from a number of studies cited here are suggestive of the idea of attentional skills being placed on a continuum. Research put forth by Adams and Snowling (2001) also provide support for the idea of an attentional skills continuum. They found that children rated as 'hyperactive' by their teachers, but not clinically diagnosed or presenting pervasive difficulties associated with a diagnosis of ADHD, demonstrated impairments in executive function, which has been found to be the case in ADHD samples (Barkley et al., 2001).

According to the attentional skills continuum, ADHD would be placed at the extreme end of a continuous pattern of behaviour that occurs to different extents in different individuals across the entire population (Levy et al., 1997). As previously noted, the definition of HKD is more restrictive than ADHD focussing more on extreme hyperactive behaviours. In the context of the attentional skills continuum HKD may be placed at a greater severity compared to ADHD. Although Kewley (1998) would argue against this interpretation suggesting that HKD is analogous to predominantly hyperactive type ADHD, it may be the case that hyperactivity symptoms reflect a greater severity of attentional difficulties and additional motor control difficulties. The empirical evidence in support of ADHD varying genetically across the population (Levy et al., 1997) is consistent with Rutter's (1996) ideas concerning category or continuum in psychopathology. Rutter suggests that it is important to be aware that disorders are rarely defined only in terms of an extreme on a single behavioural trait and goes on to suggest that it may be more accurate to examine constellations of behaviour that characterise individuals rather than separate individual traits. It is also important, as Empson (2001) and Empson and Nabuzoka (2004) suggest, to examine the appropriateness of behaviour. Some behaviours which violate the social norms of one group or one situation may be acceptable to another. The appropriateness of behaviour can also depend on factors such as context, age and gender, and as social behaviours are often used as a measure of typical development, it is important that these factors are taken into account. The persistence of psychopathology across development is also an important factor to consider according to Rutter (1996). He suggests that as well as changing physically during the lifespan, individual differences are also subject to change. This makes it clear that any difficulty a child may have is subject to change in terms of the level of the difficulty and situational variables.

1.2.4 Manifestations of Attentional Difficulties

Inattentive, hyperactive and impulsive behaviour has been studied intensively in recent years (Barkley et al., 1990; Barkley, 1997; Chhalildas et al., 2001; Kewley, 1998; Hinshaw, 1992), with various models being proposed to account for this behaviour (e.g. Barkley, 1997; Sonuga-Barke, 1994, 2003). These models are commonly based on the premise that differences in brain structure and function in children with ADHD can lead to secondary difficulties which can cause persistent and pervasive problems for the affected individual. Reduced motor (Kroes et al., 2002; Kalff et al., 2003), and particularly cognitive abilities (Barkley et al., 1990; Barkley, 1997; Frith, 1992) are commonly reported in children with ADHD. Cognitive difficulties are reported to have a detrimental effect on social competence resulting from a lack of understanding of social interaction with peers and adults, and this is compounded by problems of low-self esteem due to rejection as a result of the behavioural manifestations of the cognitive difficulties (Nixon, 2001; DuPaul et al., 2001; Hinshaw et al., 1997; Clark et al., 2002; Charman et al., 2001). Further, poor academic achievement can result (DuPaul et al., 2001), ADHD in childhood has been attributed to delinquency (Satterfield et al., 1982) and undiagnosed attentional difficulties to higher incidence of criminal arrests in later life (Fergusson et al., 1997).

A number of these manifestations associated with ADHD have also been attributed to children with attentional, hyperactive or impulsive difficulties that were not diagnosed (Fergusson et al., 1997; Adams and Snowling, 2001). Fergusson et al. used parent and teacher ratings to divide their typically developing sample into five classes of inattentive behaviour. Although the participants did not have a clinical diagnosis of ADHD, manifestations associated with ADHD such as academic failure and criminal arrests were more likely in participants whose scores were high for inattentive behaviour. Using the strengths and difficulties questionnaire Adams and Snowling (2001) also found that children identified by teachers as 'hyperactive' performed at a significantly lower level compared to matched controls on measures of literacy, inhibition of inaccurate responses, and higher order cognitive function involving planning, termed executive function. These empirical findings based on children attending mainstream schools, support the position of attentional difficulties being a common problem in the typical population.

1.2.4.1 Academic Underachievement

Numerous studies have supported a link between attentional difficulties and academic underachievement. DuPaul et al. (2001) found that preschool children with ADHD exhibited preacademic skills deficits before school entry. Significantly lowered academic achievement in ADHD children was observed when compared to children without ADHD, and this finding held when comorbid learning disabilities were controlled for (DeShazo Barry et al., 2002). On academic task persistance in boys with ADHD, Hoza et al., (2001) found that they solved fewer puzzles, were more likely to stop working on a task, and generated fewer responses on a word task. They were also found to be less effortful and less cooperative. Adams and Snowling (2001), in their investigation of children rated as hyperactive by teachers, noted a significant relationship between behaviour and academic attainment. Pro-social behaviour was positively correlated with reading and arithmetic attainment, whereas, hyperactivity and conduct problems were negatively correlated with these academic skills. Further, it has been asserted that inattention-hyperactivity is a stronger predictor of academic underachievement than is aggression (Hinshaw, 1992). These findings clearly suggest that children with difficulties associated with the symptoms of ADHD, both with and without a diagnosis, have difficulties associated with academic achievement as a result of the associated behaviours.

It has been suggested that at least one child in every school classroom has ADHD (Dupaul and Stoner, 2003), making it highly probable that additional children within a classroom will have less severe attentional difficulties. The British government's educational stance is on inclusion rather then excluding children presenting difficulties, from the mainstream school environment.

The principles and procedures of the Special Educational Needs (SEN) Code of Practice (DfEE, 2002) are adhered to and applied by schools and Local Education Authorities (LEAs) when dealing with children with physical and psychological learning difficulties. The SEN procedures are used to identify and assess children's physical and psychological difficulties that have a detrimental effect on academic achievement. These difficulties are then classed as special educational needs. The category of Behaviour, Emotional and Social Development incorporates difficulties more commonly known as Emotional and Behavioural Difficulties (EBD's). This category includes children who are withdrawn, isolated, disruptive and disturbing, hyperactive and lack concentration, have immature social skills and present challenging behaviour. This definition makes it clear that children with difficulties associated with inattention and hyperactivity-impulsivity could be included in this category.

As Maras et al. (1997) write,

> '...ADHD may apply to a small proportion of children and young people who experience particular difficulties that can be best described under the broad umbrella term emotional and behavioural difficulties (EBD's).' (p. 39)

Evidence for the presence of symptoms of inattention, hyperactivity and impulsivity in children with EBD's comes from a study by Place et al., (2000). The authors undertook a study in a British school specifically for children identified as having Emotional and Behavioural Difficulties. Using teacher rating scales and undertaking psychiatric interviews with the parents, both based on the DSM-IV criteria for psychiatric disorders, they demonstrated that 86% of the children were rated as having at least one psychiatric disorder, the most common disorder being ADHD. According to their measures, 65% of the sample had ADHD, of which 24% had conduct disorder, 22% had overanxiety and 47% had depressive disorder, in addition to ADHD. Very few of these children already had a diagnosis of ADHD.

1.2.5 Conclusions

Taken together, these findings clearly indicate that both inattentive and hyperactive-impulsive behaviours, whether diagnosed at a clinical level or not, have a limiting effect on a child's potential for academic achievement. Results from intervention studies are encouraging. Semrud-Clikeman et al. (1999) reported the results of an intervention programme for children with attentional difficulties as rated by parents and teachers. The 18-week intervention programme included attention and problem-solving training, and the findings revealed that children with attentional difficulties performed better on visual and auditory attention tasks after the training. The children with attentional difficulties who did not receive the intervention, however, did not show any improvement on the measures. Attentional difficulties can vary a great deal in severity and number, and findings emphasise that to be able to identify problems associated with inattention, hyperactivity and impulsivity would enable identification of children in need of intervention.

The preceding sections have illustrated that behavioural symptoms associated with attentional difficulties are problematic in the school environment, having a detrimental affect on academic achievement. It has been further illustrated that these behavioural manifestations may occur in children without a diagnosis of a developmental disorder as a result of individual and developmental differences. Possible explanations for individual differences in behavioural manifestations associated with attentional difficulties will be explained in more detail in section 1.3 by comparing typical and atypical cognitive development of higher order cognitive processing.

1.3 Higher Order Cognitive Function in Children with Attentional Difficulties

Theories to explain ADHD often centre on a failure of higher order cognitive processing (Barkley et al., 1990). To provide a basis for examining at which stages in cognitive processing failures may occur for children with attentional difficulties it is necessary to firstly review the literature relating to the typical development of higher order cognitive processing. The literature regarding the typical development of higher order cognitive processes will, therefore be reviewed in section 1.3.1 followed by a review of the literature concerning atypical development of higher order cognitive processes in section 1.3.2.

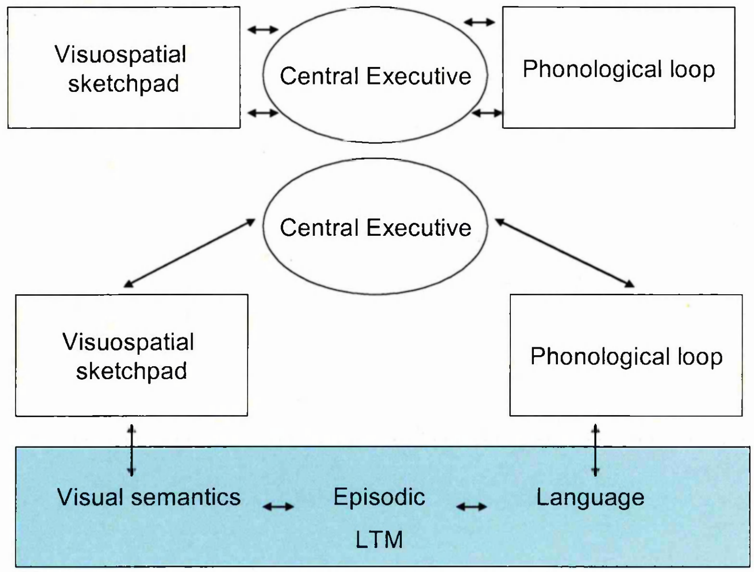
1.3.1 Typical Development of Higher Order Cognitive Processes

The development of the functions of the working memory model (Baddeley and Hitch, 1974; Baddeley, 2000) which are executive in nature are crucial to the development of higher order cognitive abilities. The responsibilities of working memory that are executive in nature are dealt with by the central executive component of the working memory model developed by Baddeley and Hitch (1974) and updated by Baddeley (2000). The most recent conceptions associated with working memory and executive function will be described in sections 1.3.1.1 and 1.3.1.2 respectively. These sections will be followed by section 1.3.1.3 which will review the evidence for the developmental trajectory of these higher order cognitive processes and will outline how they are associated.

1.3.1.1 Working Memory

The distinction between executive function and working memory is based on a distinction between attentional resources and memory resources. Attentional resources are thought to be under the control of executive function but are needed for the operation of working memory. The three component model of working memory (WM) was proposed in 1986 by Baddeley and further developed by Baddeley (2000) (see Figure 1.1).

Figure 1.1: The working memory model (Baddeley, 2000, p418)



The central executive was thought to control the working memory system and is assisted by two further systems, known as the slave systems, the phonological loop (PL) and the Visuo-spatial sketchpad (VSSP). As the names imply, the phonological loop processes and stores verbal and auditory information using a temporary store and an articulatory rehearsal system. It is now generally accepted that the phonological loop and visuo-spatial sketchpad components of working memory are dissociated, with various studies finding evidence for a dissociation of these mechanisms. Support for this comes from a number of different sources such as experimental behavioural studies using typical (Brooks, 1967; Logie et al., 1990; Farmer et al., 1986) and atypical groups (Jarrold et al., 1999), and from neurological case studies (Hanley et al., 1991). The less investigated of the two slave systems, the visuo-spatial sketchpad is thought to process and store visual and spatial information and is considered to be fractionable into separate visual, spatial and perhaps kinaesthetic components. A further component of working memory, which has been added in recent years (Baddeley, 2000), is the episodic buffer. This component is said to store information in a multi-dimensional code providing a temporary interface between the slave systems and long-term memory. The episodic buffer is thought to be controlled by the central executive, which binds information from different sources into coherent 'episodes'.

The model of working memory gives an integrated account of how information is processed and stored in short-term memory. It has been successful, since its conception during the 1970's, in conceptualising the role of temporary information processing and storage in the performance of complex cognitive tasks. It is proposed that the development of a number of cognitive capacities, such as language development (Adams and Willis, 2001), are dependent on the development of working memory. The model was developed from previous short-term memory models put forth by theorists such as Broadbent (1958) and Atkinson and Shiffrin (1968). The distinction between these original models and the working memory model, together with the fact that the model is a multi-component opposed to a unitary model, lies in the importance placed on processing in working memory, rather than merely a storage, or memory system. The processing and storage aspects of working memory are thought to work together in order to accomplish complex cognitive activities. It is likely therefore, that this dual-processing will be dependent on the attentional mechanisms implicated in executive function.

Working memory, as it is used here, can be described as;

> 'a limited capacity system allowing the temporary storage and manipulation of information necessary for such complex tasks of comprehension, learning and reasoning.' (Baddeley, 2000, p.418)

1.3.1.2 Executive Function

As the name implies the central executive is executive in nature and is viewed as organising executive resources or functions, namely attentional control. It would seem likely, therefore, that the development of working memory would be dependent on the development of executive function. So it is important to provide a review of the theoretical literature describing executive function in order that parallels between the constructs can be drawn.

Executive function is now a widespread term to describe higher order cognitive processes. A recent definition of executive function suggests that 'Rather than referring to a single process, 'EF' is an umbrella term for all of the complex set of cognitive processes that underlie flexible goal-directed responses to novel or difficult situations' (Hughes and Graham, 2002, p.131). The structure of executive function remains under debate, however, Pennington and Ozonoff (1996), conclude that 'In cognitive psychology, executive processes are a kind of residual, the part of cognition that logically must occur after perception but before action.' (p. 55).

The prefrontal cortex is the region of the brain that has been proposed to regulate executive function (Barkley et al., 2001). Such a contention has been supported by empirical findings. Children with frontal lobe epilespsy (FLE) when compared to children with temporal lobe epilepsy and generalised seizures showed impairments on tasks assessing motor coordination, verbal fluency, mental flexibility, impulse control and planning, implicating the frontal lobes in these executive functions (Hernadez et al., 2002). Further, some definitions of executive function refer directly to the frontal lobe function, '...tasks or behaviours that are sensitive to Prefrontal cortex (PFC) dysfunction require planning or programming future actions, holding those plans or programs on-line until executed, and inhibiting irrelevant actions.' (Pennington and Ozonoff, 1996; p. 55)

1.3.1.3 Development of higher order cognitive processes: The central executive and executive function

There is a tendency for memory span to increase with age with an individual's ability to retain temporarily verbal or visuo-spatial material dramatically increasing from infancy to adulthood (Baddeley, 1986; Gathercole and Baddeley, 1993). Gathercole and Baddeley (1993) suggest that the evidence points towards all three original components of working memory, the central executive and the two slave systems, being present in young children. They further suggest that the development of the system relies on the processing efficiency of the slave systems and the increase in strategy use. The efficiency of the slave systems appears to be directly related to the efficiency of the central executive and, further, the increase in strategy use clearly implicates executive functioning and, therefore, also relates to the functions of the central executive.

A recent study by Gathercole et al. (2004) has confirmed that the basic three component model of working memory is present in children from the age of six years and each component continues to develop in functional capacity throughout childhood up to adolescence. The increase in verbal memory span during childhood is due to increases in processing speed or subvocal rehearsal with age. Findings have shown that the phonological loop is present and functioning in four-year-old children and rehearsal becomes more efficient with age. It is uncertain, however, whether children as young as four or five do rehearse verbal strings in the same way as older children and adults, as it has been shown that articulatory suppression does not have the same disruptive effect on recall in this age group as it does in older children and adults (Gathercole and Baddeley, 1993).

Gathercole and Baddeley (1993) further conclude that prior to the age of 7 years children do not use the phonological loop to store the names of pictures, and at around 4 to 5 years of age can recall a sequence of two or three pictures. It is suggested that the visuo-spatial sketchpad is employed by children in this age group to recall visual information rather than converting the information into a verbal code for use by the phonological loop. Performance on visuo-spatial tasks composed of abstract patterns, which are difficult to verbally recode, appears to improve dramatically with age levelling off in adulthood and, by using interference conditions of the tasks, demonstrated that this improvement was attributable to both the sketchpad and the central executive.

These findings have illustrated that the developmental improvement in working memory can be attributed to memory capacity and, more recently, attentional control processes, otherwise known as executive function. If the development of working memory is as a result of the development of executive function this implicates the central executive. The central executive component of the working memory model is the component which is responsible for attentional control in working memory. Indeed it has been suggested by Gathercole (1999) that developmental changes in working memory could include increases in processing efficiency and capacity, and task-switching, which implicate central executive processes.

Evidence in support for an improvement in attentional control processes, and therefore central executive function, as an explanation for developmental improvements in working memory come from a number of sources. Specifically focussing on the development of visuo-spatial working memory it has been suggested by Pickering (2001) that its development is dependent on at least three factors. The first of these three factors relates to the development of processing strategies. Pickering suggests that these allow children to convert visuo-spatial information into a phonological code, in order that they can have available both a phonological and a visuo-spatial representation of the information to be remembered. The second factor is gaining a knowledge base and it is suggested that processing strategies will be linked to gaining knowledge such as learning to read. The final factor relates to the maturation of the neurological system, it is suggested that this could lead to increased attentional capacity and processing speed. These processes are dependent on the development of the central executive.

Further, with reference to verbal working memory, Baddeley (1986) explains findings of an association between verbal memory span and speed of processing using the working memory model, suggesting that memory span is dependent on the central executive. The phonological loop will be employed to store information freeing capacity for storing more items, either directly within the central executive or indirectly by the more efficient use of control processes. With increasing age verbal processing will become more and more efficient requiring less and less processing by the central executive. Baddeley's position, therefore, is that when information is unfamiliar it will require more attention from the central executive, reducing the capacity remaining for subsequent items. This argument would explain why as processing speed increases so does memory span. It is suggested that the processing of visual information is considerably more demanding and this would explain why the memory span for visual information appears to develop later than for verbal information.

Although the evidence presented above clearly implies that the development of executive processes under the control of the central executive is responsible for the improvements in working memory throughout childhood, these executive processes are not clearly specified. These reports do not suggest what may underlie changes in executive function and how these develop. The development of executive function which may reflect development of the central executive has, however, been investigated by Zelazo and Frye (1998). They concluded that it was the development of inhibitory or monitoring skills associated with maintaining an active representation of a complex set of rules and being able to reflect on these that accounts for developmental differences on cognitive tasks. Their findings imply that the development of working memory is dependent on the development of executive function.

More recent investigations of working memory have also gone further to provide explanations for the development of attentional control processes by using tasks which are proposed to tap the central executive and therefore executive function. Investigations into the development of complex working memory span performance in children between 6 and 10 years of age have shown, in line with previous findings, that improvements with age are related to both general speed of processing and storage ability, related to operational efficiency (Bayliss et al., 2005). It was further argued on the basis of these findings that although the speed of the cognitive system increases with age, age is also responsible for separable increases in the speed in which processing operations can be completed and the speed with which storage items can be reactivated or refreshed and these have an overall effect of improving working memory performance. These processes may describe executive function and, therefore explain the relationship between working memory and higher level cognitive abilities. A further study also related age to improved accuracy and faster performance in a developmental study of visuo-spatial and audio-spatial working memory in 6-13 year old children, using n-back tasks (Vuontela et al., 2003). N-back tasks are working memory tasks which have a number of levels of demands and could, therefore, be described as central executive tasks. They usually require participants to make responses dependent on stimuli presented just prior to the cue for recall (1-back), two stimuli prior to the cue for recall (2-back) and so on. The findings were interpreted as reflecting the development of the prefrontal cortex through childhood and that this development is accompanied by development of cognitive abilities such as working memory and executive function.

These investigations go further than those with purely an interest in investigating the components of working memory, to explain the how the development of executive function and working memory may be related. As the central executive has been highlighted as key to understanding the links between working memory and executive function it is useful to discuss a framework of executive function which has been highlighted by Baddeley (1996) as an account of central executive.

The Supervisory Attentional System (SAS) account of attentional control (Norman and Shallice, 1980) appears to provide an explanation for the executive processes underlying working memory. The Norman and Shallice (1980) account of the role of attention in the control of action described two processes, those that are automatic, non-executive processes and those under conscious control, executive processes. This model, illustrated in figure 1.2, provides a clear account of the distinction between executive and non-executive processes, and, further, the type of tasks that may demand these processes. The Supervisory Attentional System (SAS) of the Norman and Shallice model was described as being responsible for novel action sequences, and for the interruption and modification of ongoing behaviour, whereas, automatic action sequences were proposed to be dealt with by contention scheduling. Contention scheduling reportedly occurred when no direct attentional control of selection was required. When well learned actions were demanded it was proposed to provide a means of selecting a particular schema when numerous others were activated at the same time. Contention scheduling provided activation and inhibition thus resolving conflict between supporting and conflicting schemas. This is achieved when sets of potential source schemas compete and selection takes place on the basis of their activation value.

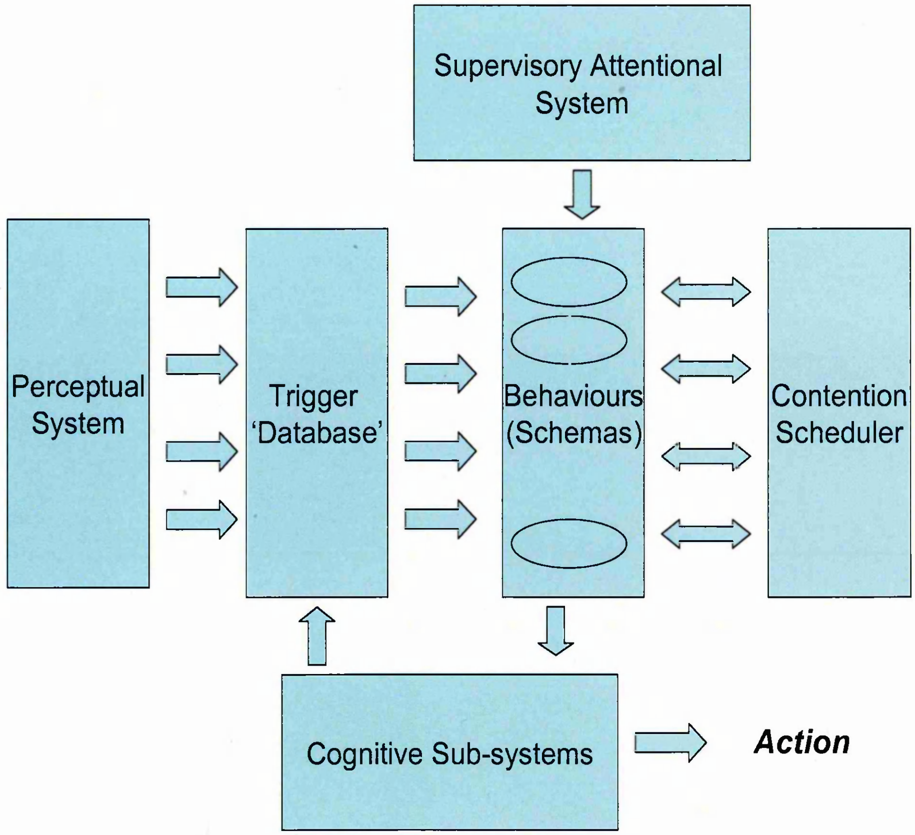


Figure 1.2: The Model of Attentional Control incorporating the Supervisory Attentional System (SAS) (Norman and Shallice, 1988)

The first principle of the theory of attentional control (shown above in figure 1.2) is that routine actions are decentralised. Automatic actions do not require the assistance of a higher order cognitive system such as the SAS, they are merely dealt with by contention scheduling. The second principle is that non-routine actions do require the assistance of a higher order cognitive system, namely the SAS. The basic units underlying action or thought are a large set of discrete programs that can be divided into two broad levels, higher level programs known as scripts and lower level programs known as thought or action schemata. These place a particular pattern of demands on a number of functionally specific subsystems. Each schema has a level of activation dependent on the triggering of inputs it receives. The process of routine selection between routine actions of thought operations as previously noted is known as contention scheduling, however, this system cannot explain all levels of selection of action or thought operation therefore the SAS is proposed to account for willed actions.

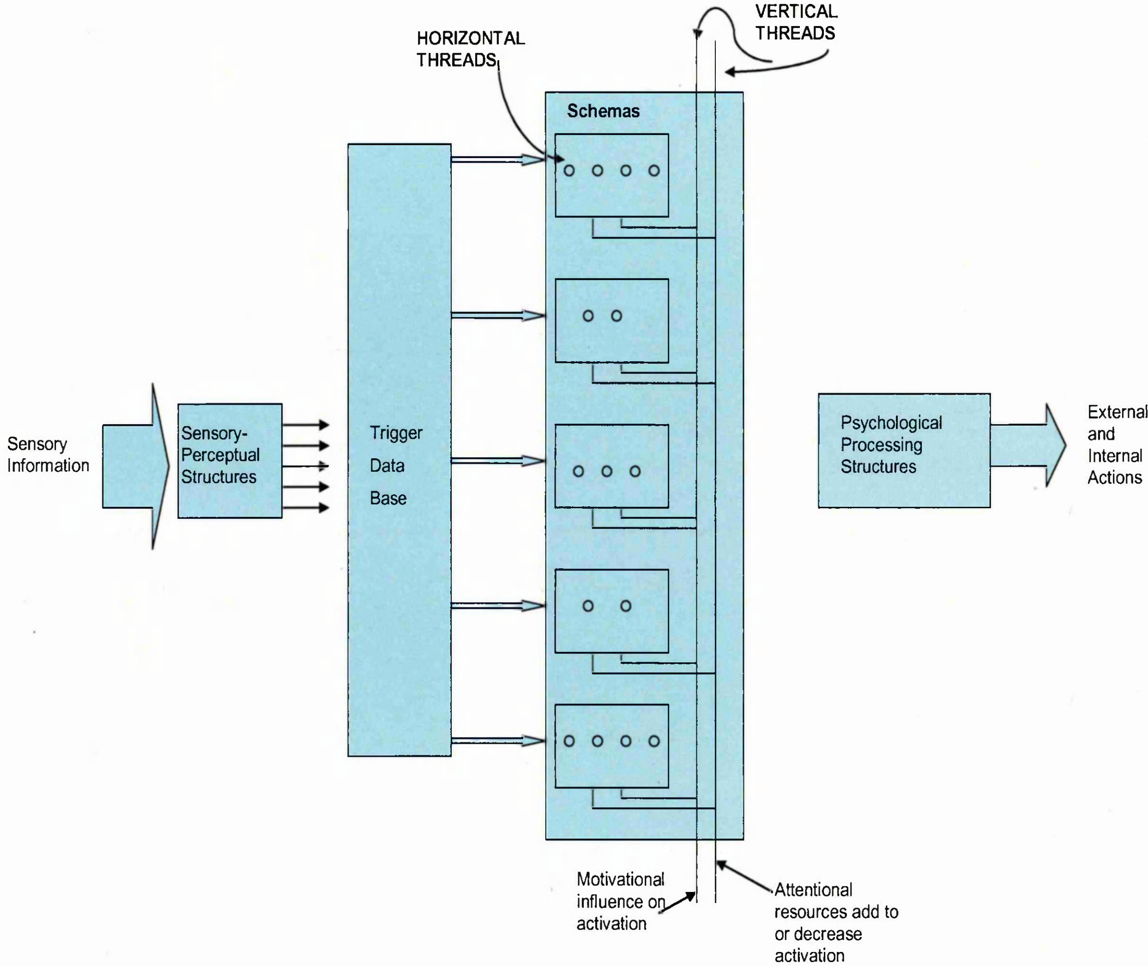


Figure 1.3: The Supervisory Attentional System (SAS) (Norman and Shallice, 1980; p.7)

Executive functions are often defined in terms of the tasks that are said to measure them. The SAS is employed in situations where deliberate conscious control of attention are demanded, such as those which involve planning or decision making, are novel or ill-learned, judged to be dangerous or technically difficult, or require the overcoming of a strong habitual response (Norman and Shallice, 1980). This demonstrates the association between the SAS and working memory (Baddeley and Hitch, 1974). When executive function tasks demand working memory the central executive will be employed (Baddeley, 1996). In these situations contention scheduling cannot take place for fear that an error may occur.

A criticism of the Norman and Shallice (1980) framework is that it does not account for developmental change and perhaps should be modified to incorporate this. However, although the SAS was developed based on studies of adult frontal lobe patients its principles could be applied to explain the developmental changes in working memory and executive function outlined above. Baddeley (1986) suggests that as working memory develops the slave systems will be employed to store information, and this will free capacity for storing more items, either directly within the central executive or indirectly by the more efficient use of control processes. The Norman and Shallice (1980) model of attentional control would predict that this development of working memory is due to novel actions becoming well learned and processing transferring from the SAS to contention scheduling. If information processing becomes more efficient it will require less processing by the central executive or the SAS as Norman and Shallice (1980) would term it.

This suggests that unfamiliar information will require more attention from the central executive reducing its storage capacity. This explains the relationship between processing speed and memory span found in working memory investigations. The findings suggesting that the memory span for visual information appears to develop later than for verbal information, could also be explained with reference to the SAS. Baddeley's (1986) explanation is based on the idea that the processing of visual information is considerably more demanding than for verbal information. If visual information is more complex than verbal information this will result in a longer period for these actions to become well-learned and subsequently a longer period to transfer to contention scheduling from the SAS.

Investigations specifically focussing on the development of executive function, but which demand working memory, can also be interpreted as reflecting the development of the SAS (Zelazo and Frye, 1998). These investigations have shown that typically developing infants, between the ages of 8-10 months, are likely to make perseverative errors on problem solving tasks. Perseverative errors are usually assessed when rules are changed during the performance of a task. Perseverative errors occur where the participant persists with an old rule when they have been asked to adopt a new rule. In the typical population these errors are unlikely to occur by the age of 3 (Zelazo and Frye, 1998). These findings suggest that a system must be in place to deal with the executive nature of the task, implying therefore, that the findings reflect the preliminary stages of the development of executive function and therefore central executive processes as described by the SAS in 3 year olds.

Kirkham et al. (2003) more recently, however, found that three year old children had difficulties switching between rules when undertaking a task, whereas, this difficulty was less evident in four year old children. The results were interpreted as providing support for the theory of 'attentional inertia' which proposes that inhibitory processes are underdeveloped in three year olds, and that they are unable to switch between rules as they are unable to inhibit the use of the previous rule. In a further experiment, Brooks et al. (2003) asked three year old children to sort cards according to a particular rule, such as, place the dog card on the dog stand, and place the airplane card on the airplane stand. They were subsequently requested to sort the cards according to an opposite rule, such as, place the dog card on the airplane stand, and place the airplane card on the dog stand. Findings indicated that three year old children had no difficulty in performing either of the tasks, and number of correct responses increased with age. A second experiment introduced an extra irrelevant dimension of colour to both games resulting in a significant reduction in performance on both of the tasks.

The findings of Brooks et al., and Kirkham et al., were interpreted in terms of a difficulty associated with complexity in terms of the Cognitive Complexity and Control (CCC) Theory (Zelazo and Frye, 1998), but could equally reflect the functioning of the SAS. The CCC theory explains the degree to which children are able to consciously reflect on their plans and the development of these abilities. CCC theory suggests that 2 year olds can only represent a single rule at a time, at 3 years of age they are able to represent two rules simultaneously, and at 5 years of age they are able to represent a higher order rule such as a rule which allows selection between two incompatible pairs of rules which might occur on a card sort task. These processes are implied to reflect the development of executive function. Explanations for this are that 3 year olds are able to understand two rules, however, they are unable to integrate these into a new higher order structure that is demanded for switching tasks. An alternative explanation which Zelazo and Frye (1998) present is that 3 year olds are unable to inhibit a prepotent response (the typical response which would be expected to be demanded in a certain situation) due to immaturity of inhibition mechanisms. Findings of a further study, in which the children were asked to comment on whether a puppet was sorting cards correctly or incorrectly, contradicted the idea of a failure of the inhibition mechanism. These findings demonstrated that the three year olds had difficulties in knowing what should be done in addition to difficulties in performing the correct actions, implicating monitoring abilities. These interpretations would equally be accounted for by the SAS framework as it is proposed to deal with the interruption and modification of ongoing behaviour.

Although Zelazo and Frye (1998) rejected the idea that the development of inhibitory mechanisms could explain their results, the findings could be related to some aspects of inhibitory control. An investigation into the development of selective inhibitory control was conducted by Bedard et al., (2002) using a computer administrated stop-signal task. The findings indicated that both the reaction time to response execution and to selectively inhibit a response is improved and reduced with increasing age. The findings did indicate, however, that these two processes may have different developmental trends with response execution being more heavily dependent on age, and selective inhibition less so. These findings provide support for the idea that inhibitory mechanisms may have more varied responsibilities than originally hypothesised.

Karatekin and Asarnow (1998) investigated attentional allocation during the completion of single and dual condition problem-solving tasks in 10 year olds and adults. Accuracy, response time, and pupillary dilation, as a measure of attention, were taken. On a single response time task, although children's response times were on average slower than adults, they were equally able to follow instructions, and children were no less efficient in inhibiting attention to stimuli. On a single digit span task, accuracy in children was lower than adults, and the pupillary dilation data were interpreted as indicating that children allocated fewer resources to the task. In particular, children appeared to have recruited fewer resources than adults once memory load approached or exceeded their capacity. On the dual task condition, response times in adults did not increase with increasing sequence length, whereas children's did. Accuracy in the digit span declined slightly from single to dual condition in adults, but did not differ in children.

The stimuli appeared to have been processed by children and adults in the same way on both single and dual conditions. When the demands of the task began to involve active rehearsal rather than passive retention, however, the children began to fail. The conclusions made were that 10 year olds allocated attention in a similar way to adults however their ability to recruit resources at higher loads was not on a par with adults. These interpretations implicate the development of systems of cognitive control such as the supervisory attentional system (SAS) (Norman and Shallice, 1980).

Overall the experimental findings seem to suggest that the ability to complete higher order cognitive tasks depends on the development of executive function, and therefore the central executive. These findings have also more clearly specified the processes which are under the control of the central executive. Such mechanisms are associated primarily with the ability to selectively attend to stimuli and keeping correct actions in mind, otherwise termed inhibition and monitoring respectively. Together it presumed that the ability to inhibit responses when required and to monitor information will result in strategy application and this is clearly consistent with, and builds on, the SAS framework which claims to deal with the interruption and modification of ongoing behaviour. These empirical findings further suggest that monitoring, in particular, would be implicated in working memory functions. These mechanisms appear to emerge at around 3 to 4 years of age and are fully developed by the age of 7, therefore lowered performance on central executive tasks in children aged 7 and above may, amongst other reasons, reflect developmental delay or deficits in these processes. Cognitive Complexity and Control (CCC) theory has been proposed to explain the development of monitoring abilities in children (Zelazo and Frye, 1998), and the development of the SAS has been used to explain the development changes in inhibitory control (Karatekin and Asarnow, 1998). Although there are disagreements surrounding whether developmental changes are associated with inhibitory or monitoring mechanisms, the evidence does appear to reflect the development of executive function.

The findings presented here are also consistent with more recent developments of the SAS. Shallice and Burgess (1993) present evidence from neuropsychological case studies suggesting that the SAS is not a single resource. Shallice (2002) suggests that the SAS can be fractionated and that there may be four processes associated with the SAS. These include top-down Supervisory System modulation of schemas in contention scheduling, the monitoring and checking of behaviour using a number of internally generated criteria, the specification of a required memory trace and the setting up and realisation of intentions. As both inhibitory processes and monitoring processes have been implicated in the development of executive function and therefore working memory by way of the central executive, these factors may be analogous to the separable processes of the SAS framework. It may also be possible to apply these ideas to deficits reported in ADHD and this will be considered in later sections.

The theoretical and empirical evidence for the development of working memory, clearly demonstrate the requirement for the development of executive function. If executive function is either impaired or the development of the functions are delayed in children with attentional difficulties this has implications for the adequate functioning of working memory. Section 1.3.2 will review the literature relating to atypical cognitive development, particularly as it relates to attentional difficulties, to attempt to explain how executive function and working memory may be affected.

1.3.2 Atypical Cognitive Development – Attentional Difficulties

Early theoretical accounts of ADHD centred on an attention deficit explanation. More recently, however, specific deficits in attentional capacity have not been found in some children with ADHD. Rather they have been found to be less efficient than controls in information processing which is hypothesised as due to executive function impairments (see Sergeant and Van der Meere, 1990, for a review). A large number of empirical investigations have centred on executive function in children diagnosed with ADHD (Clark et al., 2002; Charman et al., 2001; Adams and Snowling, 2001; Kempton et al., 1999; Barkley et al., 2001). All of these investigations have reported significant differences between children diagnosed with ADHD in comparison with control children on some if not all behavioural measures of executive function.

Specific support for an executive function rather than an attentional capacity explanation of ADHD comes from an investigation of impulsiveness in children with ADHD aged between 7 to 12 years. Schachar et al. (1993) found deficits in inhibitory control of an ongoing action and in the reengagement of an alternative action following this. They found no evidence that deficient attentional capacity could account for these impairments, as on a dual task participants were able to respond to both a primary and a secondary task. The results, therefore, were interpreted as reflecting a deficit in executive control of action and would therefore implicate the central executive.

A number of conditions have been linked to executive function deficits. These include learning disability, autism (Pennington and Ozonoff, 1996), and Attention Deficit/Hyperactivity Disorder (ADHD) (Barkley, 1997). The executive function deficits in these groups are often linked to impairments of other cognitive functions, such as working memory. Working memory impairments are reported to occur as a result of executive function deficits (Sergeant et al., 1999; Pennington and Ozonoff, 1996; Barkley, 1997). A number of models have been put forward to explain executive function impairments in ADHD, and how they impact on the cognitive functions that rely on them, such as working memory. These models have received some empirical support as explanations for the cognitive impairments associated with ADHD. The current models will be reviewed in section 1.3.2.1. and are summarised in table 1.1.

1.3.2.1 Models of Cognitive Function in Attentional Difficulties

Currently there are five dominant models of ADHD (Sergeant et al., 2003). Depending upon the theoretical position of each author or authors of the models, they differ in the extent to which they stress top-down or bottom-up processes. Top-down models emphasise deficit or dysfunction of the frontal cortex, whereas bottom-up models suggest the origins of attentional difficulties are in sub cortical areas (Sergeant et al., 2003). It is suggested, however, that a number of brain regions in conjunction are implicated in ADHD. In a review, Castellanos and Tannock (2002) suggest that there may be three endophenotypes that characterise ADHD, an abnormality in reward-related circuitry, deficits in temporal processing and deficits in working memory. The most widely reported brain structural abnormality is associated with the right prefrontal cortex (Castellanos et al., 1996; Filipek, 1997), however the abnormality in reward-related circuitry together with theories of delay aversion implicate lower brain regions as well as these prefrontal regions in ADHD.

1.3.2.1.1 Executive Function Model – Pennington and Ozonoff (1996)

The executive function model proposes that executive function deficits are consistently found in ADHD and, moreover, inhibition is the prominent executive function deficit in this profile. A hierarchical model, however, is not overtly proposed. Working Memory is characterised as executive in nature, and its importance in relation to inhibition stressed. Pennington and Ozonoff's (1996) model has a primary aim of distinguishing between developmental disorders by specifying on which executive functions each group fails. As the name suggests the model gives a top-down account of developmental disorders emphasising the 'frontal metaphor'. Their review of previous experimental studies of executive function in ADHD revealed that children with ADHD performed significantly worse than controls on the majority of tasks reported to measure executive function. Further, executive function deficits were found in both ADHD and autism, but not in conduct disorder or in Tourette's syndrome. The severity and profile of the executive function deficits were also found to differ between ADHD and autism with inhibitory deficits central to ADHD but not to Autism. Pennington and Ozonoff (1996) went on to suggest that there may be a double dissociation of inhibition and verbal working memory across ADHD and Autism.

1.3.2.1.2 Sergeant, Oosterlaan, and Meere van der (1999) - Cognitive-Energetic Model

The cognitive-energetic model is a bottom-up model emphasising ADHD effects at three levels, cognitive mechanisms, energetic mechanisms and executive function control systems. The model predicts that disorders with common problems with executive function control systems can be differentiated at an energetic level or at elementary cognitive stages. The cognitive energetic model has its basis in bottom-up processes, suggesting the root of the ADHD deficit is at sub-cortical or brain stem regions. The model attempts to incorporate both delay aversion (the reward-punishment relationship) and inhibition models. This model does not suggest a single executive function deficit in ADHD. Rather inhibitory control is highlighted as key to ADHD, and is thought to be reliant on reward, or bottom-up, mechanisms. Sergeant et al. (1999) consider executive function to be associated with five principal domains, inhibition, set-shifting, planning, fluency and working memory. The model proposes that working memory deficits in ADHD are associated with problems of inhibition of responding.

1.3.2.1.3 Behavioural Inhibition / Activation Model – Quay (1997)

Quay's (1997) under functioning BIS hypothesis was based on the behavioural inhibitory system (BIS) proposed by Jeffery Gray (1985; 1987; 1991; cited in Quay, 1997) and simply describes the underlying bottom-up processes involved in inhibitory control. Quay's model also attributes both top-down and bottom up process to inhibitory control and suggests that they are compatible. The BIS is thought to respond to stimuli for punishment, causing passive avoidance and extinction. The output of the BIS causes the cessation of ongoing behaviour, increases non-specific arousal, and focuses attention on relevant environmental cues. These properties make the BIS important to the understanding of inhibitory ability. The anatomical location of the BIS is thought to be in the septo-hippocampal area and its connections to the frontal cortex. Quay suggests that in addition to providing a descriptive model of the core deficit in ADHD, the anatomical definition of the BIS allows it to be investigated using neuroscientific techniques. Brain imaging studies comparing the volume of brain regions implicated in the BIS in ADHD and control children are reviewed by Quay.

1.3.2.1.4 The Delay Aversion Model – Sonuga-Barke (1994) / The Dual Pathway Model (2003)

The Delay Aversion Model of ADHD was proposed by Sonuga-Barke (1994). This model countered the claim that children with ADHD have an inhibitory control deficit, and suggested that they are 'delay aversive' instead. The model is a bottom-up model suggesting that deficits are in motivation, and was based on findings that hyperactive children preferred to reduce overall delay rather than maximise reward during a task where they were asked to choose between small immediate and large delayed rewards (Sonuga-Barke et al., 1992). This finding only occurred, however, when the choice of the immediate reward led to shorter duration of the task in total irrespective of the amount of reward available. When the experimenter paced the length of the trials, ADHD children waited for the larger delayed reward. Sonuga-Barke suggested that models based on an impairment of inhibitory mechanisms could not explain these findings, however his motivationally-based account could. More recently Sonuga-Barke (2003) has suggested there may be a place for the inhibition hypothesis in a 'dual-pathway model of ADHD'. This model attempts to bring together top-down and bottom-up approaches to account for different sub-types of ADHD with different developmental pathways. The model predicts that both delay aversion and deficient inhibitory control is associated with combined type ADHD, and that these processes are dissociable at the behavioural level and associated only at the neuro-biological level.

1.3.2.1.5 The Inhibition Model - Barkley (1997)

Barkley (1997) put forward a unifying model to explain the cognitive deficits involved in ADHD. The theory has its basis in neuropsychological theories of the function of the prefrontal lobes. Poor behavioural inhibition is implicated as the central deficit in ADHD. In particular the model is suggested as more applicable to ADHD children who are of predominately hyperactive type and are more likely to be affected by poor behavioural inhibition or impulsivity, compared to children who have predominately inattentive type ADHD. This makes this model particularly applicable to children whose problems with inhibition are directly affecting their school functioning. The model suggests that this group of children are unable to delay responding to stimuli around them even in the pursuit of goals, and this deficit arises firstly from the prefrontal and frontal cortex of the brain. A deficit in the principal executive function, response inhibition, leads to a deficit in four further executive functions, working memory, internalisation of speech, self-regulation of affect-motivation-arousal, and reconstitution. This results in decreased control of motor behaviour. It is suggested that the four subordinate executive functions depend on response inhibition for their effective performance. The anatomical location of these functions is thought to be the brain's motor system, the prefrontal and frontal cortex. Barkley suggests that behavioural inhibition can be assessed by performance on cognitive and behavioural tasks that require withholding of responding, delayed responding, and resisting distraction.

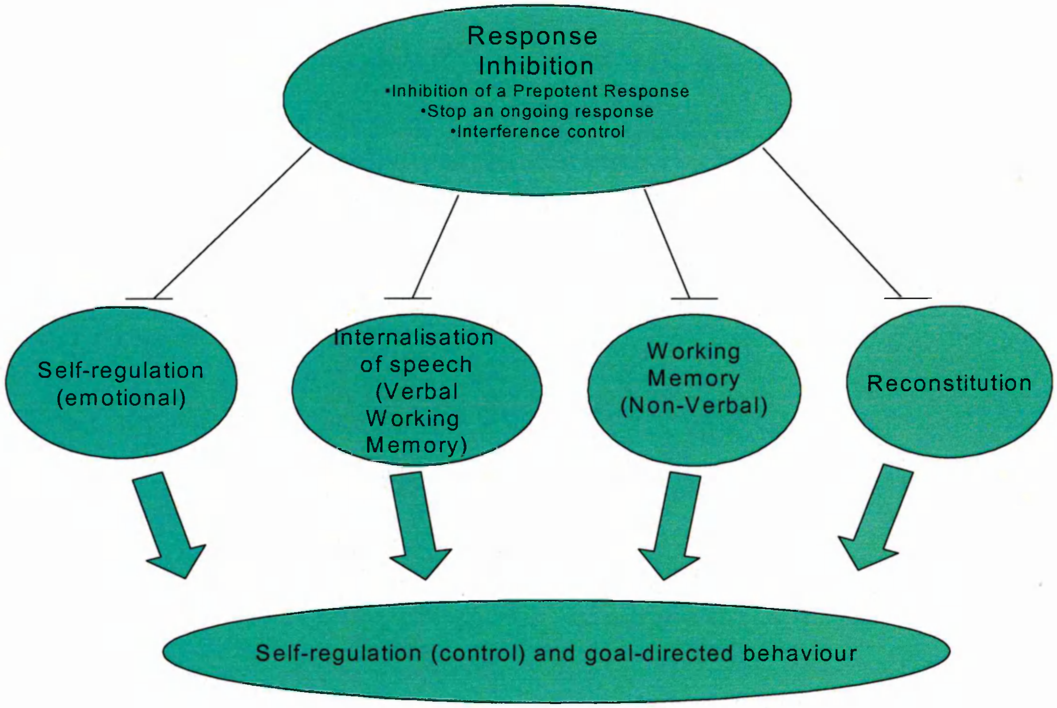


Figure 1.4: Barkley's (1997, p.73) conceptual model linking response inhibition to the performance of the other four executive functions.

Barkley's concept of response inhibition encompasses three activities or responsibilities. These are stopping an ongoing response, inhibition of a prepotent response and interference control. Working memory as it is referred to here represents visuo-spatial working memory or the short-term retention of visuo-spatial information. Self-regulation deals with emotional self-control, social perspective taking, drive and motivation and regulation of goal directed action amongst others. Internalisation of speech can also be thought of as verbal working memory, or the short-term retention of verbal information. Reconstitution is the executive function which analyses and synthesises behaviour, controls behavioural and verbal fluency, and behavioural simulations such as the acting out of an event in the mind.

1.3.2.2 Overview of the models

Each of the models summarised in the previous sections, like the literature on typical cognitive development, use the inter-related terms executive function, attention, inhibition, and working memory to account for the manifestations of ADHD. The premise of each of these models is that the term executive function, which summarises top-down processes which may have their origins in reward-punishment circuitry, are impaired in children with ADHD and, therefore, have a detrimental effect on higher level cognitive processes such as working memory. Barkley (1997) uses the term executive function to describe both response inhibitory processes and the higher cognitive processes, such as non-verbal working memory, which are dependent on response inhibition. Pennington and Ozonoff (1996), however, describe only processes associated with executive attention or response inhibition as executive function. Bottom-up models (Sonuga-Barke, 1994; Quay, 1997) do not distinguish between different executive functions as these models favour motivational hypotheses to explain ADHD, and could therefore be considered as part of the cognitive-energetic model (Sergeant et al., 1999).

Table 1.1: A summary table of the current models of executive function in ADHD

Author(s)	Model	Neuropsychological basis	Description	Working memory	Empirical Support	Strengths	Weaknesses
Pennington and Ozonoff (1996)	Executive Function	Top-down	Not hierarchical, inhibition prominent in EF deficit profile for ADHD.	Refers to central executive responsibities Suggests working memory is key to understanding the links between EF tasks and the functioning of the Prefrontal cortex.	Adams and Snowling (2001) – impaired on planning and inhibition but not working memory. Scheres et al. (2004) – impaired on inhibition, planning and fluency. Shallice et al. (2002) – impaired on most measures of EF.	Provides empirical evidence by comparing and contrasting clinical groups known to have executive function deficits. Importance of the central executive highlighted.	Details unclear for empirical testing.
Sergeant, Oosterlaan, and Meere van der (1999)	Cognitive-Energetic	Bottom-up	Emphasises ADHD effects at three levels, cognitive mechanisms, energetic mechanisms and executive function control systems. Does not suggest a single executive function deficit but inhibitory control is highlighted and is linked to bottom up mechanisms.	Working memory considered to be one of five principle domains of executive function. Provides a clear outline of the executive nature of working memory.	Shallice et al. (2002) - impaired on most measures of EF. Charman et al. (2001) - impairments on measures of inhibition but not on planning.	Comprehensive Clear account of where working memory fits in the model. Clearly distinguishes between working memory and executive function.	Requires more detail on inhibitory control at higher level. Details unclear for empirical testing.

Quay (1997)	Behavioural Inhibition / Activation	Bottom-up	Based on behavioural inhibitory system – underlying bottom-up processes involved in inhibitory control. Attributes both top-down and bottom-up processes to inhibitory control. Inhibitory control highlighted	Does not cover higher order cognitive constructs such as working memory.	Not reviewed.	Provides good bottom-up/neuropsychological account of inhibitory control.	Does not go on to explain behavioural manifestations associated with inhibitory control deficits.
Sonuga-Barke (1994; 2003)	Delay aversion / Dual pathway	Bottom-up	Deficits in motivation rather than inhibitory control Although more recently suggested inhibitory control deficits could characterise some sub-types of ADHD.	Does not cover other aspects higher order cognitve function such as working memory	Not reviewed.	Provides a detailed account of bottom-up processes associated with delay aversion and inhibitiory control.	Does not attempt to explain deficits in other cogntive constructs such as working memory at the behavioural level.
Barkley (1997)	Inhibition	Top-down	Poor behavioural inhibition results in deficits in working memory, internalisation of speech, self-regulation and reconstitution. Plus motor deficits.	Nonverbal and verbal working memory described as EF's Working memory EF's are subordinate to the EF of inhibitory control	Lawrence et al. (2002) – impaired on some measures of inhibition and working memory. Charman et al. (2001) - impairments on measures of inhibition but not on planning. West et al. (2004) – impaired on measures of response inhibition Berlin et al. (2004) - impaired on all measures of Barkley's model except a measure of motor contorl. Muir-Broaddus et al. (2002) – impaired on response inhibition and working memory. Mahone et al. (2002) impaired on measures of inhibition and working memory. Shallice et al. (2002) – impaired on working memory and on inhibition but attributed to the SAS.	Is more specific than other models in terms of inhibition by describing three activities of inhibtory control. Hierarchical arrangement of the model builds on other models of EF in ADHD. Provides a good framework for empirical testing, and therefore has received a lot of empirical support.	Relationship between the EF of inhibitory control and the subordinate EF's such as verbal and non-verbal working memory not clearly specified. Unclear whether the model includes executive responsiblities of working memory namely CE responsibilities or just slave systems. Provides a clear model ammenable to empirical testing.

The top-down models reviewed here describe executive function as having the property of executive attentional control which in turn appears to have the property of inhibitory control and monitoring. The processes of executive attentional control also appear to be required for the processes Barkley (1997) terms response inhibition for stopping an ongoing response, inhibition of a prepotent response and interference control. These processes, whether termed executive function, executive attention, or response inhibition are thought to be needed for higher level cognitive processes, in particular working memory.

Working memory features highly in all these models, particularly those based on explanations regarding top-down processing (Barkley, 1997; Pennington and Ozonoff, 1996; Sergeant et al., 1999). Working memory is emphasised in Pennington and Ozonoff's model, and they suggest that the construct is key in understanding the links between executive function tasks and the functioning of the prefrontal cortex. It should be noted that the term working memory used here refers only to the executive part of the system, termed the central executive by Baddeley and Hitch (1974). Sergeant et al. (2003) clearly outline how they distinguish working memory and executive attention suggesting that working memory requires executive attention to function adequately and that inhibitory control is a property of executive attention. Barkley's (1997) model suggests that the activities of response inhibition, stopping an ongoing response, inhibition of a prepotent response and interference control, are needed for the adequate functioning of working memory. The three top-down models of executive function are all consistent with the idea that attentional difficulties are associated with a deficit in central executive function and therefore the Supervisory Attentional System (SAS) (Norman and Shallice, 1980).

Most of the EF models presented here suggest that inhibitory control is key to cognitive functioning in ADHD, Barkley's model goes one step further to incorporate this idea clearly into the model by placing it above the other suggested executive functions in a hierarchy. Barkley's model also goes further to identify separate activities associated with inhibitory control. It is a clear and simple model which lends itself well to empirical testing.

1.3.2.3 Empirical findings of investigations based on models of higher order cognitive function in children with ADHD

A number of the models presented above to explain ADHD have been tested using children with attentional difficulties to assess their utility in characterising these disorders. The model that has most often been subjected to testing is Barkley's model, probably due to its structure lending itself well to empirical testing. The most recent of these investigations are summarised below (table 1.2) in the form of a meta-analysis. The majority of these investigations were based on Barkley's (1997) inhibition model (Lawrence et al., 2002; Charman et al., 2001; West et al., 2002; Berlin et al., 2004; Muir-Broaddus et al., 2002; Mahone et al., 2002), although Adams and Snowling (2001) referred to Pennington and Ozonoff's (1996) executive function model, as well as Baddeley's (2000) working memory model, and Scheres et al. (2004) referred to Pennington and Ozonoff's model only. Shallice et al. (2002) referred to all of current models with the exception of Sonuga-Barke's (1994) Delay Aversion Model. Most of these investigations have reported lowered performance in attentional difficulty groups in comparison to controls on a number of cognitive tasks.

Table 1.2: A summary table of recent empirical investigations of executive function and attentional difficulties based on current executive function models of ADHD

Author(s)	Sample	Matching	Cognitive Model	Measures and Results			
				EF Tasks	EF/Constructs	Other Tasks	Relative performance of AD group to controls/archival data
Lawrence et al. (2002)	6-12 yr olds. Females excluded, IQ80, AD Group (n=57) Diagnosed, PR ADHD-PI & CT, CoM Ex. NC Group (n=57) SR.	Individually matched - age (within 6 months), - performance IQ (within 1 SD).	Barkley (1997)	Videogame - Target Game (Point Blank) Adventure Game (Crash Bandicoot) Zoo - Simple Route, Complex Route	Behavioural Inhibition Nonverbal WM Verbal WM Reconstitution Motor Control Flexibility	WISC	Impaired on interference control but not inhibition of a prepotent response or interruption of an ongoing response. Working memory impairments in videogame but not zoo task. Reconstitution did not differentiate the groups as hypothesised. Motor control – slower on more challenging tasks.
Charman et al. (2001)	6-11 yr olds. Females excluded, IQ in normal range. AD Group (n=22)= Diagnosed, TR, ADHD –CT. CoM Ex, OffMed. NC Group (n=22) = TR	Group matched for age. Significant group differences on IQ - controlled for in analysis.	Barkley (1997), but credits all other models	Tower of Hanoi GoNoGo Paradigm	Executive Function	WISC-III Social Competence Theory of mind	Impaired on measure of inhibition – GoNoGo. No differences on ToH
Adams and Snowling (2001)	8-11 yr olds. IQ80. AD Group (n=21, 17 boys, 4 girls) = TR as 'hyperactive'.	Individually matched for sex, age and IQ.	Pennington and Ozonoff (1996) and Baddeley (1996)	EF tasks: Trails Task Visual Search Modified Opposite Worlds WM Tasks: Digit Span	Executive Fucntion	Fluency measures: Counting forwards Counting Backwards Articulation rate	Impaired on trail task and MOW task, which required the inhibition of a prepotent response. Impaired on phoneme deletion but not on any measure of fluency or working memory.

	NC Group (n=21, 17 boys, 4 girls) = TR.			Counting Span		Motor skill Literacy tasks: Phoneme deletion Decoding skill Spelling	
Shallice et al. (2002)	7 - 12 yr olds. 2 Subgroups divided by age. 7-8 yrs (ADHD=10, NC=16), 9-12 yrs (ADHD=21, NC=17). IQ in normal range	Group matched for sex, IQ, and age (No significant group differences on IQ and age).	All models credited with the exception of Sonuga-Barke (1994, 2003)	The Junior Brixton Spatial Rule Attainment Test. The Junior Hayling Sentence Completion Task N-Back Working Memory Task Letter Fluency SART Vigilance Task Number Stroop Task	Executive Function	WISC-R Modified Silhouettes Test Token Test	Impaired on all tasks except letter fluency. Interpret findings as not impaired in stopping or inhibiting processes, but attribute failures to a failure of the SAS.
	AD Group (n= 31, 29 boys, 2 girls), Diagnosed, PI, PR, TR ADHD, CoM Ex.						
	NC Group (n=33, 28 boys, 5 girls).						
Scheres et al. (2004)	6-12 year olds, Females Excluded, IQ70.	No significant differences between groups on age or IQ. Age, IQ and Non-EF measures covaried in the analyses, Comobidity considered in the analyses.	Pennington and Ozonoff (1996)	The Stop Paradigm	Inhibition of a prepotent response	WISC-R Categories Test of the SON-R	Deficits in interference control, inhibition of ongoing responses, planning and letter fluency. Differences disappeared, however, after controlling for age, IQ and non-EF measures. Question distinctiveness of different forms of response inhibition.
	AD Group (n=23) = Diagnosed, PI, PR, TR ADHD-CT, ADHD-I and ADHD-HI, Off-Med, CoM Inc.			Circle Tracing Task Follow Task	Inhibition of an ongoing response	Corsi Block Tapping Test	
	NC Group = PR, TR (n=22).			Stroop Color-word Test Flanker task	Interference Control		
				TOL	Planning		

				WCST	Set-shifting		
				Self-ordered pointing Task (SOP)	Working Memory		
				COWAT	Verbal Fluency		
West et al. (2002)	6-13 yr olds, females excluded, IQ80.	Individually matched within 3 months of age. No significant group differences on age, verbal IQ or performance IQ.	Barkley (1997)	SART	Response Inhibition		Impaired on all three measures, however, ADHD group made significantly fewer impulsive responses.
	AD Group (n=50= Diagnosed, PR, ADHD-I (n=14) ADHD-CT (n=36). CoM Ex.			The Children's Memory Scale	Memory		
	NC Group (n=50) = SR			TEA-Ch	Attention		
Berlin et al. (2004)	7-10 yr olds, females excluded, IQ70.	Individually matched on age and ethnic background. 2 matched controls for each ADHD child.	Barkley (1997)	Go/No-go paradigm	Inhibition of a prepotent response	WISC	Impaired on all measures of EF except repetition of hand movements.
	AD Group (n=21) = Diagnosed, PR, TR, SR, OffMed, CoM Inc, ADHD-HI, ADHD-CT,			Stroop Task	Interference Control		
				Kaufman Hand Movements Test	Working Memory		
	NC Group (n=42)= PR.			Time reproduction task	Non-verbal working memory		
				Puzzle Cheating Task	Internalisation of speech		
				CPT - Omission errors Parental Rating Scale	Self-regulation of Affect/Motivation/Arousal		
				Analysis and synthesis of a short story	Reconstitution		

Muir-Broaddus et al. (2002)	Diagnosed ADHD (n=78, 57 boys, 21 girls). Mean Age 11yrs 10months. IQ above 70, OnMed, ComInc.	Archival data Compared to Norms and Parent Behavioural Ratings	Barkley (1997)	California Verbal Learning Test - Children's Version Vigil Continuous Performance Test WSCT	Response Inhibition	Multilingual Aphasia Examination (MAE) Token Test WRAML WISC-III to measure Span of attention VCPT to measure sustained attention CVLT-C WRAML to measure single-trial learning CVLT-C WRAML to measure learning with repition WISC-III to measure working memory WJ-R to measure academic achievement	Performed poorly relative to norms on span of attention, sustained attention, response inhibition and working memory. In normal range on measures of retention.
Mahone et al. (2002)	6-16 yrs old. IQ80. AD Group (n = 51) = Diagnosed ADHD-I, ADHD-HI, ADHD-CT, PI, PR (32 males, 19 females), CoM Ex. NC group (n=41) = PR (18 males, 23 females).	Age, sex, presence of LD, IQ, and FSIQ were controlled for in the analyses.	Barkley (1997)	Rey Osterrieth Complex Figure (ROCF)	Planning, visual working memory	WISC-R WISC-III	Impaired on working memory aspect of the ROCF. Made significantly more commission errors, and greater variability of responses. Not impaired on fluency or planning measures.
				Tests of Variables of Attention - Visual Test (TOVA)	Inhibitory control, response preparation		
				Letter Word Fluency	Unclear		

Key to Terms: ADHD = Attention Deficit/Hyperactivity Disorder; ADHD-CT = ADHD-Combined Type; ADHD-PI = ADHD-Predominately inattentive type; ADHD-HI = ADHD Predominately Hyperactive-Impulsive type. Diagnosed = Meeting criteria for DSM-III/DSM-IV ADHD (APA,1987; 1994).

Group Membership allocated using - PI = Parent Interview, PR= Parent Rated, TR = Teacher Rated, SR = School Records.

Med = On medication, OffMed = Off medication or never been on medication, IQ70 = IQ is 70 or above, IQ80 = IQ is 80 or above, CoM Inc = Comorbid diagnoses present, CoM Ex = Comorbid diagnoses excluded.

Key to Tasks: WCST = Wisconsin Card Sorting Task, WISC/WISC-R = Wechsler Intelligence Scale for Children, TOL = Tower of London, TOH = Tower of Hanoi, COWAT = Controlled Oral Word Association Test, SON-R = Smijders-Oomen Non-verbal Intelligence test, SART = Sustained Attention to Response Task, TEA-Ch = The Test of Everyday Attention for Children, CPT = Continuous Performance Test.

Empirical findings are varied on measures of response inhibition, however, most investigations found that at least one activity associated with inhibitory control was impaired in ADHD groups. In Lawrence et al.'s (2002) investigation interference control was found to be impaired in ADHD children. The same investigation, however, found no evidence of impairment on measures of inhibition of a prepotent response or interruption of an ongoing response. Charman et al. (2001) found impairments in the ADHD group on the GoNoGo task that appears to measure the interruption of an ongoing response. Adams and Snowling (2001) found impairments in an ADHD group on tasks which required the inhibition of a prepotent response. It was reported by Scheres et al. (2004) that ADHD children were impaired on measures of interference control, inhibition of an ongoing response but not the inhibition of a prepotent response, and these differences disappeared after controlling for age, IQ and non-EF measures. Berlin et al. (2004) measured inhibition of a prepotent response and interference control and found both impaired in children with ADHD, they did not measure, however, interruption of an ongoing response. Impairments on a measure of response inhibition were also found by Muir-Broaddus et al. (2002) and Mahone et al. (2002) found that the ADHD group made more commission errors and the variability of responses was greater in this group on a measure of inhibitory control. Shallice et al. (2002) although finding a lowered performance by the ADHD group on measures of inhibitory control, attributed the findings to an impairment associated with the SAS. They suggested the finding that the ADHD group were less likely to be able to report using a strategy was due to strategy generation processes of the SAS being impaired. The explanation of this interpretation was, however, unclear.

Most of the empirical investigations administered measures of working memory and most reported that children with ADHD were impaired on these measures (Mahone et al., 2002; Muir-Broaddus et al., 2002; Berlin et al., 2004; Shallice et al., 2002). Lawrence et al. (2002), however, demonstrated impairment in working memory in ADHD children only in one of two task settings that were proposed to reflect 'real life' situations. Working memory was found to be impaired in the ADHD group on the videogame task but not during a visit to the zoo. Adams and Snowling (2001) found no differences with children rated as hyperactive and controls on a measure of working memory. Measures of emotional self-regulation, however, were only applied by Berlin et al. (2004) who found that the ADHD group were impaired on this measure.

By far the most disputed impairment attributed to response inhibition in ADHD is termed by Barkley (1997) as reconstitution. This executive function is normally assessed using fluency measures. Verbal fluency, non-verbal fluency and ideational fluency measures are usually applied to assess this executive function. Scheres et al. (2004) administered a verbal fluency task only and found that ADHD children were impaired on this task. These differences disappeared, however, after controlling for age, IQ, and non-executive function measures. Berlin et al. (2004) also reported impairments in ADHD children on a measure of reconstitution. A number of investigations, however, did not find any differences between groups on measures of fluency (Lawrence et al., 2002; Adams and Snowling, 2001; Shallice et al., 2002; Mahone et al., 2002). It should be noted, however, that the majority of these investigations only employed measures of verbal fluency, neglecting nonverbal and ideational fluency. This should be addressed by testing all aspects of fluency in children with attentional difficulties.

Most of the investigations reviewed here provide some support for Barkley's (1997) model in explaining attentional difficulties. The most consistent findings are impairments in children with attentional difficulties on measures of executive attentional control such as those described by Barkley as constituting response inhibition. Further, working memory measures often significantly differentiated the groups. The majority of these investigations, therefore, drew strong associations between executive attentional control processes such as inhibitory processes and working memory. Other cognitive functions hypothesised as dependent on response inhibition did not clearly differentiate the groups suggesting that the demands for executive attentional mechanisms were lower for these tasks.

Before making any firm conclusions regarding these empirical findings, however, methodological factors should be taken into account. Although most of these investigations have applied matching and exclusion criteria in the selection of their samples these criteria vary from study to study. Some of the studies have individually matched participants (Lawrence et al., 2002; Adams and Snowling, 2001; West et al., 2002; Berlin et al., 2004;), others have group matched the participants (Charman et al., 2001; Shallice et al., 2002) or controlled for group differences in the analysis (Scheres et al., 2004; Mahone et al., 2002), and one investigation used only an ADHD group and compared findings to archival norm data (Muir-Broaddus et al., 2002). Most of these investigations matched on age, sex, and IQ, although one went further to match for ethnic background (Berlin et al., 2004).

Differences in matching procedures can make comparisons between the findings of investigations difficult. More important, however, are the measures used to assess group membership. The majority of the these investigations use ADHD diagnosed groups, the exception being Adams and Snowling (2001) whose objective was to assess children rated by teachers as hyperactive. Some of the investigations using ADHD samples have supplemented a clinical diagnosis with parent interviews (Shallice et al., 2002; Scheres et al., 2004; Mahone et al., 2002), parent (Shallice et al., 2002; Scheres et al., 2004; Lawrence et al., 2002; West et al.,2002; Berlin et al., 2004; Mahone et al., 2002) and teacher ratings (Shallice et al., 2002; Charman et al., 2001; Berlin et al., 2004), and school records (Berlin et al., 2004). Muir-Broddus et al. (2002), however, did not supplement a diagnosis of ADHD. Adams and Snowling (2001) used only teacher ratings to select groups.

Some investigations restricted participant selection criteria to those with a particular sub-type of ADHD, combined type, predominately hyperactive type, or predominately inattentive type. Others, however, did not differentiate between subtypes (Shallice et al., 2002; Muir-Broaddus et al., 2002). This may have implications for the interpretation of the findings, as it may be the case that particular symptoms of subtypes of ADHD may reflect particular cognitive impairments, which others do not and it may be that this detail is lost if groups are not clearly defined. Further, some investigations included participants who had comorbid disorders (Scheres et al., 2004; Berlin et al., 2004; Muir-Broaddus et al., 2002), whereas others eliminated such participants. If disorders are not clearly defined as in the inclusion of participants with comorbid disorders this will have similar implications for the interpretation of the findings, in that if cognitive impairments emerge these may be a result of comorbid rather than attentional disorders.

Although the majority of these investigations were based on current models of executive function in children with ADHD, the tasks which they employed varied widely, again making comparisons of findings difficult. This is a difficulty common to all investigations of higher order cognitive function, as definitions of executive function are not universal (see section 2.4.2.1). Commonly used tasks to assess executive function are the Tower of Hanoi (ToH) (Handley et al., 2002) or Tower of London (ToL) (Shallice, 1982) tasks, Stroop tasks (Kane and Engle, 2003), Wisconsin Card Sorting Task (WCST) (Heaton, 1981; 1993), Go no go (Charman et al., 2001) and n-back (Shallice et al., 2002; Vuontela et al., 2003) paradigms, digit recall (Pickering and Gathercole, 2001), continuous performance tasks (CPT) (Conners, 2002), word fluency (Benton, Hamsher, and Sivan, 1983). These tasks are proposed to demand higher order cognitive processing. Some are problem solving tasks, e.g. ToL and ToH, but others require the inhibiting of a prepotent response, e.g. stroop tasks, WCST, go no go paradigms, CPT. Further, a number of tasks aim to tap working memory functions, e.g. digit recall, n-back paradigm. Some of these tasks, inevitably, will have cross over demands for both executive function and working memory.

In addition to the use of different tasks, claims about what these tasks actually measure also vary in these investigations. These varying functions go from more specific, e.g. inhibition of a prepotent response, inhibition of an ongoing response, interference control, planning, set-shifting, verbal working memory, non-verbal working memory, fluency, motor control, flexibility to less specific, e.g. memory, attention, response inhibition.

Despite these criticisms these investigations demonstrate a clear pattern of dysfunction in executive attentional mechanisms in children with attentional difficulties in comparison to control groups. Further this appears to have a detrimental impact on working memory abilities. Failures at differing levels of executive attentional control by the attentional difficulty group across investigations could be explained by the different matching criteria applied or differing tasks used. Although, generally, the central executive and SAS models go unmentioned in the models of EF in ADHD presented above, and are rarely (Shallice et al., 2002) used to explain empirical findings, a number of these findings could be explained with reference to these models. The following sections will deal with how these findings concerning executive function relate to working memory in children with attentional difficulties, and will reflect on central executive and SAS frameworks.

1.3.3 Working Memory and Attentional Difficulties

The previous sections on models of cognitive function (1.3.2.1) and empirical findings using psychological test batteries (1.3.2.2) have illustrated the importance of working memory in attentional difficulties. The majority of studies investigating executive function in ADHD populations have included a measure of working memory, although no single definition of working memory is used in these contexts. Barkley (1997) and Barkley et al. (2001), for instance, used tasks that are proposed to measure verbal working memory and non-verbal working memory. These are similar but not directly comparable to tasks that measure the phonological loop (PL) and visuo-spatial sketchpad (VSSP) mechanisms of the Baddeley and Hitch (1974) model of working memory.

The theoretical basis for using these tasks does, however, borrow heavily from the Baddeley and Hitch (1974) model but the term 'working memory' is used to describe a particular type or types of executive function. These processes are measured using tasks such as digit recall to measure verbal working memory, and Corsi blocks (Corsi, 1972) /Simon game (Barkley et al., 2001) to measure non-verbal working memory. Although most investigations of ADHD do not clearly define working memory, strong associations between ADHD and working memory are usually implied, as are associations between working memory and executive function. Further, empirical investigations of other neuropsychological deficits have found support for a link between working memory and executive function. A study of patients with Parkinson's disease, for example, found that auditory and visual working memory measures were related to measures of executive function (Cecil et al., 1999).

A review of the investigations of working memory in developmental disorders and specifically in attentional disorders will follow. The aim of these sections will be to firstly demonstrate the utility of the working memory construct for characterising attentional difficulties, and secondly, for explaining the association between working memory and executive function in children with attentional difficulties.

1.3.3.1 Investigations of working memory in developmental disorders

Although few experimental studies investigating ADHD have used Baddeley's working memory model, the model has been used in investigations of other disorders. Learning disability (Swanson and Ashbaker, 2000), Down's syndrome and Williams syndrome (Jarrold et al., 1999), Schizophrenia, Alzheimer's Disease (Borgo et al., 2003), and Parkinson's Disease (Owen et al., 1997) are all disorders which have been investigated using the working memory framework. These investigations have both provided interesting insights into such disorders, and strengthened the argument for separable subsystems in working memory.

The relevance of investigating working memory impairments in developmental disorders is the impact they have on everyday achievement. The importance of working memory for academic achievement was highlighted by Gathercole and Pickering (2000). They presented an investigation demonstrating that 6 and 7 year olds with low attainment on English and maths performed more poorly on measures of complex working memory in comparison to children with normal attainment levels. This impairment was demonstrated on visuo-spatial and central executive components in particular.

Despite the fact that very few studies have focussed specifically on the Baddeley and Hitch (1974) model of working memory in ADHD, some empirical support has been provided for a link between working memory difficulties and ADHD. Karatekin and Asarnow (1998) for example, investigated working memory in schizophrenia and ADHD. Their findings indicated that both children and adolescents with schizophrenia and those with ADHD demonstrated deficits in verbal working memory using a digit span task and spatial working memory using a dot test, in which children and adolescents with a mean age of 14 years were presented with a dot on a page and were asked to mark its location on a blank page.

Further, McInnes et al. (2003) investigated listening comprehension and working memory abilities in children with ADHD, both with and without language impairments (LI). Basic language and cognitive skills tasks, verbal and spatial working tasks, and listening comprehension tasks were administered. The findings indicated that ADHD children did not differ from normal children in verbal span, but demonstrated significantly poorer verbal and spatial working memory. These findings suggested that memory capacity was not the cause of working memory deficits in children with ADHD, and therefore, implicates executive function, and thus the central executive.

A more rigorous investigation into the components of the working memory model, in children with ADHD was implemented by Roodendrys et al. (2001). They examined the working memory components of the phonological loop and the central executive in three groups of children. The groups were those with ADHD and reading disability, those with reading disability without ADHD and a group of typical controls. They proposed that a central executive deficit was core to ADHD. The findings supported this assertion demonstrating a deficit in central executive function to be specific to ADHD whereas a deficit in phonological loop function was related to reading disability. Karatekin (2004) also investigated the components of Baddeley's working memory model in ADHD. An initial study investigated the slave systems of the model, the phonological loop and the visuo-spatial sketchpad. The results demonstrated that the rehearsal of verbal and visuo-spatial information undertaken by the slave systems was processed in the same manner as control children. Generalised impairments of working memory function, for example in tasks supported by only the visuo-spatial sketchpad or the phonological loop, did not occur in children with ADHD. On the basis of the initial result the central executive was assessed using a dual-task condition. The performance on this task revealed a central executive deficit in children with ADHD compared with controls.

Cornoldi et al. (2001) presented a study investigating working memory deficits in children rated as having ADHD symptoms compared to a matched control group. The groups were asked to perform a listening span task where the requirements were, to process strings of words, to tap on the table when an animal noun was presented, and to remember the last word in each string, which increased as the task continued. The last word in each string had to be recalled at the end of each block of trials, which consisted of two, three or four strings. The groups were also asked to perform a dual span task. Again, the word strings increased in length over time and the children were required to tap when an animal noun was heard and also recall every word in the string immediately after it had been presented. The findings indicated no differences between the groups on the dual task, however the ADHD group made significantly more intrusion errors on the listening span task. The findings were interpreted as indicating that the ADHD group only had difficulties with listening span working memory tasks where high control was required. They concluded that a task requiring a whole pool of material to be recalled, even if a dual request is incorporated, does not disrupt performance in ADHD groups, and suggested that this confirms that working memory deficits in children with ADHD are related to inhibition problems and more specifically to the interference control function of inhibition. In a second experiment visuo-spatial working memory was examined using a matrix task. The experimenter touched a number of positions in the matrix, creating a string. In some strings the positions were aligned vertically, horizontally or diagonally whereas in others they were not aligned. The task was to decide if the string was aligned or not and to recall the last position in a series of strings, which increased in number. If the participant touched a position which had been in the string but not at the end this was counted as an intrusion error. If the position touched had not been part of the string at all this was classed as an invention error. The findings showed that intrusion errors were more common suggesting that working memory problems are associated with suppression of irrelevant information, a responsibility of the central executive. Further the ADHD group was more likely to make intrusion errors. These findings overall can be interpreted as suggesting that working memory problems in children with attentional difficulties are associated with working memory tasks which demand interference control, which implicates the central executive. This is consistent with the viewpoint that executive attentional mechanisms such as monitoring and inhibition are implicated in central executive function and could be explained with reference to the Superviory Attentional System (SAS) (Norman and Shallice, 1980) as a difficulty applying these mechanisms to achieve the interruption and modification of ongoing behaviour.

The Karatekin (2004), Roodendrys et al. (2001) and Cornoldi et al. (2001) studies reviewed above appear to be the only investigations of children with attentional difficulties that specifically test the Baddeley and Hitch (1974) model of working memory in children with ADHD. Few of the studies which claim to measure working memory provide measures of all of the working memory components specified in the Working Memory model proposed by Baddelely and Hitch (1974). In the majority of these studies there does not seem to be a measure of the central executive or if one is used it is not clearly specified as such.

The findings suggest that the basic functioning of the slave systems, and particularly the phonological loop, of the working memory system are not affected in children with attentional difficulties. Roodendrys et al. (2001) reported that a deficit involving the phonological loop was specific to children with reading disability, rather than those with ADHD. It appears to be case that tasks which do not demand central executive processes or the SAS are relatively unaffected in these children. The question remains, however, why investigations of the executive function profile in children with ADHD, reported in section 1.3.2.3, have found impairments on tasks which appear to be measures of the slave systems. It may be the case that these tasks which are ordinarily thought of as being dealt with by automatic processes, such as contention scheduling in the SAS framework, do load onto the central executive in children with attentional difficulties. This may be particularly true of visuo-spatial tasks which have been suggested as more complex in comparison to verbal tasks and therefore performance on such tasks is slower to develop (Baddeley, 1986). The suggestion that visuo-spatial tasks are more complex may be due to the idea that visuo-spatial material requires more manipulation compared to verbal information. This explanation implies that central executive processes are more heavily weighted on visuo-spatial rather than verbal working memory tasks. This proposal is also supported by the findings of Miyake et al. (2001) who assessed the performance of adults on a number of tasks measuring executive function, visuo-spatial working memory, visuo-spatial short term memory, spatial visualisation, spatial relations and perceptual speed. They found that visuo-spatial short term memory and working memory span tasks were related to executive functioning equally and could not be clearly differentiated. This finding implicated executive function in the performance of both storage only and storage and manipulation visuo-spatial tasks. Further, they demonstrated that the three spatial ability factors differed in the extent to which they implicated executive functioning. This appeared to be dependent the demands of the tasks for sequencing, the management of task specific goals, and the resistance to perceptual interference. They interpreted these findings as demonstrating that the visuo-spatial sketchpad has close ties to the central executive. On the basis of these interpretations this research programme will focus on visuo-spatial working memory and the central executive components of working memory.

To summarise, the results of the studies discussed previously have led to confusion over the relative importance of working memory components in the cognitive deficits associated with attentional difficulties. Also how working memory components contribute to an executive function deficit in ADHD is unclear in Barkley's (1997) model. Cornoldi et al. (2001) have gone some way to address this issue by looking at the role of inhibition in working memory tasks, however, more research is required to clarify this issue. The preceding sections have clearly illustrated the utility of the working memory construct in relation to attentional difficulties. The next section aims to illustrate how this model can be used to further define this and demonstrates how the association between working memory impairments and ADHD can be explained with reference to executive function.

1.3.3.2 Recent developments of the working memory model and their utility for the investigation of attentional difficulties.

Recent investigations into the structure of the Baddeley and Hitch (1974) model of working memory have proposed not only new components, such as the episodic buffer (Baddeley, 2000), but have also suggested that original components may be fractionated. The phonological loop is assumed to comprise two processes, one for speech perception, the phonological store, and one for speech production, the articulatory rehearsal component (Baddeley, 2000). The phonological loop appears to play an important role in language development due to its capacity for storing and rehearsing speech based information (Baddeley, 2003).

For many years, however, both the visuo-spatial sketchpad, and particularly the central executive were subjected to very little investigation. More recently, investigations have revealed that it may also be possible to fractionate the functions of both the visuo-spatial sketchpad (Logie and Pearson, 1997; Pickering et al., 2001) and the central executive (Baddeley, 1996). It has been proposed by Logie (1995), Logie and Pearson (1997) and Pickering et al. (2001) that a dissociation between activities relating to visual tasks and activities relating to spatial tasks may be possible. It is also suggested that these separable components may make varying demands on the central executive (Handley et al., 2002). Further, it has been proposed that the central executive can be fractionated into four functions (Baddeley, 1996). These new theoretical accounts may prove useful in the investigation of attentional difficulties as strong links of these to working memory function and in particular to visuo-spatial sketchpad and central executive function have been revealed following empirical findings (Roodendrys et al., 2001, Karaketin, 2004).

As section 1.3.3.1 demonstrated, the fractionation of the visuo-spatial sketchpad is of relevance here as empirical investigations seem to show that it is more likely for ADHD groups to perform more poorly than control groups on measures of visuo-spatial working memory, rather than phonological loop measures. Further, Pennington and Ozonoff (1996) suggested that there may be a double dissociation of inhibition and verbal working memory across ADHD and Autism, in that verbal working memory is relatively unaffected in ADHD groups. The phonological loop, therefore, will not be central to the investigations presented in this research programme although measures, such as articulatory suppression, to account for phonological loop function on visuo-spatial tasks will be used. Explanations for findings of differences between ADHD and control groups on measures of visuo-spatial working memory, therefore, may be better illustrated using a more articulated model of the visuo-spatial sketchpad. Whilst a distinction between visual and spatial components of the visuo-spatial sketchpad has been upheld in developmental investigations of working memory (Logie and Pearson, 1997; Pickering et al., 2001) studies of children with attentional difficulties have not investigated this difference. The proposal to investigate this further in children with attentional difficulties would be supported by Cornoldi and Vecchi (2000 cited in Vecchi et al., 2001) who suggest that a distinction between the visual and spatial parts of the visuo-spatial sketchpad may be helpful in understanding differences in visuo-spatial ability in specific populations. They propose that by using highly specific tasks to examine visuo-spatial performance it may be possible to show exactly where difficulties lie. Further, a number of these investigations refer to measures of spatial working memory (e.g. Barnett et al., 2001) rather than to visuo-spatial working memory. This implies that the task is judged to be more spatial in nature, yet often performance on this measure is not compared to a task which is visual in nature. As the remit of these investigations did not concern the fractionation of the visuo-spatial sketchpad this point remains unclear.

1.3.3.2.1 Fractionation of the Visuo-spatial Sketchpad

The proposed fractionation of the working memory model into the visuo-spatial sketchpad and the phonological loop is widely accepted. However, a proposed fractionation of the visuo-spatial sketchpad into two components has only recently begun to receive support. Evidence for the fractionation of the visuo-spatial sketch pad has emerged from a number of cognitive studies (Logie and Marchetti, 1991; Quinn and McConnell, 1996; Smyth and Pendleton, 1989; Milner, 1971; Logie and Pearson, 1997; Della Sala et al., 1999), and also neurological studies (Luzzati et al., 1998).

In a relatively early attempt to dissociate visual and spatial memory, Baddeley and Lieberman (1980 cited in Baddeley, 1986), compared two potentially disrupting secondary tasks on a primary task, the Brook's matrix task (Brooks, 1967). The Brook's matrix task required participants to retain a number of spatial relations that were given in the form of sentences. A condition was also incorporated in which participants were given nonsense sentences. The secondary tasks were firstly, a task that involved spatial but not visual processing and the second involved visual processing with limited spatial processing. The spatial task involved the participant being blindfolded and seated in front of a swinging pendulum that emitted a sound at a steady tone.

The participant was given a flashlight and when this was shone on the pendulum the tone changed. The participant was given instructions to keep the flashlight focussed on the bob of the pendulum and the participant would be aware that they were on target due to the change in tone emitted from the pendulum. The second disruption task was to make judgements of brightness. Participants were shown blank slides illuminated at two levels of brightness, they were simply required to press a key when the brighter slide appeared.

The secondary tasks were then combined with the Brooks matrix primary task. The results demonstrated that the non-visual task disrupted the retention of the spatially coded sentences more than the nonsense sentences, whereas, the nonsense sentences were disrupted significantly more by the brightness task. The spatial task was not significantly disrupted by the brightness task, thus eliminating the possibility that the spatial task was more sensitive to disruption. These findings offer clear support for the contention that visual and spatial working memory can be dissociated. The experiment appears to demonstrate that a secondary spatial task will disrupt memories which are spatial in nature and conversely that a visual task will not disrupt memories which are spatial in nature. These findings imply that separable systems deal with visual and spatial processing.

Further evidence for a fractionation of the visuo-spatial sketchpad comes from Tresch et al. (1993). The spatial task they used involved remembering the location of a dot and the visual task required memorising the form of an object. They found that spatial memory was selectively impaired by a movement discrimination task, and object memory selectively impaired by a colour discrimination task, again offering support for the idea of separable spatial and visual working memory.

An interference paradigm was implemented by Quinn (1994) to investigate the type of movement that may cause disruption in spatial processing. Predictable and non-predictable, and passive and active movements were investigated for their contribution to disruption in the form of errors on the Brooks matrix task. It was concluded that interference did occur when the task required movement to a sequence of specified targets, and when the participant knew the target sequence in advance. This implies that when a movement sequence is required to be retained, disruption is caused to the processing of other spatial stimuli, whereas when the movements are passive or predictable disruption does not occur. These findings suggest that memory for movement sequences and spatial processing are dealt with by the same system, whereas other types of visuo-spatial information are dealt with by a separate system, adding support for the previous findings of dissociable visuo-spatial systems. This is an important issue considering that most of the tasks used to assess spatial working memory require movement.

The development of the separate visual and spatial components of the visuo-spatial sketchpad was investigated by Logie and Pearson (1997). Their findings offered support for the revised model of the visuo-spatial sketchpad (Logie, 1995) presented in figure 1.5. 5-6, 8-9 and 10-11 year old children were asked to undertake visual and spatial tasks in both recognition and recall formats. During the visual task participants were presented, for a period of 2 seconds, with a grid with a number of squares filled. On the recognition version of the task, after a 2 second pause, a test grid was displayed with one filled square removed, the task was to indicate which square had been changed. On the recall version of the task the test grid was blank and the task was to indicate which squares had previously been filled. The Corsi blocks task was used to assess the spatial component of the visuo-spatial sketchpad. The examiner pointed to a series of blocks, in the recognition version of the task, after a 2 second interval the examiner repeated the sequence omitting one block. The participant was required to indicate which block was missing from the sequence. In the recall condition after the 2 second interval the participant was required to repeat the entire sequence. The findings indicated a significant advantage for visual memory for both recognition and recall versions of the tasks, and further this difference was more apparent on the recognition versions. They suggested that pattern (visual) memory develops much more rapidly across age than block sequence (spatial) memory, and this is consistent with the idea that different cognitive systems deal with static visual patterns and sequences of targeted movements. Logie and Pearson addressed alternative explanations for the results, such as level of difficulty, and concluded that if sequence memory is more difficult than pattern memory this is entirely consistent with the theory of fractionation of visual and spatial components.

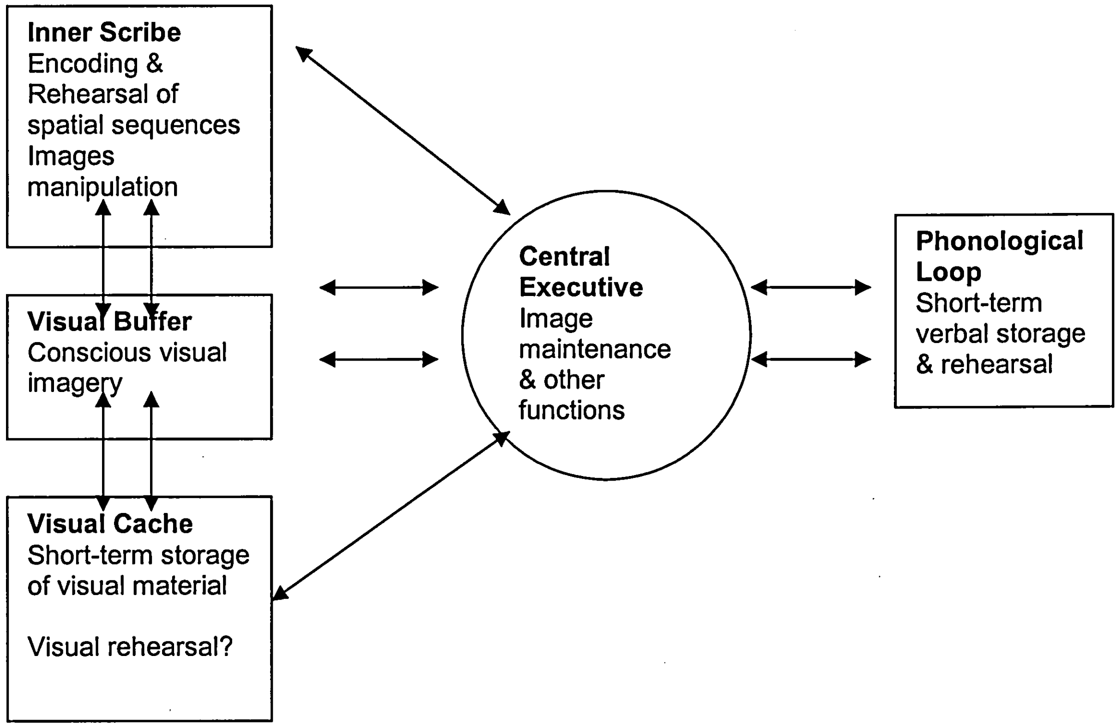


Figure 1.5: Logie's (1995) Working Memory Model including dissociation of the visual and spatial components of the Visuo-Spatial Sketchpad

Della Sala et al. (1999) provided new evidence for the visual and spatial dissociation, in addition to strengthening the reliability and validity of two tasks believed to tap on to these two components. The Visual Patterns Test (VPT) was intended as a purely visual task, shorn of its spatial and sequential elements, whereas the Corsi blocks task was thought to tap on to the spatial component. Using both double dissociation and interference paradigms Della Sala et al. (1999) provided evidence that the VPT and the Corsi Blocks task measured different functions.

Pickering et al. (2001) took a different position in explaining a fractionation of the visuo-spatial sketchpad by suggesting that the fractionation may depend on the static or dynamic properties of the tasks rather than the visual or spatial stimuli. They suggested that the tasks generally used to assess spatial and visual working memory do not only differ in their visual and spatial components but also in the extent to which the information is presented in a dynamic (in the case of spatial tasks) or static (in the case of visual tasks) format. They hypothesised that the subcomponents of the visuo-spatial sketchpad may operate on information that is either, static or dynamic in nature rather than visual or spatial and assessed this in a developmental investigation. Five, eight and ten year olds completed a mazes task in both a static and dynamic format, and a matrices task in a static and dynamic format. The findings provided evidence for a developmental dissociation in performance on static and dynamic matrices and mazes tasks as performance on the static tasks increased more steeply with age in comparison to the dynamic tasks. The results were interpreted as suggesting that the static and dynamic properties of the tasks may tap different subcomponents of the working memory system. The also found no evidence to suggest that the findings could be explained by simple verbal recoding being used on the static tasks and not on the dynamic task.

Another alternative hypothesis for the fractionation of the visuo-spatial sketchpad comes from Cornoldi and Vecchi (2000 cited in Vecchi et al., 2001). The *distributed 'continuum' model* suggested that working memory processes vary by the nature of the information that is to be processed and also the amount of active information processing which is required. These theorists make a clear distinction between 'passive' tasks that require only that a visuo-spatial representation be maintained and 'active' tasks that require maintenance and manipulation. At the passive level these theorists appear to agree with the multicomponent model in that different types of information are processed independently and the cognitive systems are domain specific, however at the active level they propose that techniques are utilised which are domain independent and require interconnections between different sensory systems.

This section has reviewed the evidence for a fractionation of the visuo-spatial sketchpad. A number of empirical investigations have provided support for this contention. Logie and Pearson (1997) concluded that visual working memory develops much more rapidly with age in comparison to spatial working memory providing support for separate visual and spatial subcomponents of the visuo-spatial sketchpad, however, Pickering et al. (2001) suggest that this is due to the static and dynamic nature of visual and spatial tasks respectively. Cornoldi and Vecchi (2000 cited in Vecchi et al., 2001) further hypothesize that the distinction within visuo-spatial working memory is due to the passive or active nature of the tasks. This final interpretation clearly implicates the central executive as active tasks are dependent on manipulation of information rather than merely maintenance. Each of these theories is based on the development of the subcomponents of the visuo-spatial sketchpad. If children with attentional difficulties are developmentally delayed in comparison to their peers in terms of cognitive function, using one of the paradigms described here may be an appropriate method of investigation particularly with regard to working memory.

1.3.3.2.2 Fractionation of the Central Executive

As Cornoldi and Vecchi's (2000 cited in Vecchi et al., 2001) hypothesis regarding the fractionation of the visuo-spatial sketchpad suggests, some visuo-spatial tasks may require input from the central executive. This suggests that some of the working memory tasks which have been administered to children with attentional difficulties may have had requirements for central executive functions. If this is the case it may provide an explanation for the association between executive attentional mechanisms and working memory task performance, as the central executive has the responsibility for recruiting these resources. It is necessary, therefore, to discuss the responsibilities attributed to the central executive in more detail.

The central executive component is the least investigated of the components (Baddeley, 1997) of the working memory model leaving many of its functions and processes little understood. The central executive is reported to coordinate activity within working memory and control the transmission of information between other parts of the cognitive system, in that, it allocates inputs to the phonological loop and the visuo-spatial sketchpad (Gathercole and Baddeley, 1993). Other theorists agree that the main functions of the central executive are storage and processing, which occur simultaneously. This process facilitates the regulation of information flow within working memory (Pickering and Gathercole, 2001; Roodendrys et al., 2001; Gathercole and Baddeley, 1993; Baddeley, 1990; 1996).

The central executive allocates attentional resources, monitors information processing and actively manipulates temporarily stored representations (Baddeley, 1986). It is assumed that incoming stimuli are dealt with by the attentional mechanisms that organise them and place them in a temporary storage facility. Information from this temporary store is transferred to the central executive. The central executive is considered to achieve problem solutions by focussing attention and using long-term memory. The central executive distributes information to the relevant slave systems where low order information is maintained and passed to the output system, high order information may be passed back to the central executive via buffers if strategies are required for the maintenance of the information, then passed back to the slave systems prior to output.

Baddeley (1990) suggested that the central executive should be thought of as an attentional system rather than a memory store. As such Baddeley suggests that the central executive is analogous to the Supervisory Activating System (SAS), a component of the Norman and Shallice (1980) model of attentional control.

Although for many years the central executive has been termed a general purpose workspace for the control of memory, more recently (Baddeley, 1996) attempts have been made to outline in detail the functions of the central executive. Comparisons to the SAS have been helpful in this process as have the empirical findings of many experiments performed by Baddeley and colleagues (see Baddeley, 1996).

The results of these investigations provided support for the fractionation of the central executive into at least four categories; firstly, the integration of information from the phonological loop and the visuo-spatial sketchpad and the capacity to coordinate two separate tasks; secondly, strategy generation and capacity to switch retrieval strategies (Baddeley, 1996; Roodendrys et al., 2001); thirdly, the capacity to attend selectively to one stimulus and inhibit the disrupting effect of another; and finally the retrieval and integration of information from long term memory (Baddeley, 1996). The functions are thought to interact depending on task demands, and can also act independently of each other, although the final function, integration of information from long term memory, will play a role in tasks which utilise each of the other three functions, and is therefore difficult to assess in isolation.

The proposal that the central executive is fractionable can be linked to the idea of the SAS as internally modular rather than internally equipotential, as Shallice (2002) suggested. This idea was based on neurological findings (Shallice and Burgess, 1993) that different areas of the frontal lobes were responsible for different cognitive functions which were hypothesised as performed by the SAS. Shallice (2002) went further to suggest that the SAS can be fractionated and that there may be four processes associated with the SAS. These include top-down Supervisory System modulation of schemas in contention scheduling, the monitoring and checking of behaviour using a number of internally generated criteria, the specification of a required memory trace and the setting up and realisation of intentions. Empirical findings are consistent with the fractionation of the central executive and these will be reviewed in the following section.

1.3.3.2.3 Empirical evidence for the fractionation of the central executive and the relevance of this for the investigation of attentional difficulties

A number of experimental paradigms have been used to offer support for the fractionation of the functions of the central executive. Dual-task paradigms have been reported by Baddeley (1996) as providing support for a specific function of the central executive for the integration and coordination of tasks. The results of investigations implementing other paradigms, not expressly investigating the separable components of the central executive, such as multi-tasking (Law et al. 2004), can also be used as evidence to support this idea. Baddeley's (1996) review outlines empirical investigations undertaken to provide evidence of the processes attributed to the central executive. These investigations were based on unfamiliar laboratory style tasks incorporating experimental manipulations. Further empirical investigations have applied these paradigms to the investigation of cognitive function in ADHD. The following section will illustrate how the empirical evidence for the fractionation of the central executive may have links to cognitive difficulties experienced by children with attentional difficulties.

Integration and Coordination of Tasks

The function relating to the integration and coordination of two separate tasks has been examined using the dual-task paradigm. Patients with Alzheimer's Disease (AD) in addition to an elderly and a young control group, were compared on their performance of two tasks proposed to need the service of the phonological loop and the visuo-spatial sketchpad respectively (Baddeley et al., 1986 cited in Baddeley, 1996). Their performance on the tasks individually was also compared to their performance when the tasks were combined. Reaction time to a tone was found to disrupt a visuo-spatial tracking task in the AD group, whereas the control group were relatively unaffected by the secondary task. This was also the case when the visuo-spatial task was paired with a digit span task, however, articulatory suppression did not have the same detrimental effect. Baddeley et al. took these findings as support for task combination, integration and coordination, as a function of the central executive, and offered arguments to discount alternative explanations such as impairment occurring on the peripheral tasks, and an overall deficit associated with intelligence.

Variations on the dual-task paradigm have been used more recently using patients with brain abnormalities. Law et al. (2004) investigated the effects of interruptions on multitasking ability in healthy participants and dysexecutive patients. Participants were given four tasks to undertake in a 10-minute period. Three of the groups were interrupted and asked to undertake another task at differing points during the main task and a final group was not interrupted at all. Results suggest that in healthy adults interruptions do not have a negative effect on multitasking efficiency. In dysexecutive patients an impaired multitasking performance was observed in comparison to controls, however the interruption condition did not impair this performance any further. The authors suggest that the results offer support for the contention that patients who have suffered brain damage particularly to the frontal lobes have difficulty in multitasking, this problem has been termed strategy application disorder (Burgess, 2000) which is argued as being due to an SAS dysfunction.

An investigation of multitasking ability using a six elements test (SET) modified for children (Siklos and Kerns, 2004) demonstrates the relevance of the theoretical fractionation of the central executive to the study of attentional difficulties. ADHD children were asked to undertake 6 different tasks in a 10 minute period, while keeping two rules in mind. Three tasks were in red boxes and three in blue boxes. The rules were that they would get most points for at least attempting all 6 tasks, although they were told it was not possible to complete all of the tasks in 10 mins, and they were not allowed to attempt tasks from two boxes of the same colour consecutively.

The ADHD group were found to attempt significantly fewer tasks than the control group, and looked at the clock significantly less. These findings were interpreted as reflecting an inability to plan and organize their behaviour, and monitor their ongoing performance to complete all tasks. The groups did not differ on the number of times a rule was broken, suggesting their ability to remember the rules was not impaired. Further, all of the children were able to answer questions about the rules after task completion, supporting this notion. Siklos and Kerns (2004) proposed that the SAS explains the results, in that the SAS would be needed for the activation of the processes found to be lacking in children with ADHD in terms of multitasking ability. They did not consider the possible role of the central executive. In addition to implicating a dysfunction in ADHD children in the integration and coordination of tasks, their evidence also suggests difficulties associated with strategy generation and the capacity to switch retrieval strategies, and also selective attention and inhibition.

Strategy Generation and the Capacity to Switch Retrieval Strategies

The second function of the central executive proposed by Baddeley was strategy generation and the capacity to switch retrieval strategies. This second proposed function had its basis in earlier findings (Baddeley, 1966) of studies of random generation, where participants are asked to generate random series of letters. The findings demonstrated that as the generation rate increased, randomness decreased. Baddeley more recently explained these findings in terms of the SAS (Norman and Shallice, 1980), and suggested that contention scheduling would normally deal with the production of letters, however, the SAS would be required to ensure that the production remained random, thus intervening if responses became non-random. The SAS was, therefore, strongly implicated in this particular function of the Central Executive due to its ability to halt ongoing schemata and activation of new schemata.

Capacity to attend selectively to one stimulus whilst inhibiting the disrupting effect of another

Selective attention was a third function Baddeley (1996) attributed to the central executive. The validity of this function was supported by findings of a series of studies comparing the performance of middle-aged to elderly participants. They were requested to perform a task, in which a key pressing response was required when a circle appeared on a screen. Performance was compared on four conditions, the first required the task to be undertaken as described, secondly accompanied by irrelevant tones, thirdly with an instruction to provide the response to both circles and tones, and finally with an instruction to switch between responding to circles or tones dependent on a cue being given.

The findings demonstrated that reaction time was reduced when the irrelevant stimuli were present and by the instruction to switch, and the elderly participants were slower than the middle-aged participants. However age differences were not apparent when IQ was taken out as a covariate. A further experiment assessed the effect of the irrelevant stimuli presentation in the same modality as the target stimuli. This included circles as the target stimuli and triangles as the irrelevant stimuli. Comparing the findings of both experiments, it was found that slower responding occurred when irrelevant stimuli had to be ignored and this was particularly the case when the irrelevant stimuli were in the same modality, again the elderly group responded more slowly overall. An interesting finding indicated that covarying IQ did not eradicate the age effect when the target and irrelevant stimuli were in the same modality. These findings were interpreted as support for selective attention as a function of the central executive, and were described as consistent with a decline in inhibitory control with age. The findings presented here, and in section 1.3.1, clearly implicate a developmental difference in the acquiring of abilities associated with task switching performance in typically developing children, and a specific pattern in the decline of these into old age. Further to these findings significant differences have been observed between 6-12 year old children with ADHD in comparison to control children using a switching paradigm (Cepeda et al., 2000). ADHD children demonstrated substantially larger switch costs in comparison to control children, on blocks of trials in which every third trial a slightly different task and instruction was given, when compared to trials in which no switch was required. Again, the findings were linked to inhibitory control and strong reference was made to the inhibitory deficit theory of ADHD (Barkley, 1997).

1.3.4 The Central Executive, the Supervisory Attentional System and Inhibitory control

Section 1.3 has demonstrated that there are clear differences between children with and without attentional difficulties in task performance on tasks which require working memory, in particular those tasks which tap the central executive, tasks which have demands for the Supervisory Attentional System (SAS), or those which need response inhibition. These cognitive resources have been termed executive functions (Barkley, 1997; Sergeant et al., 2003; Pennington and Ozonoff, 1996).

The literature reviewed here clearly demonstrates that central executive, SAS, inhibition and executive function are used as inter-related terms. It is often unclear, however, how these constructs are related. Baddeley and Hitch's (1974) definition of the working memory model makes it clear that although the central executive allocates attentional inputs for the benefit of memory whilst undertaking a task, it does not control these inputs, which are the responsibility of the executive functions. Similarly, Pennington and Ozonoff (1996) suggest that working memory and inhibition together represent executive function. The association between working memory and executive function is most clearly explained by Sergeant et al. (2003). They suggest that working memory should be better conceived as active long-term memory. They suggest that the link between working memory and executive function lies in the fact that the selective activation of long-term memory requires executive function, namely executive attention, and further they suggest inhibitory control is a property of executive attention. The investigation by Bayliss et al. (2005) reported in section 1.3.1.3 revealed that the development of complex working memory span performance in children between 6 and 10 years of age, was related to both general speed of processing and storage ability. Development of complex working memory span was attributed to not only an increase in the speed of the cognitive system with age, but also to separable increases in the speed with which processing operations can be completed and the speed with which storage items can be reactivated or refreshed. This developmental improvement in working memory could be explained with reference to attentional resources. If attentional difficulties reflect delayed development of attentional resources, such as those provided by the central executive or the SAS for the reactivation of stored items, these findings would explain why children with ADHD are impaired on measures of both working memory and executive function.

There are clear links between the theoretical constructs of the central executive and the SAS. They are both hypothesised as being required for the successful completion of higher order cognitive tasks. The SAS construct, however, seems to more clearly specify the processes involved in the control of action when higher order cognitive tasks are undertaken. The SAS describes the modulation of action selection by activating or inhibiting schemata (Norman and Shallice, 1980), whereas the central executive describes the allocation and organisation of resources for higher order cognitive tasks. The SAS also appears to take motivational influences into account. The central executive is narrower in its remit, and a benefit of this narrower approach is greater ease of fractionation of its processes. The literature is consistent with the idea that SAS processes are needed for the adequate functioning of the central executive, an inhibitory control or executive attentional control dysfunction would, therefore, disrupt the functioning of both these systems.

The central executive and SAS constructs have in common a link with consciousness. Both constructs are specified as being utilised when tasks are within the conscious awareness, and under deliberate conscious control, this aspect being crucial to their definition. The episodic buffer (Baddeley, 2000) is a relatively recent addition to the working memory model and emerges as a key construct when considering higher order cognitive tasks that demand deliberate conscious control and ultimately prospective memory. Prospective memory is a hypothetical cognitive ability that is said to enable an intention to be carried out in the future (Burgess and Shallice, 1997). Hypothesised impairments associated with central executive control and the SAS could feasibly be linked to impairments in prospective memory. It could be suggested that the service provided by the episodic buffer could be associated with the SAS, as the SAS is also proposed to have access to a representation of the environment and of intentions and cognitive capacities, and would be required for action selection.

The empirical and theoretical literature which has been presented in this section (1.3) clearly demonstrates the importance of the development of executive attentional control for adequate performance of cognitive tasks. The literature reviewed in this section (1.3.3) has further revealed that executive mechanisms such as inhibitory control and monitoring are requirements of the SAS and that SAS processes are required for the adequate performance of central executive tasks. The links between executive function, the SAS and working memory have, therefore, been illustrated and provide an explanation for the pattern of performance demonstrated by children with attentional difficulties. The lowered performance of children with ADHD compared to controls on measures of executive function and working memory is hypothesised to be a result of either deficient or delayed development of central executive and SAS mechanisms.

1.4 Conclusions

Executive function impairments are currently receiving the most support as explanations for academic underachievement in children with a diagnosis of ADHD. Various executive function models have been proposed to explain the difficulties associated with ADHD (Barkley, 1997; Pennington and Ozonoff, 1996; Sergeant et al., 2003). Both executive attentional mechanisms and working memory mechanisms have been implicated in these models and this suggests the importance of assessing executive function and working memory in children with attentional difficulties in mainstream schools.

As section 1.3.2.1 has demonstrated there have been a myriad of investigations of executive function in children diagnosed with ADHD, very few theorists have investigated executive function in children with a lesser level of attentional difficulties. As discussed in section 1.2, a theory which is gaining increasing interest is that attentional skills may lie on a continuum (Conners, 1997; Adams and Snowling, 2001). Differences in terms of attentional skills may be a result of individual differences due to a developmental delay. Evidence to support the continuum theory came from the difference in prevalence rates between countries (Taylor and Hemsley, 1995). This was taken to imply a sliding scale of symptom severity in ADHD. Further evidence came from an empirical investigation by Levy et al. (1997) who, on the basis of a twin study, concluded that the behavioural symptoms of ADHD vary genetically across the entire population. This literature clearly supports the theoretical position of attentional difficulties as a continuum, ranging from mild to severe or diagnosable, and therefore supports the investigation of attentional difficulties in children with problems but not of a degree requiring a diagnosis.

The aim of the thesis, which was stated in section 1 of this chapter, was to investigate cognitive function in children with observed and rated difficulties associated with inattention, hyperactivity and impulsivity, referred to here as attentional difficulties. The review of the literature has raised a number of important points. These include the role of executive function in the lowered performance on cognitive tasks in children with attentional difficulties, the association between executive function and inhibition, the association between executive function and working memory, and also how these are inter-related.

The review of the literature concerning the development of working memory and executive function (section 1.3.1.3) has revealed that the cognitive system undergoes a large degree of change up to the age of 7 when it becomes relatively stable (Zelazo and Frye, 1998). Further, the diagnostic criteria for ADHD, suggest that the onset of symptoms should be prior to the age of 7 years. For these reasons the research programme will focus on children in the age range 7-9 years on the assumption that diagnosable clinical difficulties associated with ADHD have not been identified in this group, and that cognitive function should be relatively stable.

The present research programme will initially select an experimental group of children. These children will be both observed by the researcher to have difficulties associated with inattention, hyperactivity and impulsivity and rated as such by teachers (AD group). The control group will be both observed by the researcher to have good attentional skills and rated as being in the typical range in terms of attentional skills by teachers (NC group). These two groups of participants will be asked to perform various cognitive tasks in order to ascertain whether they differ in their performance. Conclusions will be drawn from the pattern of success or failure by the AD group in comparison to the NC group on the cognitive tasks administered. Further, these experiments are intended to assess the relevance of the executive attentional mechanisms, such as response inhibition, to any cognitive problems identified.

It is intended that this series of studies will provide answers to the following research questions;

1 Is it possible to identify a group of children with observed and rated difficulties associated with inattention, hyperactivity and impulsivity, not severe enough for a diagnosis, in mainstream schools?

2 Do children with observed and rated difficulties associated with inattention, hyperactivity and impulsivity demonstrate a significantly lowered performance, in comparison to controls, on tasks proposed to measure the executive functions demonstrated by Barkley (1997) as impaired in children with ADHD?

3 Are there differences in performance on different visual or spatial tasks between the AD and NC groups?

4 Can differences between groups on various tasks be explained with reference to different models, such as working memory, executive function, Barkley's inhibition model, and developmental models.

2.1 Introduction

As chapter 1 has illustrated, the aims of the research programme are to investigate executive function and working memory in children with observed and rated attentional difficulties. The purpose of this chapter is to provide a detailed description, critical evaluation, and rationale for the methods that will be employed to achieve these aims. The chapter will, further, illustrate that the methods used are reliable and valid and can yield representative findings.

The first stage of the research programme was to identify the two groups of participants who would take part in the subsequent experiments. Study 1, therefore, constituted the development and administration of an observation measure for children between seven and nine years of age to be administered within mainstream classrooms and the collection of teacher ratings of inattention, hyperactivity and impulsivity using Conners' Teacher Rating Scale (CTRS:L) (Conners, 2001) for these children. When an attentional difficulty (AD) group and a normal control (NC) group had been selected using these measures non-verbal ability scores were obtained and the participants in the two groups were matched for sex, age and non-verbal ability. The remaining three experiments implemented cognitive tasks to assess hypothesised differences between the matched groups on executive function and working memory.

The methods used to assess cognitive function in children with attentional difficulties were primarily quantitative in nature, consisting of an observational study to allocate children to groups followed by a series of experimental studies. Some qualitative data was also gathered, and constituted analysis of verbal responses to fluency tasks during experiment 1 and responses to questions about the tasks employed in experiment 3. Due to the nature of the research questions quantitative methods were predominant in this thesis. The objectives of the research programme were to examine cognitive *processes* in order to explain behaviour resulting from these processes. Due to this requirement it was necessary to undertake systematic testing (Robson, 2002). This was achieved by using experimental methods employing tight control of variables, and subjecting ideas to possible disconfirmation.

2.2 Methodological Issues

There were two broad aims of the thesis to identify a group of children with observed and rated difficulties associated with inattention, hyperactivity and impulsivity and a matched control group without such difficulties, and to investigate cognitive function in these groups. It was considered important to select the groups using clearly documented and replicable observational procedures. Particularly as the population in question does not constitute a clinical group, it is vital that the selection measures are clearly operationalised to ensure replication. It is also important to ensure that valid and reliable measures of cognitive function are selected or developed.

Sample Selection

A number of issues that can complicate accurate clinical diagnoses of developmental disorders can also complicate sample selection of children with attentional difficulties. Issues of co-morbidity, age of onset, and sex differences in prevalence can result in sample selection based on criteria other than the behavioural manifestation of inattention, hyperactivity and impulsivity.

Empirical evidence has suggested that the symptoms associated with ADHD can be manifest in conjunction with symptoms of other disorders such as depression, anxiety, conduct disorder (Place et al., 2000), and psychopathic tendencies (Colledge and Blair, 2001). There is little doubt that these co-morbid difficulties could contribute to the secondary difficulties associated with ADHD. This evidence highlights the importance of selecting children whose problems are primarily with inattention and hyperactivity-impulsivity, as co-morbid difficulties will have a confounding effect on the findings of any experimental procedures. Castellanos and Tannock (2002), highlight the ways in which children with co-morbid difficulties may inadvertently be included in a research sample. They report that some studies investigating ADHD use rating scales in which ratings of hyperactivity can be confounded by aggression and oppositionality. The selection procedures implemented here were designed with these concerns in mind. The observation checklist was designed to account for behaviour associated with both inattention and hyperactivity-impulsivity and attempts to reduce the counting of behaviours associated with aggressive and oppositional actions were made by including precise descriptions of target behaviours. It is assumed, therefore, that any problem associated with teacher ratings highlighted by Castellanos and Tannock will be addressed by implementing an observation measure prior to using teacher ratings. The teacher rating scale used (CTRS:L) was specifically designed for the identification of behaviour associated with inattention, hyperactivity and impulsivity and has been shown to be reliable (Conners, 2001).

There is no upper age limit for the diagnosis of ADHD, however, it is suggested in the DSM-IV criteria for ADHD (APA, 1994) that the onset of symptoms should be prior to the age of 7 years. It was assumed, therefore, that in a group of mainstream school children if a diagnosis of ADHD was going to be made it would have already been made. A decision was made on this basis to examine children in the age range 7-9 years on the assumption that if any of these children had been displaying symptoms of inattention, hyperactivity and impulsivity at a level equal to clinically diagnosable ADHD, a diagnosis would have already been made. Further support for using this age group is derived from empirical evidence suggesting that the higher order cognitive system is typically fully developed and should remain stable by this age (Zelazo and Frye, 1998).

Although the explanations for a sex difference in ADHD prevalence are currently under debate figures show that the frequency of ADHD in boys is several times greater than girls (Barkley, 1998). One explanation for this difference concerns differences in personality attributes and that internalising symptoms of attentional disorders such as inattention may be more common in girls, and therefore are more likely to go undetected, in comparison to boys (Barkley, 1998). This might decrease the chance of problems associated with inattention being identified using traditional methods of diagnosis. It was considered important, therefore, that internalising behaviours associated with inattention, hyperactivity and impulsivity were included. As the effects of attentional difficulties will be detrimental to both boys and girls, both sexes were included in the study. To limit confounding effects of any sex difference the groups were matched for sex.

As illustrated in section 1.3.2.3, sample selection problems are common in the ADHD literature. Advantages may be gained by using the procedures developed here. Firstly, a number of studies involving children with ADHD report that the participants are diagnosed but often do not provide details of how and when they were diagnosed with ADHD. Other studies have reported the use of ADHD samples yet do not report any details of diagnosis other than teacher ratings. Despite some investigations supplying detailed information regarding diagnosis of ADHD groups there often remains the problem of the diagnosis being made in different clinics, by different clinicians, and at different times. A further advantage to be gained by using an undiagnosed group of children is that observations are made relatively blind to any difficulties the children have and therefore reducing bias which is often associated with existing labels. Section 2.3 will illustrate how these issues have been addressed.

Measures of Cognitive Function

The second methodological issue concerns the tasks employed, the findings can only be applied in the context of these tasks not generalised to other tasks. It is hoped, however, that the thesis will provide a convincing argument for children with attentional difficulties having particular problems with tasks that demand the use of common underlying constructs. Further, it is important to be fully aware of non-cognitive determinants of cognitive performance such as motivation, in the interpretation of task performance. Section 2.4 will illustrate how these issues have been addressed.

2.3 Participant Selection Procedures

2.3.1 Introduction

A number of clinical measures are used for the diagnosis of attentional disorders. These include diagnostic interviews with the child, parents and teachers, neuropsychological tests, cognitive tasks and parent and teacher rating scales (Zaparniuk and Taylor, 1997). A combination of measures is often implemented to ensure the objectivity, reliability, and validity of the evidence used for diagnosis. As section 2.2 illustrated, in order to ensure the representativeness of the sample it was necessary to implement a rigorous selection procedure.

The use of direct observation to select participants would avoid difficulties associated with using samples of children with ADHD from psychiatric clinics. Corkham and Segal (1993) in a review have criticised poor subject selection in Continuous Performance Test research with ADHD participants. They suggest the use of community control groups could inflate the differences found between the ADHD participants and controls, as socioeconomic status and family variables could vary to a great extent between the two groups.

Previous work using ADHD diagnosed groups (see section 1.3.2.3), does not clearly define the measures used for selection, therefore using a measure as described here may be a useful addition to selection measures used in these previous studies. This problem has been addressed in this research. All of the children involved in the study are from mainstream schools. They have similar socio-economic, educational, and family backgrounds, and none of the children have a diagnosis of a psychiatric or developmental disorder.

Description of Schools

The 157 children, who were to be observed as part of study 1, attended four different schools in the Sheffield area. Schools A, B, C and D were all situated within a few miles of each other in the Northern part of the city and were judged to be similar in terms of the working class socio-economic status of general population in those areas (Sheffield City Council, accessed 05/02/03). The ethnicity of the pupils was predominantly white British. Table 2.1 below shows the number of participants from each school taking part in each study. It should be noted that although school A had a special resource facility, no children from the special resource took part in the research programme. The schools were carefully selected to ensure variations in background were kept to a minimum to avoid the possibility of confounds.

Table 2.1: Numbers of participants per school and per group

	Number of Participants						
	Study 1	Experiment 1		Experiment 2		Experiment 3	
School		AD	NC	AD	NC	AD	NC
A	43	11	4	9	3	9	3
B	29	3	6	3	6	3	6
C	31	5	3	5	3	5	3
D	54	5	11	5	10	5	10

Adhering to suggestions regarding the use of multiple measures for selection of participants, both direct observation and teacher rating measures were used to select the attentional difficulty and control groups. An observation checklist was designed and used to observe 157 children in six different mainstream school classrooms and this was followed by teacher ratings of approximately 50% of this sample.

2.3.2 Observational Procedures

2.3.2.1 Rationale for the use of observational procedures

Direct classroom observation is a widely used and important method of assessing the behaviour of children. The advantages of using direct observation as opposed to an experimental paradigm include access to non-verbal cues, the influence of the researcher is minimised relative to other research methods, and situations can be examined which are not amenable to replication in a laboratory (Banister et al., 2002), or by using a different research paradigm (Martin and Bateson, 1986). Observational paradigms are also credited with the power to uncover major variables controlling a behaviour pattern (Martin and Bateson, 1986). Support for the use of observational measures to identify children with attentional difficulties comes from a number of studies (Blatchford et al., 2003; Muir-Broddus et al., 2002). Muir-Broaddus et al. (2002) demonstrated that higher levels of inattention or hyperactivity reported by parents using the Adaptive Behaviour Scale (ABS) were associated with worse performance relative to norms on neuropsychological tests associated with executive functioning, which is implicated in ADHD (Barkley, 1997).

Specific direct observation measures have been designed to record the behaviour of children diagnosed with ADHD. Most recent observation measures have focussed on observing children at play in a laboratory setting (Handen et al, 1998), and observing the differentiated classroom behaviour of children with ADHD with respect to gender and the presence of a co-morbid disorder (Abikoff et al., 2002).

As with all research paradigms, observational methods do have some disadvantages. Problems of external validity are common using observational methods. Researchers can become subjective resulting in observer bias (Banister et al., 2002; Sideridis, 1998; Breakwell et al., 2000), this leads to selectivity in both observation and interpretation of the data, and reactivity to observations (Banister et al., 2002; Sideridis, 1998; Breakwell et al., 2000). These effects can be countered to some extent by ensuring that inter-observer reliability of observational methods is high during pilot studies (Breakwell et al., 2000). Observational methods are time-consuming and labour-intensive (Banister et al., 2002), and can become inaccurate due to boredom (Breakwell et al., 2000). A more practical disadvantage associated with direct observation concerns the risk that participants may disappear from view during the observation period (Martin and Bateson, 1986).

Despite the disadvantages, the observational method emerges as useful for the purposes of selecting children with observable attentional difficulties. Various sources of bias make it problematic to accept ratings of behaviour from only one source. By providing an observation measure of inattention, hyperactivity and impulsivity, made by an observer with no prior knowledge of a child, and comparing this to teacher ratings the risk of bias can be minimised to an acceptable level. This is an issue of particular importance when selecting a sample from a typically developing group.

The Scope Classroom Observation Checklist was developed, assessed for reliability and validity and administered to 157 mainstream school children in the age range of 7-9 years (see chapter 3 for more detail). A high level of inter-observer reliability was observed on the observation measure due to the use of comprehensive and precise descriptions of target behaviours and rigorous training of the second observer in order to minimise observer bias and observer drift (Sideridis, 1998). Inter-observer reliability was calculated both for individual observations and for categories overall. Observations of individual participants were also made across different teaching sessions to ensure the robustness of the checklist over different times of day and different school settings.

2.3.3 Teacher Rating Procedures

The efficacy of teacher ratings for the selection of children with attentional difficulties, are reportedly due to a number of factors. These include the fact that teachers spend a lot of time with their students, they are able to observe them across wide variety of tasks, they seem to be relatively objective in comparison to parents, they have opportunities to observe appropriate behaviour in a large peer group and in various environments, and research suggests that teachers are able to differentiate between children with and without ADHD (see Dowdy et al., 1998). Evidence has also suggested that teacher ratings of inattention had a high level of concordance with performance on tests of cognition indicating attentional difficulties (Papadopoulos et al., 2002).

A number of teacher rating scales have been designed specifically for the purpose of identifying children with attentional difficulties. The Child Behaviour Checklist (CBCL) (Achenbach and Rescorla, 2001 cited in Hudziak et al., 2004) has been found to have high diagnostic efficiency in assessing externalising disorders, such as ADHD and Oppositional Defiant Disorder (ODD) in children (Hudziak et al., 2004). The Conner's rating scales (Conners, 2001), however, are the scales which are currently the most widely used measures of ADHD for both clinical and research purposes (Barkley et al., 2001).

The long version of the Conners' Teacher Rating Scale (CTRS:L) (Conners, 2001) was implemented here. It comprises 11 category subscales, and 2 subscales representing totals. The subscales are, Oppositional, Cognitive Problems/Inattention, Hyperactivity, Anxious/Shy, Perfectionism, Social Problems, Conners' ADHD Index, Conners' Global Index: Restless-Impulsive, Conners' Global Index: Emotional Lability, Conners' Global Index: Total, DSM-

IV: Inattentive, DSM-IV: Hyperactive-Impulsive, and DSM-IV: Total. This rating scale is suggested for use primarily as part of a clinical diagnostic test battery, however the utility of the CRS as a research tool has been advocated by numerous researchers (Barkley, 2001; Siklos and Kerns, 2004; Parker et al., 2003) and was designed for both clinical and research purposes.

The norms for the Conners' teacher rating scales were derived from a large normative sample consisting of more than 8000 participants. The internal reliability for the CTRS-R:L was good as the reliability of each subscale ranged form 0.773 to 0.958. Test-retest reliability was also adequate with coefficients ranging from 0.47 to 0.88. The correlation matrices for subscales on the rating scale were found to be virtually identical for males and females. The mean inter-correlation for males was 0.36, and for females 0.27. In terms of discriminant validity, the ADHD group scored significantly higher than the non-clinical group on all CTRS:L scales except the social problems subscale. There were also significant differences between an ADHD group and an emotional problems group on all subscales except the hyperactivity and anxious-shy subscales. These figures suggest that the rating scale is a reliable measure for the selection of children with difficulties associated with inattention, hyperactivity and impulsivity.

Although there are numerous benefits of using teacher ratings of attentional difficulties inevitably there are some disadvantages. Adams and Snowling (2001) point out, that the disadvantage of using teacher ratings without any external validation is that a 'halo effect' may be overlooked. This effect is said to occur when a teacher views any socially inappropriate behaviour presented by low achievers in a negative way, yet overlooks such behaviour by high achievers. There may also be opposite effects where out of character inappropriate behaviour is looked upon more severely than if such behaviour is typical. Further limitations are associated with memory and interpretation issues. These disadvantages strengthen the argument for preceding the teacher ratings with independent behavioural observations. Teachers were asked to rate all children who were part of the observation study, however, due to time constraints teachers were under, not all children who were subsequently chosen for the AD and NC groups were rated at this stage. These children were, therefore, rated after groups had been selected.

2.3.4 Matching

As outlined in section 2.2 it was important to control for any confounding variables that may arise due to the sample selection. The two groups of children were, therefore, matched on sex, age, and measures of non-verbal intelligence in order to limit the chances of age, sex, or co morbid difficulties associated with intelligence confounding the results. Two measures of non-verbal ability were used, the NFER Nelson Non-Verbal reasoning test (Smith and Hagues, 1993) and the performance IQ score of the Wechsler Intelligence Scale for Children III (WISCIII^{UK}) (Wechsler, 1992). Children in year three had, just prior to the research programme taking place, been tested within the school using the NFER Nelson non-verbal reasoning test. This was the measure of non-verbal ability was used to match the year 3 participants. The year 4 participants had not been tested in school and as the NFER Nelson Non-verbal reasoning test is only available to schools the WISCIII performance measures were administered to these participants. These participants were matched using these scores. The rationale for using non-verbal ability measures was based on the contention that these measures, compared to verbal measures, provide a more accurate representation of intelligence in children who may lack motivation (Smith and Hagues, 1993). As children with attentional difficulties are often reported as lacking motivation (see section 1.2) non-verbal ability measures were considered the most appropriate measure on which to match the groups. None of the children in either the AD or NC group were considered by the schools as having learning difficulties and teachers reported that all children had achieved the expected reading levels for their age.

The NFER Nelson Non-Verbal reasoning test includes three types of non-verbal questions; similarity, series and matrix questions. Similarity questions require the children to choose one shape, from a choice of four, which they think is the most similar to a group of shapes. Series questions require the children to choose from four options the correct shape or pattern to complete a series. Matrix questions require the children to identify a shape from a choice of four to complete a pattern.

The WISCIII^{UK} performance measures were, picture completion, coding, picture arrangement, block design, object assembly, symbol search and mazes. There were a number of common rules for each of the WISC tasks, these were the start rule, which indicated on which item the examiner should begin for appropriate age group. The reversal rule stated that if full marks were not given for the first two items administered, the earlier items should be given in reverse sequence until two consecutive correct answers are given. The final rule was the discontinue rule, which simply stated that the task should be discontinued after 5 consecutive failures.

Both measures of non-verbal ability were standardised and therefore had comparable scores. They were also both reported as having good reliability and validity. The internal consistency of the NFER Nelson Non-Verbal Reasoning Test was measured using the Kuder-Richardson 20 formula (KR20). This figure was 0.932 for the year 3 sample (8 year olds) and 0.932 for the year four sample (9 year olds). The standard error of measurement (SEM) was 3.8 and there was a 68% confidence interval for standardised score of 96.2 to 103.8. Test-retest reliability was 0.69 on standardised scores for the test. To assess concurrent validity, scores on the current version of the non-verbal reasoning test were compared with scores from the older non-verbal reasoning test BD previously used by NFER Nelson. The correlation between the standardised scores was 0.74. These figures were considered adequate to assume the test reliable and valid in assessing non-verbal reasoning in children in the age range 8-9 years.

The WISCIII was also considered a reliable and valid method of measuring intelligence. The reliability coefficients of each subtest except coding and symbol search was estimated by the split-half method. The items on each subtest were divided into two half-tests that approximated parallel forms with approximately equal variances. Scores on the two half-tests were than correlated and the resulting coefficient corrected by the Spearman-Brown formula. For the coding and symbol search subtests, stability coefficients were used as reliability estimates, correlations between scores on the first and second testings. The reliability coefficients for the IQ and factor based scales were greater than those for individual subtests as would be expected. The reliability coefficient for performance IQ was 0.90 – 0.91 for 7 to 10 year olds. Standard errors of measurement for performance IQ were 4.50 – 4.74 for 7 to 10 year olds. The test-re-test stability on performance IQ for 6-7 year olds was 0.86, and for 10-11 year olds 0.88. Tests of internal validity showed that verbal subtests correlated more highly with each other than with performance subtests and performance subtests correlated more highly with each other than with verbal subtests, thus providing evidence of convergent validity. Evidence of discriminant validity was demonstrated by lower correlations between the verbal subtest and the performance subtest. When comparing normative scores to scores gained by hyperactive groups, all IQ mean scores were near the normative average. (Wechsler, 1992).

2.4 Investigation of Cognitive Function in Children with Attentional Difficulties - A Cognitive Experimental Approach

2.4.1 Introduction

The intention of this thesis was to investigate executive function and working memory in children with observed and rated attentional difficulties. Previous evidence has suggested that the behavioural symptoms associated with ADHD are caused by abnormalities in cognitive function (Barkley, 1997). It has further been suggested that by looking at cognitive development biological deficits can be uncovered (Frith, 1992), and that the differences between children with disorders caused by subtle brain abnormality and normal children can be traced to the cognitive level. For these reasons a cognitive experimental approach was taken in order to address the research questions.

The possible ways of investigating cognitive function in children with attentional difficulties are relatively limited. Spreen and Strauss (1998) suggest that although interviews with patients, family and other people familiar with the participant can identify some executive function problems, cognitive tests are required to bring most executive function deficits to light. The disadvantages of using qualitative methods are particularly relevant when investigating cognition in young children. Often young children, and further older children and adults, do not have an awareness of how their own mental processes work even when these are concerned with controlled behaviour. This difficulty is compounded when working with children suspected as having poor attentional skills and working memory difficulties. Qualitative methods, otherwise known as interpretivist methods (Denzin, 1989), deal with participants' subjective perspectives. Although, the modern principles of qualitative methods stress the importance of objectivity, reliability, validity and controllability (Perakyla, 1997) the study of cognition has rejected such methods in favour of positivist methods that have been aligned, more consistently, with the concept of objectivity (Denzin, 1989).

Although behavioural cognitive measures are dominant in the thesis the benefits of using qualitative methods such as interviews, were acknowledged as methods for gaining an understanding of the behaviour underpinning cognitive difficulties. Both quantitative and qualitative methods were used to address the problem of a lack of correspondence between cognitive processes and behaviour that can occur when using only cognitive tests (Burgess, 1998). The small amount of qualitative data (see section 2.5 for further explanation) included in this thesis will add to the quantitative findings.

In assessing cognitive function in children with attentional difficulties an obvious starting point, given the evidence for executive function impairments in ADHD children (section 1.3) is to investigate these using an array of tasks. The next step was to assess more closely how executive function impacts on cognitive functions hypothesised as dependent on them (Barkley, 1996). Working memory has been asserted as arguably the most important construct for the adequate performance of cognitive tasks (Pennington and Ozonoff, 1996, see section 1.3.2.1), therefore it is logical to assess this construct in more detail.

The following sub-sections (2.3.1 and 2.3.2) will set out the methodological implications of the three experiments and outline how the methods and paradigms used have developed over the three experiments to provide systematic investigation of the possible explanations for the differences between the groups on cognitive tasks.

2.4.2 Experiment 1 - Assessment of Executive Function

2.4.2.1 Rationale

Children with ADHD are impaired in their performance on executive function tasks (Shallice et al., 2002; Scheres et al., 2004; Barkley, 1997; Sergeant et al., 1999; Pennington and Ozonoff, 1996), and this provided a sound rationale for investigating executive function in children with observed and rated attentional difficulties it also brought to light a number of issues surrounding the measurement of executive function which remain problematic. Task definition, task complexity, interpretation of findings and debates concerning what the tasks actually measure are commonplace in investigations of executive function.

The term executive function is a relatively new one (Burgess, 1998). There is little agreement on precisely what constitutes EF, and consequently differing definitions are used in empirical investigations. Hughes and Graham's (2002) definition, however, appears to provide a broad overview of executive function. 'Rather than referring to a single process 'EF' is an umbrella term for all of the complex set of cognitive processes that underlie flexible goal-directed responses to novel or difficult situations' (p. 131). To avoid confusion this is the definition that will be used to describe executive function throughout this thesis.

With respect to task complexity in executive function investigations, Hughes and Graham (2002) have suggested that the types of executive function tasks used in research with adults could be too complex for children to complete adequately regardless of ability. It is possible that this concern may be generalisable to all cognitive tasks and therefore, to address this issue the tasks used in the experiments and particularly the third experiment were selected and in some cases adapted to be more familiar in format and to be more appealing to children.

Although theorists have come to some agreement on the functions of EF, as illustrated by Hughes and Graham's definition, there is still no agreement on which tasks tap these functions, whether and how functions overlap, and if they are dissociable. It has been suggested that EF tasks should be novel, effortful, and may also involve working memory (Phillips, 1998). One difficulty is that learning on novel tasks may cause executive tasks to become non-executive (Hughes and Graham, 2002). More than one EF may be tapped by a single task, making it an impure measure of EF and therefore difficult to dissociate different EF processes (Hughes and Graham, 2002; Burgess, 1998).

Tasks commonly defined as measures of executive function include the Stroop task (Kane and Engle, 2003) and the Wisconsin Card Sorting Test (WCST) (Heaton, 1981; 1993) proposed to measure switching and inhibitory processes, and the Tower of London (Shallice, 1982) and Tower of Hanoi (Handley et al., 2002) tasks proposed to measure planning and problem-solving. There are a number of tasks that are reported to assess Executive Function none of which, however, appear to be very specific. Although the Tower of London and Hanoi tasks are considered to be interchangeable measures of planning and/or problem-solving this has been shown not to be the case (Bull et al., 2004). In an attempt to address these issues experiment 1 required participants to undertake a battery of executive function tasks found previously to differentiate groups of children with and without attentional difficulties.

There are also practical problems associated with the interpretation of findings from cognitive tests. As Phillips (1998) suggests, there may be other explanations for poor performance on executive function tasks such as the Wisconsin Card Sorting Task (WCST) and the Tower of London Task (ToL), such as reduced motivation, opposed to failure of executive functions. These alternative explanations could become particularly apparent when dealing with children, especially those rated as having behavioural difficulties associated with concentration. Measures have, therefore, been put in place to limit the effect of these variables on performance. These include, making tasks simple to follow, with simple instructions, testing in a one to one setting, limiting distractions, and keeping motivation high with verbal and material rewards in the form of cartoon stickers.

2.4.2.2 Measures

An adapted replication of Barkley et al.'s (2001) study was undertaken, and constituted the first experiment, where a test of Barkley's (1997) inhibition model was conducted. The tasks used were, on the whole, those used by

Barkley et al. (2001) to measure executive function. Notable exceptions were the measures of working memory that were implemented. The Working Memory Test Battery for children (WMTB-C) (Pickering and Gathercole, 2001) measures were considered more reliable measures given the importance attributed to working memory in executive function investigations (Pennington and Ozonoff, 1996). The working memory measures employed by Barkley were the similar in format particularly for verbal working memory. Barkley et al. (2001) used the forward and backward digit recall subtests of the WISC-III as a measure of verbal working memory and the Simon game as a measure of non-verbal working memory. The Simon game has four different coloured keys which, when depressed, emit a different musical note. The game presents a sequence of different notes and lights up the key corresponding to each tone as it does so, the participants task is to reproduce the melody by recalling the sequence in which the coloured keys lit up.

Table 2.2: Table demonstrating the measures used in Experiments 1, 2 and 3

	Measures	
Experiment	**Name**	**Description**
1	Response Inhibition	Continuous performance task requiring continuous responding until target stimuli appears.
	Verbal working memory	Retention and recall of verbal information.
	Non-verbal working memory	Retention and recall of visuo-spatial information.
	Central Executive	Retention, manipulation and recall of verbal or visuo-spatial information.
	Reconstitution – Fluency	Generating verbal, non-verbal and ideational responses with few constraints under a time limit.
	Self-regulation	Teacher Ratings of emotional lability, such as tendencies toward crying, anger or aggressive responses.
2	4 visual tasks in a number of formats and conditions	Retention and recall of pattern information.
	4 spatial tasks in a number of formats and conditions	Retention and recall of location information.
3	Switching task	Retention, manipulation, recall and application of task rules.
	Dual-task	Undertaking two tasks simultaneously under certain constraints including a time limit.
	Problem-solving tasks	Generating novel responses and applying these to a task.

Measures of response inhibition, verbal working memory, non-verbal working memory, central executive processes, reconstitution, and self-regulation were implemented. The Conners' Continuous Performance Test II (CCPT II) (Conners, 2002) was administered as a measure of response inhibition. The CCPT II is a standardised computer-administrated continuous performance test. Single letters appeared on the screen and participants were required to press the space bar when any letter appeared, with the exception of the target letter 'X'. When an 'X' appeared the participant was required to cease responding. The intervals between each letter appearing were 1,2 and 4 seconds and each letter was displayed for 250 milliseconds. There were 6 blocks, with 3 sub-blocks, each containing 20 trials (letter presentations), and the task lasted 14 minutes in total. t scores are generated for a number of measures and the t scores for omission errors (when a response is not given to a letter which is not a target letter), which was considered a measure of inattention, t scores for commission errors (when the participant responds to letters other than the target letter) to measure inhibition, reaction times to measure inhibition, hit rate standard error, and variability, were used in the analysis. A t score of 50 represents an average score. The CCPTII was the task used by Barkley et al. (2001) as a measure of response inhibition and was reported as having good reliability and validity measures. Split-half (one half of the blocks compared with the other half of the blocks) reliability for each measure ranged from 0.66 to 0.95. Test-retest reliability for each measure were highly satisfactory for most measures and when the measures were combined into indexes for ADHD consistency across administrations was excellent (0.89). Validation studies have yielded consistent results arguing for the replicability of findings using the CPTII.

Verbal and nonverbal working memory, were measured using tasks constituting part of the Working Memory Test Battery for Children (WMTB-C) (Pickering and Gathercole, 2001). The WMTB-C consists of nine tasks designed to assess the functioning of the phonological loop associated with verbal working memory, the visuo-spatial sketchpad associated with nonverbal working memory, and the overall functioning of the central executive which inputs to both verbal and nonverbal working memory. In addition to yielding scores for each of the nine tasks, component scores for the phonological loop tasks, visuo-spatial sketchpad tasks, and central executive tasks were calculated. Test-retest reliability was assessed using Pearson's product moment correlation coefficients. For years 1 and 2 the correlation coefficients ranges from 0.53 for backward digit recall to 0.83 for listening recall. Internal validity of the correlation coefficients indicated a greater degree of construct validity and integrity for the phonological loop and central executive than the visuo-spatial sketchpad, although the WMTB-C has very high internal validity overall. External validity was demonstrated by significant correlations between the working memory measures and attainments on standardised ability tests. (Pickering and Gathercole, 2001).

All of the nine tasks in the WMTB-C followed a similar pattern, with six trials per block and up to nine blocks. Practice trials were administered at the lowest levels, and the tasks had a number of common rules. If the practice trials were completed correctly testing began at the age appropriate block. The reverse rule was put in place if the examiner had begun testing, at a block other than the first, and the participant was unable to complete four out of the six trials, in this case the examiner returned to the previous block and continued from there omitting any trials already administered. The examiner would move on to the next block if the child responded correctly to 4 trials within a block, giving the child credit for any omitted trials. The task was discontinued if three or more errors were made within any block. The examiner recorded the child's progress on a score sheet during the tasks, yielding a trial total score and span score. The reliability and validity of these tasks has been confirmed using a large normative sample (Pickering and Gathercole, 2001).

During the digit recall task the examiner provided a spoken presentation of sequences of digits which the child was required to recall immediately in exactly the same order as they were presented. The digits were presented at a rate of 1 per second. In the word list recall and nonword recall tasks again, the child was expected to recall immediately, spoken sequences of one syllable words or non words. Each sequence was required to be recalled in exactly the same order as it was presented. In the word list matching task, the examiner presented pairs of word lists to the child and they had to decide whether the words in the second list were in the same order or a different order as the first list. In some trials the second word list was in the same order as the first list, in which case the child should respond 'same', however in other trials the words in the second list may be in a different order to those in the first list, for example two adjacent words will have been switched in order. In this situation the child should respond 'different'.

Block recall involved the examiner presenting sequences tapped out on the blocks of a block recall board. The child was required to recall the location of the blocks by tapping them. When two or more blocks were presented in a sequence the child was asked to recall the location of the blocks in the exact order that they were presented. In the mazes memory task the examiner presented the child with a two-dimensional drawing of a maze, with a representation of a person at the centre of the maze. A route was marked on the maze in red showing a possible way out, and this route was traced by the examiner's finger. Immediately after the route was demonstrated the maze was removed from view and the child was asked to recall the route by drawing it in pencil in a response booklet. The complexity of the mazes increased as the task continued.

The requirements of listening recall were to listen to the spoken presentation of a series of short sentences. Some of the sentences made sense and some did not make sense. Immediately after hearing each sentence the child was asked to judge whether or not the sentence made sense and respond 'true' or 'false' accordingly. After the total number of sentences in each trial had been presented (ranging from 1 to 6), and the child had responded to each with true or false, the child was asked to recall the last word in each of the sentences. Each target word was required to be recalled in exactly the same order as it was heard. Counting recall required the child to count arrays of dots presented on a series of cards. When the dots had been counted the child was asked to recall the total number of dots on each of the cards presented in the order they were encountered. Backward digit recall required the child the recall spoken sequences of digits immediately, however, the list was required to be recalled in the reverse order. (e.g. '4, 6, 3' would become '3, 6, 4'.)

Verbal Fluency was measured using the Controlled Oral Word Association (COWA) Test (Benton et al., 1983). The COWA test has been used to assess reconstitution in numerous neuropsychological studies and has good reliability and validity (Spreen and Strauss, 1998). During the verbal fluency task the participant was given three letters (FAS) one at a time. For each letter the participant was asked to name as many different words as possible given certain constraints (excluding proper nouns, numbers, and different forms of the same word.) Letters were given one at a time and 1 minute was provided for the participant to generate as many words as possible beginning with that letter, the words were provided verbally to the examiner who wrote them down on the score sheet. The score represented the total number of acceptable words generated across all 3 letters.

The tasks used to assess nonverbal fluency and ideational fluency were those used by Barkley et al. (2001). Although Barkley et al. (2001) found that these tasks loaded on the same factor as the other working memory tests used in their study, they were the first to use tasks of this sort, and therefore norms, and measures of validity and reliability are not available. To measure ideational fluency the participant was required to generate as many different uses for an object as possible. A brick, bucket and rope were used, and a time limit of 1 minute was given for each object. The score represented the total number of different feasible uses provided for all three items. During the nonverbal fluency task the participants were given three cards representing different one-dimensional geometric shapes (square, circle, and triangle). They were asked to create as many different recognisable objects as possible using the three shapes (alone or in combination) during a two-minute period. The score represented the total number of different recognisable objects created including alphabetic letters.

Self-regulation, was measured using the emotional lability subscale on the Conner's Teacher Rating Scale (CTRS:L) (Conners, 2001). This score was taken from the teacher ratings made in the first study where teachers were asked to rate each child on a variety of subscales. The emotional lability subscale required the teacher to assess the child's level of control over emotional responses or behaviours, such as anger and crying. A t score was obtained for each child on this measure. The reliability and validity of the Conners' teacher rating scales are reported as good (see section 2.3.3.).

2.4.3 Experiment 2 - Interference and Dissociation paradigms

2.4.3.1 Rationale

The importance attributed to working memory in cognitive models of ADHD (Pennington and Ozonoff, 1996; Sergeant, et al., 2003) (see section 1.3.2.2.) provided a strong rationale for investigating working memory in children with attentional difficulties. The intention was to build on previous experiments that had investigated the fractionation of the visuo-spatial sketchpad and use the paradigm in the investigation of attentional difficulties in children.

The methods implemented to assess visuo-spatial working memory were derived from the working memory literature investigating fractionation of components of the Baddeley and Hitch (1974) working memory model. There are currently two main methods of investigating fractionation in working memory. Interference paradigms are where primary tasks are paired with secondary tasks which are proposed to tap into the same or different cognitive constructs (Baddeley and Lieberman,1980 cited in Baddeley, 1986). The second are dissociation paradigms, originally used in the neuropsychological literature, using two patients with lesions in different parts of the brain, and examining the pattern of their success and failure on two tasks. In dissociation paradigms relationships between performances on tasks designed to assess cognitive constructs that are hypothesised as dissociated are compared (Pickering et al., 2001).

Experiment two utilised a dissociation paradigm and was intended to investigate visuo-spatial working memory in children with attentional difficulties. The aim was to test the hypothesis that dissociation in task performance between the groups would emerge. A number of manipulations were applied to the two tasks in order to identify under which conditions dissociation in task performance would occur. Dissociation paradigms require the manipulation of tasks to generate a number of task conditions. It is important that each variable that may contribute to task performance, such as the type of stimuli, visual or spatial, the type of format, working memory or non-memory and the type of condition, static or dynamic, is systematically controlled for to assess which if any level of each variable may account for differences between the groups on a task.

The original tasks used to assess the fractionation of visuo-spatial working memory (see Baddeley, 1996), however, could not be used with children, particularly in a school based research programme, due to ethical considerations or for reasons of complexity. Previous experiments have required participants to remain blindfolded in a darkened room during completion of the task (Baddeley and Lieberman, 1980 cited in Baddeley, 1986), therefore, adaptations of a more recent cognitive developmental study by Pickering et al. (2001) were employed. Two tasks with varying visual and spatial components were developed and administered. Practical measures in the design of the tasks were put in place to both build on previous investigations and further limit the possible explanations for the pattern of results. The two visuo-spatial tasks used were kept as similar as possible in presentation. The location task was based on the Corsi blocks task, which has support as a measure of different abilities than those measured by the visual patterns test (Della Sala et al, 1999), however, it was presented as two dimensional rather than as three dimensional, to be consistent with the patterns task. Further, measures were put in place to limit the requirement for good motor skills, in that where the participant was asked to point during the task, the selections were confirmed by the experimenter, thus building on previous experiments using the Corsi blocks task and mazes task where good motor skills are a requirement (Pickering et al., 2001). Practical measures taken included the introduction of an articulatory suppression condition on the working memory formats to further limit the range of alternative explanations for the findings. This condition required participants to say 'the' continuously during the encoding phase of the task.

Although it was considered beneficial to design new measures for use in experiment two an inherent disadvantage is the lack of norms. It was not possible, therefore, to conclude whether the scores achieved on either task represent deficient or adequate levels of performance compared to the typical population.

2.4.3.2 Measures

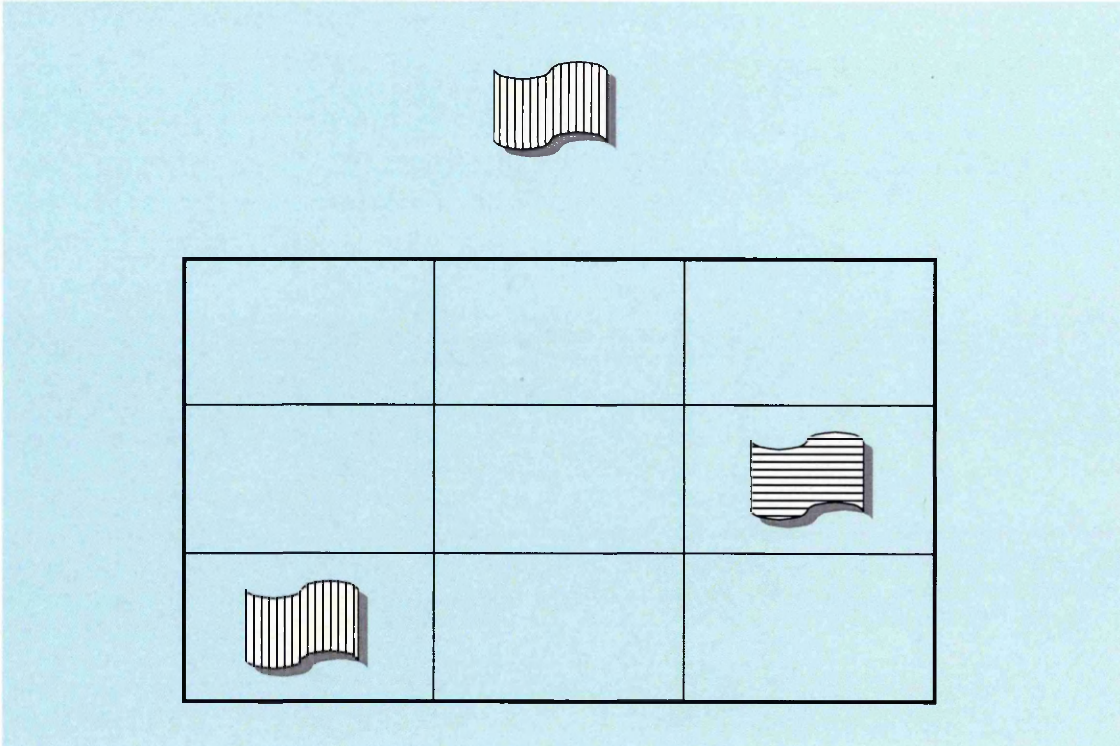
Two computer administrated tasks were designed, a visual patterns task and a spatial location task. These tasks were manipulated to incorporate a working memory format in addition to a perception format, and further a dynamic and static condition of each of these tasks was developed. On the working memory formats of each task a further articulatory suppression condition was developed. This yielded twelve tasks in total, as displayed in table 2.3 below.

Table 2.3: The conditions and task requirements of the six visual and six spatial tasks

Task Condition	Task Requirements
Visual Perception Task – Static (VPS)	Matching
Visual Perception Task – Dynamic (VPD)	Matching and Appearance Order
Visual Working Memory Task - Static (VWMS)	Matching and Working Memory
Visual Working Memory Task - Dynamic (VWMD)	Matching, Working Memory and Appearance Order
Visual Working Memory Task - Static with articulatory suppression (VWMS/AS)	Matching and Working Memory with Articulatory Suppression
Visual Working Memory Task - Dynamic with articulatory suppression (VWMD/AS)	Matching, Working Memory and Appearance Order with Articulatory Suppression
Spatial Perception Task – Static (SPS)	Identifying Location
Spatial Perception Task – Dynamic (SPD)	Identifying Location and Order Recall
Spatial Working Memory Task - Static (SWMS)	Identifying Location and Working Memory
Spatial Working Memory Task - Dynamic (SWMD)	Identifying Location, Working Memory and Order Recall
Spatial Working Memory Task - Static with articulatory suppression (SWMS/AS)	Identifying Location and Working Memory with Articulatory Suppression
Spatial Working Memory Task – Dynamic with articulatory suppression (SWMD/AS)	Identifying Location, Working Memory and Order Recall with Articulatory Suppression

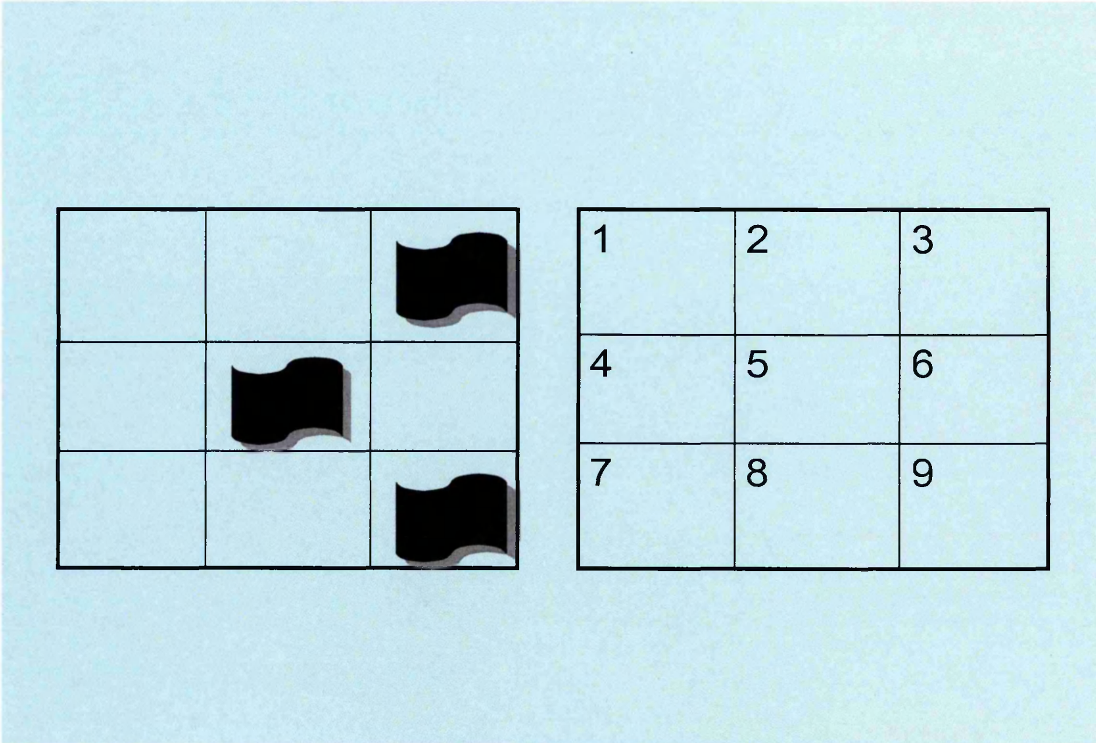
The Visual Task required the visual discrimination of patterns within a mis-shape and comparison of this pattern to other mis-shapes. Participants were required to look at the target shape positioned above the grid and point out the patterned shape within the grid that was identical to the target shape. The selected shape was confirmed with the participant to minimise any effect of poor motor skills. An example of the visual perception task is shown in Figure 2.1 below. In the working memory format of the task the target shape would appear first, alone, then would disappear after 5 seconds. The comparison grid would appear and the participant would make their response.

Figure 2.1: An example of the visual task stimuli



The Spatial Task required the recalling the locations of filled mis-shapes within a 3x3 grid. The participants were asked to look at the grid containing the stimuli and to respond with the corresponding grid position numbers, which were displayed in a comparison grid, for example 3, 5, 9. An example of the task is shown in figure 2.2 below. The working memory format required the participant to observe the target grid for a period of 5 seconds after which time it would disappear and a comparison grid would appear for the participants to make their response. Counterbalancing of grid number positions was implemented.

Figure 2.2: An example of the spatial task stimuli



On both task types the perception condition requirements are defined as immediate recall of pattern or location, with the opportunity to refer to comparison stimuli. The working memory condition requirements are recall of pattern or location after removal of comparison stimuli, without opportunity to refer to comparison stimuli. In the dynamic condition comparison stimuli (in the visual task) or target stimuli (in the spatial task) appeared independently at a rate of one per second in a sequence. In the static condition comparison or target stimuli appear simultaneously.

The working memory tasks only were undertaken under a further concurrent articulatory suppression condition. Both groups were required to simultaneously repeat the word 'the' during the encoding (stimuli presentation) phase of the task. The order of presentation was again randomised across participants. The purpose of administering these task conditions with the working memory task was to address the possibility that verbal recoding ability could explain the results.

2.4.4 Experiment 3 – Assessment of executive function demands on central executive tasks

2.4.4.1 Rationale

Experiment 1 tested differences between the groups on EF tasks and Experiment 2 tested visuo-spatial working memory in detail, it remained unclear, however, whether and how lowered performance on working memory tasks related to executive function. The aims of experiment 3 were to assess executive function demands on central executive tasks in the attentional difficulty and control groups.

The design of experiment 3 was based on laboratory tasks used in a series of studies by Baddeley and colleagues reported in Baddeley (1996). This series of studies were intended to assess and further define four activities attributed to the central executive (Baddeley, 1996). A summary of these investigations corresponding to the hypothesised activities or responsibilities of the central executive are presented in table 2.4 below.

To assess the executive function requirements for the adequate performance of central executive tasks, measures of executive function were taken on each central executive task. The rationale for the measures of executive function were derived from the previous literature concerning models of executive function in ADHD (Barkley, 1996; Pennington and Ozonoff, 1996; and Sergeant et al., 2003) and from the literature concerning higher order cognitive function (Norman and Shallice, 1980). The executive function measures taken during central executive task completion were inhibition, monitoring and strategy application, a further measure of motor control was taken in order to assess whether this difficulty reported in investigations of ADHD (Kalff et al., 2003; Kroes et al., 2002) could have an effect on working memory task performance.

Table 2.4: A summary table of the tasks implemented by Baddeley and colleagues to provide support for the fractionation of the central executive

Hypothesised Central Executive Function (Baddeley, 1996)	Laboratory based tasks utilised to assess each function (Baddeley, 1996)
Integration and coordination of information for two separate tasks, integration of information from PL and VSSP.	***Dual task*** *A nonverbal task was paired with either, articulatory suppression, reaction time to a tone, or a digit span task*
Selective attention to one stimulus whilst inhibiting the disrupting effect of another.	***Irrelevant Stimuli tasks*** *Respond to circle but not triangle*
Strategy generation and capacity to switch retrieval strategies	***Random Generation*** Participants are asked to provide constant generation of novel sequences.
Retrieval and integration of information from long term memory.	**Long Term Memory Tasks** LTM is demanded for each of the above tasks, previous knowledge of these sorts of tasks etc

To address concerns regarding the ecological validity of laboratory designs used in the previous investigations, such as those by Baddeley and colleagues (Baddeley, 1996), a decision was taken to implement 'real life' or familiar tasks. Barkley (1991), in a review of laboratory methods and natural setting measures of assessing inattention, impulsivity and over-activity, found in general most laboratory methods had low to moderate ecological validity. Laboratory methods can be described as those methods which are designed specifically as tests of cognitive function and are often undertaken in situations which are unfamiliar to participants.. The disadvantage of using laboratory methods concerns the degree to which findings can be generalised to functioning in 'real life' situations and on everyday tasks. Barkley suggested that there should be a greater reliance on assessments of behaviour in natural settings. To further support the use of 'real life' tasks findings of an investigation by Lawrence et al. (2002) demonstrated that children with ADHD demonstrated impaired working memory performance in one real life situation but not in another. These findings demonstrate the importance of assessing ability on tasks that are relevant to functioning in real life, such as at home and school, if improvements in these situations are to be made. The tasks implemented in experiment 3 were designed with these concerns in mind, and constituted tasks which were familiar to the participants, such as the pairs game and a jigsaw.

2.4.4.2 Measures

A number of novel 'real life' tasks, shown below in table 2.5, were designed to tap the activities of the central executive, thus with requirements for executive function. The aims of the experiment demanded a complex design employing aspects of both dissociation paradigms and interference paradigms. The overall design of the experiment, however, was a dissociation paradigm, as the broad aim was to investigate the relationships between performance on different tasks hypothesised to be dependent on different functions of the central executive, and further examine task performance between the two groups.

Within this overall design three tasks employing different manipulations were developed. Two of the tasks used were based on the interference paradigm, a dual-task and a switching task. The use of dual-tasks has been recommended by Baddeley et al. (1998). It is suggested that more control over both tasks is permitted, by using both single and dual conditions, and thus, clear indications of differences between groups based on differences in attentional load can be gained. The third set of tasks were intended to assess strategy development and therefore tasks of differing complexity and form were employed in the form of a test battery, for purposes discussed in the previous section regarding the difficulty in measuring executive function using only one task. All three tasks employed control conditions and therefore were based on a dissociation paradigm, and in addition the switching and dual-tasks used interference techniques as they had requirements for simultaneous processing.

Table 2.5: An overview of the three central executive tasks, there conditions and the measures of executive function taken on each

CE Tasks/ CE Function	Conditions	Measures of Executive Function
Task 1 Switching - Pairs Game / Selective attention/inhibition	Animal Rule - Non-switch condition Colour Rule - Non-switch condition Number Rule - Non-switch condition Combination of Rules - Switching Condition	Monitoring • incorrect rule used • requests for reiteration of rule Strategy application • completion time Inhibition • turning too many or too few cards over • matching errors Motor • dropping cards/turning too many over due to motor control.
Task 2 Dual-Task; Pairs Game and Jigsaw / Integration and coordination	Pairs and Jigsaw together under time constraint Jigsaw under time constraint. Pairs under time constraint	Monitoring • Looks toward timer • requests for instructions Inhibition • turning too many cards • undertaking both tasks (y/n) • incorrect match Strategy application • correct match • number pieces fitted together • pieces placed correctly near edge • Total correct pieces selected. Motor • Too many pieces turned • Pieces dropped.
Task 3 Problem-solving tasks / Generating Novel Responses	Problem-solving Eggs and Baskets Farmer task	Monitoring • Requests for reiteration of instructions Strategy application • Correct moves • Total moves • Solution time Inhibition • Incorrect moves

The switching task was a pairs game with three dimensions, colour, animal and number. Three types of colour were used; green, orange and blue; three types of animal, dog, cat, and elephant; and one, two or three animals on a card. Three rules were developed which were based on matching according to these three dimensions. There were four conditions of the task, the first three conditions required matching according to a specified rule, such as match animals, regardless of other dimensions on the card such as number and colour. The same procedure was undertaken using colour and number rules. The final condition was the switching condition where the matching rule was switched after every match. This required each rule to be kept in mind and applied in the correct order.

The dual task experiment required the performance of two single task conditions and a dual-task condition where both single tasks were performed simultaneously. The single tasks were a pairs game and a jigsaw puzzle, and the first two conditions required each of these to be completed separately under a time constraint of two minutes. The final condition required the undertaking of the tasks simultaneously under the two-minute time constraint and applying a rule that both tasks should be attempted during the two-minute period.

Two problem-solving tasks were used to assess problem-solving and generation of novel responses. The first problem-solving task required participants to move a number of characters from one side of a hypothetical river to the other, whilst keeping in mind and applying a set of rules. The following characters were arranged in front of them; a farmer, a fox, a chicken, some grain, together with a boat. They were asked to transport the characters across a river, which was represented by a piece of blue paper, bearing in mind the following rules; firstly, only the farmer plus one other item or animal can fit into the boat on each trip, secondly, the chicken can not be left alone with the grain, as the chicken will eat the grain, and finally the fox can not be left alone with the chicken, as the fox will eat the chicken.

During the second problem-solving task the participants were presented with three two-dimensional cardboard baskets of differing colours, and six cardboard eggs. They were also presented with the following information written on a piece of card; the blue basket has one more egg than the yellow basket, the pink basket has one less egg than the yellow basket. They were then asked to place the correct number of eggs in each basket.

The measure of errors was used to assess any differences between the groups on the different central executive tasks. To assess the differences in terms of executive function, various measures were taken. These measures were hypothesised to load on inhibitory control, monitoring, strategy application and motor control. Measures of inhibition included errors and impulsive actions such as turning over too many cards, measures of monitoring included the number of requests for reiteration of instructions made, measures of strategy included completion time, and measures of motor control included dropping cards.

2.5 Qualitative Data

During the collection of the quantitative data outlined in the previous sections, some qualitative data were collected. These data were collected during experiments 1, where the verbal responses given in the fluency tasks were analysed, and in experiment 3, where participants were asked a series of questions regarding their undertaking of each task. As outlined in section 2.4.1, although the dominant method used here was experimental and, therefore, from a positivist stance, the benefits of using qualitative, interpretivist methods are acknowledged. A criticism of purely experimental studies concerns the idea that behaviour may not necessarily reflect cognitive processes (Burgess, 1998). In fact, some advocates of qualitative methods suggest that quantitative measurement can obscure qualitative meaning (Oakley, 1998). This view would suggest that if differences between the groups are attributed to the task, and therefore the cognitive function it is hypothesised to measure, this will rule out other potential explanations for differences between the groups when these may be equally valid. It was considered important, therefore, to analyse responses made during the tasks and ask children to comment on any strategies they used during cognitive testing. This would ensure that any other potential explanations for differences in task performance would not be overlooked. There are practical difficulties in obtaining these data, particularly when working with children with attentional difficulties, however, it can be extremely useful in providing explanations for cognitive difficulties.

Qualitative analysis was completed on the fluency data obtained in experiment 1 and more detailed qualitative data was gained during experiment 3. After the children had completed the cognitive tasks in experiment 3 they were asked a series of questions regarding the strategies they had applied, and whether they had enjoyed the tasks. These responses were analysed using both quantitative and qualitative methods, and were considered to be a meaningful addition to the measures of task performance. Although these data appeared to add to the quantitative data, it was kept in mind that the responses given were retrospective and, given the AD children were hypothesised as having difficulties with working memory, the responses to these questions may not fully reflect the processes they were intended to reflect.

2.6 Ethical Considerations

The British Psychological Society ethical guidelines were adhered to at all times during the undertaking of the research programme.

Consent

The head teacher and classroom teachers of the participants were initially asked to indicate which children were suitable to take part in the study. The head teacher or classroom teacher eliminated a number of children from the study at this stage if they had physical difficulties such as hearing problems, psychological disorders, or due to personal or family issues they felt that participation or contact with parents to confirm consent would be problematic. The caregiver of each of the remaining children was given a letter outlining the study and requesting consent for their child to take part (Appendix 1). The caregivers were given the letters personally by the teacher and were provided with verbal information about the research when they came into the school to collect their child. Caregivers were asked by the teachers to either inform them verbally or return the form if they did not want their son or daughter to take part in the research. This process resulted in a small number of children being eliminated from the research programme.

Right to withdraw

Participants and parents were informed that they had the right to withdraw from the research programme at any time. Prior to each testing session the participants were asked if they would like to take part in that particular session and data collection only began if the participant agreed that they would like to continue at that time. The participants were also given the option to stop during the testing session and either continue at another time or not at all. Parents were informed by letter and by the classroom teacher that they could withdraw their child at any time.

Confidentiality

All data gathered was kept strictly confidential by storing it under a code that could only be identified by the researcher. Files were kept in locked filing cabinets in a lockable office.

2.7 Working with schools

The data was collected in Local Education Authority primary or junior schools in Sheffield. There are a number of advantages of working with schools in addition to the fact that they provide access to a large number of participants. Children can be tested in familiar surroundings and therefore should respond to tasks in a manner consistent with their normal ability. Cognitive tasks are often similar to tasks the children are required to do at school and therefore the testing sessions constituted a relatively normal part of the school day. More generally, working with schools can foster links between education and research psychology.

There are, however, a number of disadvantages to collecting data in schools, which have been addressed during the research programme. These include the fact that a number of distractions can take place due to the large number of people, staff and pupils, who typically attend the school, meaning interruptions can take place. There may be limitations on the space available for testing. The school timetable limits the times when data can be collected. Absence from school or participants leaving the school can disrupt the research programme. Further, teachers are likely to have a heavy workload and, therefore, may not be able to contribute fully to the research programme in terms of completing rating scales and providing information.

Working within schools has allowed links to be been drawn between the problem of attentional difficulties in children and the policy of inclusion in schools (see section 1.2.4.1). Findings have been interpreted, and suggestions for intervention made, therefore, based on an intention to improve children's functioning at school and thus academic achievement. It is hoped, however, that these findings contribute as fully as possible to experimental psychology and may also inform clinical practices.

2.8 Analysis and interpretation of the findings

As the majority of the data collected in this thesis constituted quantitative data, statistical analysis was the dominant form of analysis used. Although the statistical tests used here, such as ANOVA, are robust to variations in the distribution of the data, each data set was subjected to exploratory data analysis to assess whether the data adhered to parametric assumptions, and for the amendment of outliers as necessary (Tabachnick and Fidell, 2001).

Variability

Each data set gained during the research programme was assessed for normal distribution. Histograms were produced and compared to the normal distribution and where appropriate the Kolmogorov-Smirnov test was employed. This was of particular importance during study 1 where normal distribution of scores was a requirement for the selection of the AD and NC groups. It was important that the distribution of the observation scores was comparable to the normal distribution in order to ensure that the groups were not selected from a non-normal population, which for example was highly skewed towards inattentive, hyperactive and impulsive behaviour or likewise towards typical behaviour. It was a requirement that the amount of variability in scores on the checklist was comparable to a typical degree of variability.

The variance in scores on each measure implemented was compared to the normal distribution. Each data set was assessed and the possible reasons for variability considered. If it was considered that there may be sub-groups within either or both of the groups which could explain the presence of outliers, analyses were run both with and without outliers. If the results of these analyses did not differ substantially, and therefore did not change any conclusions made, outliers were amended. Where this was the case the method used for dealing with outliers was to amend the scores to either one point above the next highest score, or one point below the next highest score as appropriate. Although, where there were some variability in scores findings were interpreted with a consideration that subgroups may exist within the groups.

Descriptive statistics were produced and were followed by inferential statistics that were deemed to be most suitable. In the main, parametric tests such as t-tests, analysis of variance (Anova), and multivariate analysis of variance (Manova) were employed, however, experiment 3 necessitated the use of non-parametric tests such as, Mann-Whitney, Wilcoxon, and Friedman, in addition to parametric tests. Post-hoc analyses were also performed where necessary.

The fluency data, collected in experiment one, and children's responses to questions regarding strategy, collected in experiment three, were analysed using both quantitative and qualitative methods. The qualitative method employed on these data was thematic analysis.

Chapter 3 - Study 1 - The identification of children with and without behavioural manifestations of inattention, hyperactivity and impulsivity, in mainstream school: The development of the Scope Classroom Observation Checklist.

3.1 Introduction

It has been reported that children identified in schools as having Emotional and Behavioural Difficulties (EBD's) can be rated as having symptoms of Attention Deficit/Hyperactivity Disorder (ADHD) (Place et al., 2000). These children, however, rarely have a diagnosis of ADHD. Possible explanations for undiagnosed children presenting behavioural symptoms associated with inattention, hyperactivity and impulsivity centre on the idea of a continuum theory of attentional difficulties (Conner, 1997). This theory contends that it is possible for individuals to vary in their propensity for symptoms associated with ADHD dependent on factors other than disorder, such as personality (Parker et al., 2004) or as a result of differences in functional brain activation (Hester et al., 2004). Support for the continuum theory is provided by the results of a twin study reported by Levy et al. (1997). They suggested that '...ADHD is best viewed as the extreme of a behaviour that varies genetically throughout the entire population rather than a disorder with discrete determinants.' (p. 737).

Further support for this theory comes from the evidence that differences in diagnosis criteria between countries such as Britain and America (Reid and Maag, 1997) appear to result in different prevalence rates of ADHD in these countries. This suggests that the more inclusive the diagnostic criteria the greater the rate of diagnosis. The purpose of the present study, therefore, was to ascertain whether it was possible to identify two groups of children who differed significantly in their behavioural manifestation of symptoms of inattention, hyperactivity and impulsivity, but who did not have a diagnosis of ADHD. Children presenting these behaviours are often reported as underperforming academically (Day and Peters, 1989) and this may be as a result of cognitive impairments (Adams and Snowling, 2001). If children are identified as presenting behavioural manifestations associated with inattention, hyperactivity and impulsivity, this may have implications for the cognitive function and resultant academic achievement of these children.

The intention of this study, therefore, was to select participants on the premise of the 'attentional skills continuum' (Conner, 1997). Children rated and observed as having attentional difficulties would therefore, be placed at the opposite end of the continuum to those rated and observed as having good attentional skills. A further aim was to develop a reliability assessed observation measure which would be used to select these dichotomous groups. The development, implementation and findings of the observation measure will be reported here. The primary aim of this study was to select a sample. However, it is also anticipated that developing and implementing a new measure and using this together with an existing measure will address some of the concerns regarding the differing parameters used for sample selection in ADHD investigations (see section 2.3.1).

There will be two hypotheses for this study based on the evidence presented here. The first hypothesis states that there will be children in mainstream classrooms, without a diagnosis of any psychiatric disorder, who are rated as presenting behaviour associated with the DSM-IV (APA, 1994) criteria for ADHD. The second hypothesis states that two groups of children will significantly differ on their observation checklist score.

3.2 Method

3.2.1 Development of the Scope Classroom Observation Checklist - Construction and Piloting

The Scope Classroom Observation Checklist (see figure 3.1) was designed to be used in the classroom setting to measure the participants' observable behaviour associated with inattention, hyperactivity and impulsivity. Informal observations led to the construction of the Classroom Observation Checklist. Informal observations were made over a period of four weeks. The observer made continuous observations during the morning or afternoon teaching sessions of the normal school day. Informal observations were made in the classrooms that were subsequently used for data collection. Notes were made on the array of behaviours that may be possible in a classroom setting to ensure that the final checklist could account for most behavioural outcomes. Time sampling of observation periods was applied to the collection of the observation data. The rationale for using time sampling rather than event sampling was that it was considered important to be systematic in the collection of the data in order to assess behaviour over an entire school lesson rather than at a particular point in that lesson. Time sampling ensures that representative samples of behaviour, which occur relatively frequently, are obtained (Breakwell et al., 2000). These issues are particularly important when measuring the inattentive, hyperactive and impulsive behaviour of young children as it is likely that these behaviours are displayed infrequently by children in this age range as part of their normal repertoire of behaviour. Using a method such as event sampling may increase the likelihood of errors in the assessment of group membership being made. The checklist was adapted from categories used in existing Classroom Observation Checklists (Handen et al., 1998; Dowdy et al., 1998; Abikoff et al., 2002). The checklist also incorporated DSM-IV (APA, 1994) diagnostic criteria for ADHD, for the definitions of behaviour. The DSM-IV definitions were refined as a result of the informal observations made previously.

Figure 3.1: The Scope Classroom Observation Checklist

Date:		School:		Observer:	
Child ID:		Lesson:		N:	
Other Adults Present: Y/N ( )					
Type of Activity					
	Frequency of Occurrence of Behaviours				
Behaviour	**1st period (2 mins)**	**2nd period (2 mins)**	**3rd period (2mins)**	**4th period (2mins)**	**Sub Totals**
Off - Task — ***Distracted*** Is off-task due to sight or sound.					
Off - Task — ***Daydreaming*** Staring into space, not distracted.					
Fidgety tapping pencil, hands, feet or squirming in seat.					
Out-of-seat Stands up, climbs, and gets down to the floor.					
Interrupting Shouting out, interrupting other children, making excessive noise.					
On-task Working quietly, without disturbing others unnecessarily.					
Teacher Interaction — ***Pos***					
Teacher Interaction — ***Neg***					
				Total:	
Notes/Other Behaviours:					

Full definitions of behaviours and instructions for observers can be found in appendix 2.

Table 3.1 shows how the criteria used in the classroom observation checklist compares to the DSM-IV criteria for a diagnosis of ADHD. Definitions of behaviour were adapted from the DSM-IV criteria in order that the data yielded from the checklist could be comparable to the models of cognition developed to account for children with a DSM diagnosis of ADHD. The On-Task category was included as another way of differentiating between the experimental and control groups in terms of attentional behaviour. Some of the DSM-IV criteria do not relate to observed behaviour, therefore those criteria had to be excluded from the observational checklist.

Table 3.1: A comparison of DSM-IV criteria for ADHD and criteria used for the Scope Classroom Observation Checklist

DSM-IV Symptom Criteria for ADHD (APA, 1994)	**Scope Classroom Observation Checklist**
Inattention - often does not listen when spoken to directly, is often easily distracted by extraneous stimuli.	**Off-Task Distracted** - looking away from a task or the teachers' direction, attending to extraneous stimuli, ignoring teacher's requests or not listening to instructions.
Inattention - often avoids, dislikes or is reluctant to engage in tasks that require sustained mental effort.	**Off-Task Daydreaming** - looking away from a task, not focussing on anything in particular, e.g. staring out of a window.
Hyperactivity - often fidgets with hands or feet or squirms in seat.	**Fidgety** - displays repetitive movements which appear to be primarily purposeless, twisting or sliding in seat, unable to stand still, kicking or throwing.
Hyperactivity - often leaves seat in classroom or in other situations in which remaining seated is expected, often runs about or climbs excessively in situations in which it is inappropriate.	**Out-of-seat** – child stands up from chair unless specifically requested to do so or needs to be standing to undertake a task. Includes climbing and getting down on to the floor.
Impulsivity - often blurts out answers before questions have been completed, often has difficulty waiting turn, often interrupts or intrudes on others.	**Interrupting** - interrupts the teacher, talks to other pupils when talking is not allowed, shouts out answers inappropriately, makes excessive noise.
-	**On-Task** - remains on-task and remains seated without talking or disturbing others.

Care was taken in the design of the checklist to include all categories necessary to record all the relevant behavioural responses, indicative of good as well as poor attentional skills. The number of categories used was kept to a minimum, however, to make the measurement of each more reliable (Martin and Bateson, 1986). It was, therefore, particularly important to select categories carefully and be certain that each was precisely defined and operationalised (Breakwell et al., 2000).

3-second duration of one type of behaviour was classed as one unit of behaviour. In the case of the category daydreaming, this was extended to 5-seconds, allowing 2 seconds extra to account for 'thinking time' when mentally engaging in a task. The maximum score per behaviour per 2-minute observation period was 40 3-second units (24 5-second units for daydreaming). Thus, the possible range of scores which a child could receive are from -160 indicating a high level of On-Task behaviour, therefore low on attentional difficulties, to +640 indicating an extremely high level of attentional difficulties. Scores could be conceptualised as the number of attentional lapses, therefore high scores (usually positive numbers) represent behaviour associated with attentional difficulties whereas low scores (usually negative numbers) represent behaviour associated with good attentional skills.

None of the off-task categories are mutually exclusive, a child can be both Off-task (Distracted) and Interrupting, and fidgeting, and so forth. Only if a child scored simultaneously on Off-task, fidgety, out-of-seat, and interrupting throughout all four observation periods would they receive a score as high as +640.

The checklist was piloted on small numbers of children and resulted in simplification of the observation procedures. Simplification was thought necessary to increase the reliability of the procedure (Sideridis, 1998). A brief note of behaviours included in each category was added to the checklist and served to refresh the observers' memory of the definition of categories. This was intended to reduce observer drift (Sideridis, 1998), in which observers may 'drift' from the operational definition of a category of behaviour. The type of lesson or activity that was taking place was to be recorded to ensure that each child was observed across similar situations, and a section for the noting down of other behaviours was included to ensure that all behaviour which occurred during the observation period could be recorded. The piloting of the checklist also led to redefinition of categories and the addition of behaviours to categories.

Inter-Observer Reliability

A colleague, familiar with classroom observational techniques, was trained by the researcher (Sideridis, 1998). She was fully briefed regarding definitions of behaviours, and how they should be recorded, and introduced into the classroom environment where she undertook approximately three hours of practice observations. The researcher and trained observer then observed 20% of the sample simultaneously. These simultaneous observations were then compared and the concordance between them ascertained.

The data were analysed using the percentage agreement method. The total units of behaviour recorded for each child per category were summed. The higher total, be it recorded by the researcher or trained observer, was divided by the lower total to achieve a reliability index. This index was subsequently multiplied by 100 to calculate the percentage agreement between the two separate observers. The overall mean Inter-observer reliability Index was calculated as .989 (98.9% agreement) and the mean Inter-observer reliability indexes for each behaviour category are displayed in table 3.2. below.

Table 3.2: Mean Inter-observer reliability Indexes for each behaviour category on the Scope Classroom Observation Checklist

Behaviour	Reliability Index
Distracted	.986
Daydreaming	1
Fidgety	.988
Out of Seat	.998
Interrupting	.991
On-Task	.973

The reliability between observers for each category of behaviour, for each individual participant was also calculated, and was found to range from between 0.9 to 1. Observations of individual participants made across different teaching sessions were also found to concord highly. This was to ensure the robustness of the checklist over different times of day and different school settings. These figures reveal that the observations concord highly indicating high inter-observer reliability for the research tool and it was considered appropriate to go on to use the Scope Classroom Observation Checklist. (Appendix 3).

3.2.2 Participants

These were 157 children, 78 were male and 79 were female, (Mean age = 7 years 9 months). The children were recruited from four mainstreamed schools in Sheffield, UK, and had just entered year three or year four at the beginning of the research programme. Children were excluded from the study if they had a diagnosis of any psychological or physical disorder, and if parents declined to consent to their child's involvement in the study. Teachers also declined consent for children to take part if they felt this was necessary due to varied personal reasons. Altogether, approximately 15 children were excluded for these reasons.

3.2.3 Design

The purpose of the study was to select two groups of participants to take part in experiments 1-3 and a triangulation approach was employed for this purpose. The Observation Checklist described here, and the long version of the Conners' teacher rating scale (2001) was used to assess the 157 participants. Both were designed as measures of observable behaviour associated with inattention, hyperactivity and impulsivity. All participants were subjected to an identical procedure. From the sample of 157 participants it was proposed that two groups be formed, each consisting of approximately 60 participants to take part in experiments 1, 2 and 3. These comprised a control group of children with typical attentional skills and an experimental group of children rated as having a lowered attentional ability. Participants were observed under similar conditions, the typical classroom environment surrounded by their peers, and at similar times of day and week. Five participants were observed during each hour long session. The participants were unaware that they were being observed individually, and therefore were not aware when they were the focus of an observation period.

3.2.4 Measures

The groups were identified using the Scope Classroom Observation Checklist, teacher ratings of behaviour using the Conner's Teacher Rating Scale (2001), and non-verbal reasoning scores of the NFER Nelson Non-Verbal reasoning test (Smith and Hagues, 1993) and the performance IQ score of the Wechsler Intelligence Scale for Children III (WISCIII^{UK}) (Wechsler, 1992).

3.3.4 Procedure

The observations of the 157 participants were undertaken in morning literacy teaching sessions. These sessions generally comprised a mixture of teacher led instruction and independent academic work under the teachers' supervision, in line with education guidelines. Should the session deviate from this format observation ceased and was reconvened in a more appropriate session. Observations were made under the awareness of classroom and school rules, which were obtained from the teacher, in order to reduce the chance of recording behaviour that had been permitted by the teacher in error. Each of the 157 children in the sample were observed over an hour long session, for 4 periods of 2 minutes, thus yielding 8 minutes of data on each child.

Data was collected for each two minute interval with a one minute interval between each two minute interval to allow for locating the next child and changing observation sheets. The focus was on 5 children per observation session of one hour. Each of the 5 children was observed for 4 periods of 2 minutes during the hour long session. The two minute intervals were timed with the use of a stop watch. This procedure yielded a score on the Scope Classroom Observation Checklist for each child.

Teachers were then requested to complete the Conner's Teacher Rating Scale (Conner, 2001) long version, without prior knowledge of the Observation Checklist findings. These were ratings of behaviour during the previous month. Ratings for 72 of the 157 children were obtained and the scores on the observation checklist were compared to the scores on the teacher rating scale to assess the level of agreement between the measures. Teacher ratings for all of the children were not gathered as some of the classroom teachers were not able to complete the rating scale due to time constraints.

Scores for each participant on the teacher rating scale were calculated by adding together the scores for each subscale associated with inattention and hyperactivity-impulsivity. Of the 11 subscales of the Conners' rating scale 6 are associated with inattention, or hyperactivity-impulsivity. These 6 subscales represent, cognitive problems/inattention, hyperactivity, Conners' ADHD index, Conners' Global Index: Restless-Impulsive, DSM-IV Inattentive, and DSM-IV Hyperactive-Impulsive.

Each participant who had been rated by a teacher received a raw score between 0 and 153+ in total based on these 6 subscales. On the Conners' rating scales males would have to gain a higher score than females to fall into the atypical range, as certain impulsive behaviours are considered typical for boys yet atypical for girls in the typical population. Males, therefore, would have to score 63 or above to score in the atypical range on each of the six subscales, whereas females need to score 38 or above. This converts to a *t*-score of 56 or above on each of the 6 subscales. Any scores below 63 for males and below 38 for females would be classed as falling into the typical range, converting to a *t*-score of 55 or below on each of the 6 subscales. Should a child score outside the typical range on one particular subscale, yet perform well within the typical range on others, the overall score is likely to be within the typical range. Raw scores were used to more precisely calculate scores on the teacher rating scale.

If a high level of concordance between the researchers' and the teachers rating of behaviour emerged, the argument for using the observation checklist to identify an experimental and a control group would be strengthened. When the groups had been identified using the observation checklist, teachers were asked to rate any children who had not yet been rated, using the Conner's Teacher Rating Scales (2001).

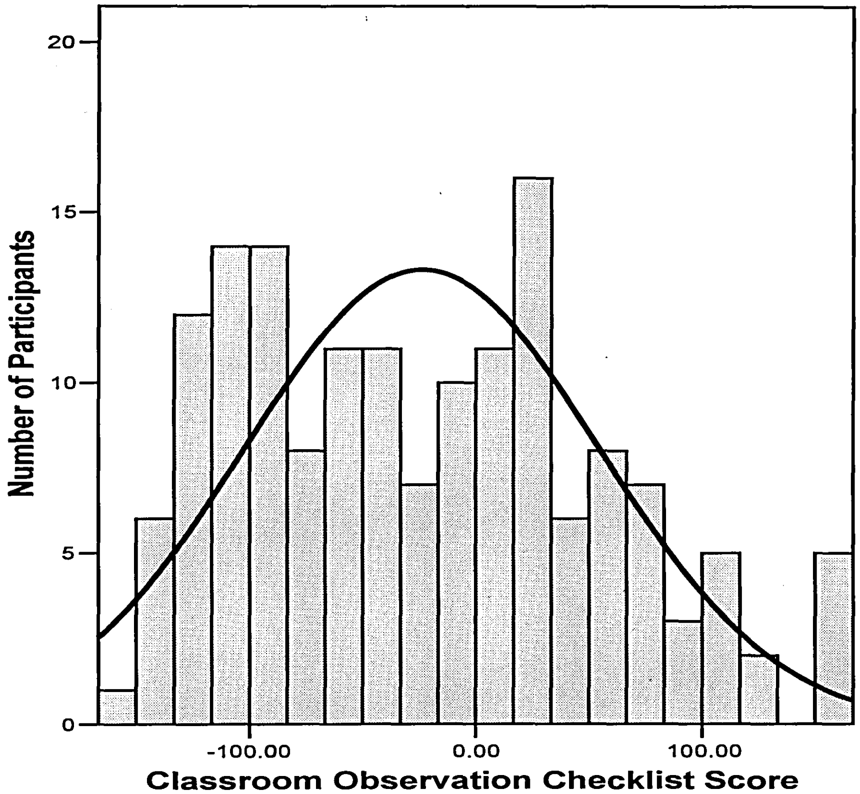
Once group membership had been confirmed by both the Scope Classroom Observation Checklist and Teacher Ratings, a final stage in the participant selection procedure was to match the groups for sex, age and non-verbal ability. The information on sex and age was gathered from the teacher rating scale, and non-verbal reasoning scores (Smith and Hagues, 1993) for year 3 children were taken from school records. Non-verbal ability scores for the year 4 children were obtained using the Wechsler Intelligence Scale for Children (WISC) (Wechsler, 1992). Performance measures of the test battery were administered individually to the participants in a quiet room in the school.

3.3 Results

3.3.2 Distribution of Scores on the Classroom Observation Checklist

The distribution of scores obtained by participants on the observation checklist is shown in figure 3.2. The histogram demonstrates a slightly skewed distribution of scores on the Classroom Observation Checklist. A high outlying score was amended to represent a score one above the next highest score (+241 to +159) (Tabachnick and Fidell, 2001). The distribution of these data, skewed slightly toward the typical range, would be expected for this type of population. The range of scores achieved on the checklist was -152 to +159 with a mean of -23.8 and a standard deviation of 78.4. Scores represent attentional lapses, therefore, scores with a negative value indicate good attentional skills whereas scores with a positive value indicate attentional difficulties.

Figure 3.2: Distribution of scores on the Classroom Observation Checklist

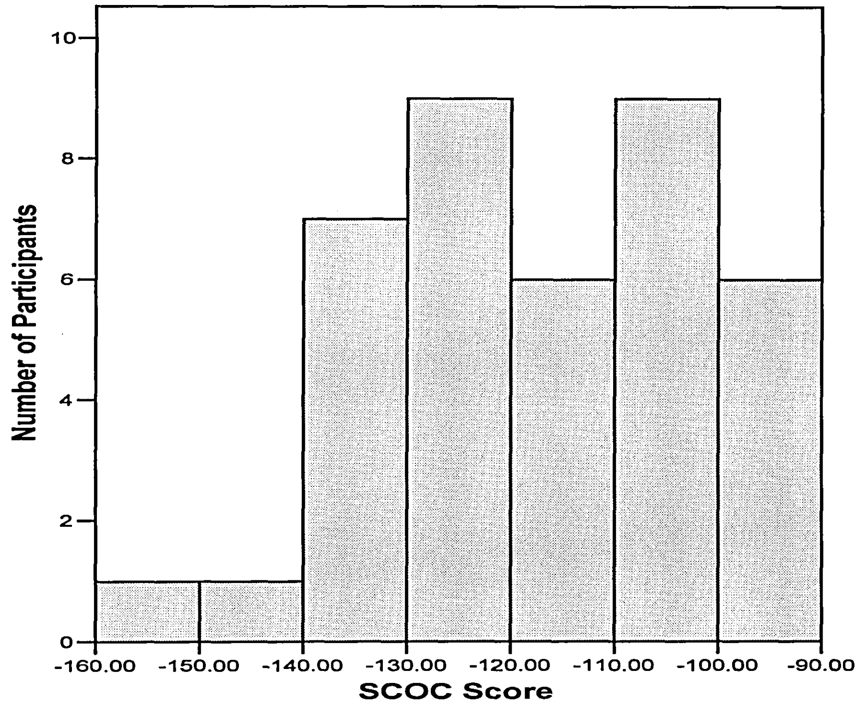


The inter-quartile range was calculated and participants whose observation checklist scores fell into the top or bottom quartiles of the data were selected as the experimental and control groups. 39 children scoring –92 or less were selected as controls (16 males and 23 females), and 41 children scoring 30 or more were selected for the AD group (28 males and 13 females).

3.3.2.1 The distribution of Scores of the Normal Control group.

The distribution of scores for the 39 children who fell into the bottom quartile of the data, and who were therefore initially selected as being eligible as controls, is shown below in Figure. 3.3;

Figure 3.3: Distribution of scores on the Scope Classroom Observation Checklist (SCOC) within the Normal Control Group

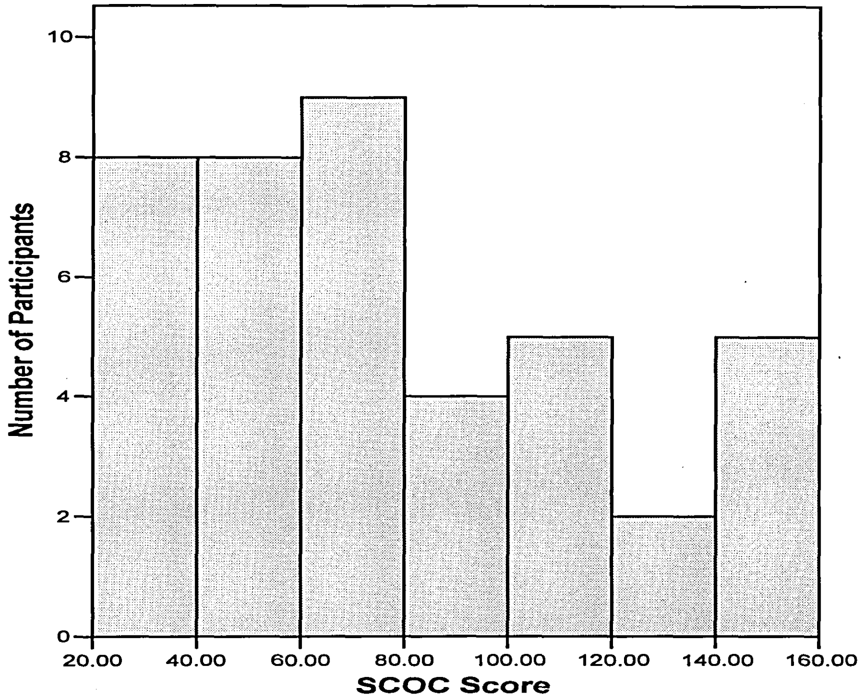


The histogram demonstrates a skewed distribution towards the typical range of scores, with fewer participants gaining extremely low scores indicating extremely good attentional skills. This sort of distribution would be expected as relatively few children in the general population would have excellent attentional skills. The mean score within the NC group was -117.4 with a standard deviation of 15.7.

3.3.2.2 Distribution of scores within the Attentional Difficulty group.

The distribution of scores for the 41 children who fell into the top quartile of the data, and who were therefore initially selected as being eligible for the Attentional difficulty (AD) group, is shown below in Figure. 3.4;

Figure 3.4: Distribution of scores on the Scope Classroom Observation Checklist (SCOC) within the AD Group



Again, the histogram demonstrates a skewed distribution, with relatively few participants scoring at the extreme. This distribution of scores would be expected as most participants should gain scores around the mean of the entire sample. The mean score within the AD group was 78.7 with a standard deviation of 39.9. The standard deviation was much bigger for the AD group compared to the NC group indicating more variation in behaviour as would be expected.

The histograms together demonstrate that the control and attentional difficulty groups fall in the tails of the distribution as a whole, emphasising that the entire sample has a normal distribution thus supporting the selection of participants. It should be noted that the standard deviations of the observation scores for each group and the flatter distribution suggest that there is more variability in scores for the AD group in comparison to the NC group. This may indicate that there are sub-groups within the AD group and this should be considered when interpreting the findings of the subsequent experiments.

3.3.3 Concordance rates between the Scope Classroom Observation Checklist (SCOC) and Teacher Ratings.

56 out of the 72 teacher ratings corroborated the observation checklist scores, and 16 disagreed with them. The concordance between the measures for each of the schools completing the teacher ratings at this stage is show in table 3.3. There was no significant association between school and concordance (Appendix 4).

Table 3.3: A table demonstrating the rate of concordance between the SCOC and the teacher ratings for each school

	Concordance		
School	**Agreements**	**Disagreements**	**Percentage Agreement**
A	32	11	74%
B	24	5	83%
Total	56	16	78%

The teacher ratings confirmed membership of the AD group for 17 participants, however, 8 of the participants gained high scores on the observation checklist, but did not gain high scores on the teacher rating scale. The level of agreement between the measures within the AD group was 68%. The teacher ratings confirmed membership of the NC group for 12 of the participants, disagreeing on none. The level of agreement between the SCOC and the TR within the control group was, therefore, 100%. Of the participants rated as falling somewhere between the top and bottom quartiles of the observation data, 27 were rated by teachers as falling here, and 8 were rated by teachers as falling into either the AD or NC groups, therefore the level of agreement here was 77%.

Overall, this represents 76.39% agreement between the measures. This percentage agreement strengthens the reliability of the observation checklist and additionally provides a triangulation approach to the selection of participants for each group. A Pearson Correlation was performed between the classroom observation score and the teacher rating scale score at this stage. This revealed a moderate positive correlation which was significant ($r = 0.596$, $n = 72$, $p < 0.05$, one-tailed).

Participants assigned to either the AD or NC groups using observation scores were rated by teachers unless this had previously taken place. Teachers were not aware of the group membership of these participants. The rate of agreement within the two groups was further assessed. If the teacher ratings did not corroborate the participants' membership of that particular group they were eliminated from the research programme, thus ensuring that the group membership of any participant taking part in experiments 1-3 had been assessed using two measures. Teacher ratings corroborated 35 of the 39 observation scores in the control group, disagreeing with 4. This yielded an 89.74% rate of agreement within the control group. Teacher ratings corroborated 32 of the observation scores in the AD group, leaving 9 scores uncorroborated. The rate of agreement within the AD group, therefore, was 78.05%. Participants with uncorroborated observation scores were eliminated and the rate of agreement between the measures in both groups was 100%.

15% of the participants rated by teachers were rated as having an elevated profile (t score of above 65) on the subscales associated with inattention and hyperactivity-impulsivity. It is suggested that further testing may show that a portion of these children have symptoms of ADHD according to DSM-IV criteria. There was no significant association in the number of elevated ratings by each school (Appendix 4).

Group differences

All of the participants selected for AD group membership displayed behaviours associated with both inattention and hyperactivity-impulsivity, in line with the types of behaviours associated with combined type ADHD. This is demonstrated in Table 3.4. The higher maximum scores associated with hyperactivity-impulsivity, opposed to inattention, can be explained by the fact that hyperactivity-impulsivity had one more category on the observation checklist associated with it. This is in line with DSM-VI criteria for ADHD (APA, 1994).

Table 3.4: The mean, standard deviation, minimum and maximum scores on the subscales of the Classroom Observation Checklist associated with inattention, and those associated with hyperactivity-impulsivity for the AD and NC groups

	AD Group (N=24)				NC Group (N=24)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Inattention	54.50	17.24	30.00	90.00	8.83	6.03	0.00	21.00
Hyperactivity/ Impulsivity	70.54	43.37	9.00	141.00	15.00	11.54	0.00	42.00

The mean scores of the AD group compared to those of the NC group clearly represent a difference between the groups on the basis of observable behaviour associated with inattention, hyperactivity and impulsivity. The standard deviations are quite large in the AD group. This could be explained by the large range of achievable scores or that there may be subgroups within the AD group as previously discussed.

Table 3.5: The mean scores and (standard deviations) for the AD and NC groups on the Classroom Observation Checklist

	AD Group (N=24)		NC Group (N=24)	
	Mean	SD	Mean	SD
Scope Classroom Observation Checklist Score	76.58	37.12	-115.67	15.78

The differences between the AD and NC groups on the Classroom Observation Checklist were significant. Children in the AD group scored significantly higher ($t = -29.173$, $df = 52.621$, $p < 0.001$, one-tailed, equal variances not assumed), than those in the NC group.

These results confirm that there are significant differences in the quantity of observable behaviour associated with inattention, hyperactivity and impulsivity between groups of children without a clinical diagnosis in mainstreamed schools.

Sex Differences

Mean observation scores and standard deviations were calculated for males and females, within the AD and NC groups, and across the entire sample. Table 3.6 demonstrates only small differences between the mean scores for males in comparison with females both overall and within the AD and NC groups. There is little deviation in the scores within the NC group for either males or females, and slightly more deviation within the AD group, particularly for females. This indicates lower consistency in the scores within the AD group.

Table 3.6: Demonstrates the means and standard deviations of observation score for males and females, overall and within the AD and NC groups

	AD Group (N=24)		NC Group (N=24)		Overall (N=24)	
	Mean	SD	Mean	SD	Mean	SD
Males (N=14)	75.57	36.54	-118.00	16.09	-21.21	102.38
Females (N=10)	78.00	39.86	-112.40	15.56	-17.20	102.02

T-tests demonstrated no significant sex differences on observation scores across the entire sample, or within the AD and NC groups (Appendix 5).

Differences between schools on the Classroom Observation Checklist

Mean observation scores and standard deviations were also calculated for each of the four schools involved with the research programme, within the AD and NC groups, and across the entire sample. Table 3.7 demonstrates quite large differences between mean scores for each school for the sample overall, which are reduced when considering the AD and NC groups separately. There is little deviation in the observation scores for each school within the groups, however, the standard deviations overall are much larger.

Table 3.7: Demonstrates the means and standard deviations of observation score for each school, overall and within the AD and NC groups

	AD Group (N=24)			NC Group (N=24)			Overall (N=48)		
School	***N***	**Mean**	**SD**	***N***	**Mean**	**SD**	***N***	**Mean**	**SD**
A	*11*	92.00	33.87	*4*	-110.50	15.29	*15*	38.00	97.27
B	*3*	54.00	22.92	*6*	-118.80	18.91	*9*	-32.40	93.20
C	*5*	82.20	48.71	*3*	-101.80	18.91	*8*	13.50	101.71
D	*5*	48.33	21.36	*11*	-101.80	1.00	*16*	-86.13	71.37

A univariate analysis of variance (Anova) revealed that there was a significant effect of school on observation checklist scores $F(3,44) = 5.239, p< 0.05$. A post-hoc Tukey test revealed a significant difference ($p = 0.002$) between scores obtained at school A and school D (Appendix 5). The participants enrolled at school D scored significantly lower (better attentional skills) than those at school A on the observation checklist. This could be explained by the fact that school A has special resource facilities. Although none of the participants used in this study were part of these classes, the presence of the unit may encourage parents of children with academic difficulties, which could be related to attentional difficulties, to enrol their children at this school. The second school by contrast had relatively good performance results. This meant a larger number of participants within the AD group were enrolled at the first school and a larger number of participants within the NC group were enrolled at the second. No differences between schools emerged, therefore, within the AD or NC groups.

Matching procedures

The children participating in experiments 1-3 were matched for sex and age. It was considered necessary to match the participants for sex to counter any effect of gender differences on measures of cognition. It was important that the groups were also matched for age due to developmental changes in performance on cognitive tasks. In order to eliminate any confounding variables related to learning difficulties it was also important that the groups did not differ significantly on the measures of non-verbal ability, and this was found to be the case. There were 14 males and 10 females in each group and the mean and standard deviation scores for age and non-verbal ability in each group are shown below in table 3.8.

Table 3.8: Demonstrates the means and standard deviations of age and non-verbal ability for the AD and NC groups

	AD Group (N=24)		NC Group (N=24)	
	Mean	**SD**	**Mean**	**SD**
Age	8 years 6 months	6 months	8 years 4 months	6 months
Non-verbal ability	94.17	13.96	100.17	11.04

One-way Anovas to test the differences between the groups for age, and non-verbal ability revealed no significant differences (Appendix 5). It should also be noted that none of the children in either the AD or NC group were considered by the schools as having learning difficulties and teachers reported that all children had achieved the expected reading levels for their age.

3.4 Discussion

3.4.2 Summary of the findings

The scores on the observation checklist were normally distributed across the sample of participants, given this, the significant difference in scores between the top and bottom quartiles of the data was expected. A high level of inter-observer reliability and agreement between the observation checklist and the teacher ratings supported the use of the observation checklist as an effective behavioural screening measure for attentional difficulties in the classroom environment. Two groups were formed to be used in experiments 1-3. Although differences between schools in the number of participants per group were observed, the reasons for this difference were considered and it was felt that this would not create any confounding variables, although this may have contributed to the variability within the groups.

3.4.3 Implications for the Continuum Theory of Attentional Difficulties

The scores on the observation checklist, although normally distributed, were slightly skewed toward good attentional skills. The normal distribution indicates that very few individuals have extremely good attentional skills, or indeed very poor attentional skills. These results support the findings of recent research which has suggested that minor attentional lapses are common in the typical population (Manly et al, 1999) and that ADHD symptomatology is continuously distributed in the entire population (Levy et al. 1997). The findings presented here, therefore, support the theory of an attentional skills continuum (Conner, 1997), as some of the participants presented varying degrees of behaviour associated with ADHD symptomatology yet did not have a diagnosis of ADHD.

It has been noted earlier that differing criteria are used for the diagnosis of ADHD between countries. The findings presented here may go toward explaining why differences in the degree of symptom severity used by different diagnostic systems may pick up more or less cases of ADHD. To further explain this point, it has been demonstrated here that teachers rate a number of mainstream school children, without any psychiatric disorder, as outside the typical range on DSM-IV criteria for ADHD. Teachers rated 15% of the children in the sample as having an elevated profile on subscales associated with inattention and hyperactivity-impulsivity. Further testing would be required to assess how many if any of these children would actually receive a diagnosis of ADHD using DSM-IV criteria. Prevalence rates of difficulties associated with inattention and hyperactivity-impulsivity in this study, however, would appear to more similarly reflect the prevalence rate of ADHD in American (3-5%) (APA, 1994) than that of hyperkinetic disorder in Britain (1%) (Cooper and Ideus, 1995). These findings also parallel those by Place et al. (2000), who too found that 70% of children with emotional and behavioural difficulties, who did not have a diagnosis of ADHD, were rated by teachers as outside the typical range for behavioural symptoms of the disorder. It could be claimed that teachers are biased when rating their pupils and Adams and Snowling (2001) warn against over reliance on such measures due to the 'halo effect' (section 2.3.3). The observation measure, however, provides external validation of the teacher ratings, although it cannot claim to be a diagnostic tool. It should be noted, therefore, that there is no suggestion that these children should receive a diagnosis of ADHD. As Conner (1997) recommends, numerous methods of assessment must be implemented prior to making any diagnosis of an attentional disorder. The results demonstrated here serve to illustrate, however, that children presenting behaviour associated with inattention and hyperactivity-impulsivity are present in mainstream school classrooms.

An explanation for the presence of children with difficulties associated with inattention, hyperactivity and impulsivity in the mainstream classroom, is the policy of inclusion set out in the Special Educational Needs (SEN) Code of Practice (DfEE, 2002). A number of the children rated here as belonging to the AD group were being monitored by the schools in line with the SEN guidelines (DfEE, 2002), whereas no children in the NC group were. This supports the contention made by Maras et al. (1997) that a small number of children described as presenting emotional and behavioural difficulties (EBD's) within the special educational needs categories, may have ADHD. Matching for non-verbal ability will eliminate confounding variables relating to learning difficulties. Although the groups were matched for non-verbal ability the standard deviations revealed that some children in the AD group had low scores on the measures of non-verbal ability. None of the participants, however, were considered by the schools to have learning difficulties and it was reported by teachers that each participant had achieved the expected reading levels for their age. The low scores on the non-verbal ability task, therefore, may reflect problems of motivation associated with attentional difficulties rather than learning difficulties. However, in order to assess whether low scores on non-verbal ability in the AD group can explain differences between the groups, these scores will be taken into account in the analyses in experiment 1.

Reports have shown that the academic achievement of children with ADHD (DuPaul et al., 2001) and those rated as hyperactive (Adams and Snowling, 2001) is significantly lower than that of their peers and this cannot be explained by comorbid learning difficulties (DeShazo Barry et al., 2002). Cognitive models have been proposed to explain this (Pennington and Ozonoff, 1996; Barkley, 1997) which suggest that impairments in executive functioning in these children result in academic underachievement. For the children selected here as presenting behaviours associated with ADHD there are, therefore, implications for academic achievement and cognitive function, and it follows that these manifestations may be present in this group, although at a lesser severity in comparison to ADHD groups.

3.4.4 Implications for sample selection: The utility of the Scope Classroom Observation Checklist (SCOC)

The findings of this study demonstrate support for the Scope Classroom Observation Checklist as a sensitive measure of inattention and hyperactivity-impulsivity in a population of typically developing children. The fact that this measure records all behaviour displayed during a specified period of time makes it more likely that it will pick up internalising behaviour rather than merely externalising behaviour. This makes the measure useful for assessing children in a classroom setting as it addresses the concerns of Bowers (2001), who suggests that internalising symptoms, perhaps more associated with the purely inattentive type ADHD, may go unreported on the assessment of EBD's using the SEN code of practice (Bowers, 2001). The results demonstrated here suggest that the observation checklist is sensitive enough to pick up at least some of these internalising symptoms. The categories associated with inattention, such as daydreaming and distracted, are often not as overt as the hyperactive-impulsive categories such as interrupting. The results showed, however, that all of the children in the AD group scored to some extent on categories associated with both inattention and hyperactivity-impulsivity.

By using an observational measure to initially select participants for membership of the AD and NC groups, any teacher bias was avoided. A high rate of agreement between the observation checklist and teacher ratings was calculated indicating that relatively very few teachers disagreed with the observation score, despite being unaware of what that figure was. Although a high rate of agreement between the measures suggests that any 'halo effect' (Adams and Snowling, 2001) has been minimised, this effect should have been reduced further by only using participants whose group membership has been confirmed by two measures.

In addition to both demonstrating the utility of the classroom observation checklist and its ability to differentiate typical children on the basis of behaviours associated with ADHD, the selection measures used here address some of the criticisms of previous studies which investigate ADHD. As section 2.3.3 illustrated, participant selection is often an area of concern in ADHD studies (Corkum and Siegel, 1993). This study has avoided any confounding variables such as differences between the groups in socioeconomic status, family background, and ethnicity, by using children from the same school classes for both the experimental and control groups.

The use of an observational method to identify children with difficulties associated with inattention and hyperactivity-impulsivity, has implications outside those associated with sample selection for research purposes. The observation checklist may prove to be a useful tool for teachers to use to identify pupils requiring extra academic support. The utility of measures for identifying children rated as having attentional difficulties have been demonstrated by Semrud-Clikeman et al. (1999). Children rated as having attentional difficulties took part in an 18 week intervention programme and showed an improvement on visual and auditory attention tasks, compared to a group rated as having attentional difficulties who did not take part in the intervention.

3.4.5 Conclusions

This study has demonstrated that difficulties associated with inattention and hyperactivity-impulsivity measured on the basis of DSM-IV criteria for ADHD (APA, 1994), are apparent in children in mainstream classrooms. It has been revealed that it is possible to differentiate between groups of mainstream school children on the basis of attentional skills. These findings have been supported by the continuum theory of attentional skills, SEN guidelines for inclusion in mainstream schools, and differences in diagnostic criteria used between countries. The Classroom Observation Checklist has emerged as a sensitive measure of difficulties associated with inattention and hyperactivity-impulsivity. It could prove to have practical utility for selecting children for intervention programmes in addition to selecting participants for experiments 1-3 here.

The initial hypothesis was that there would be children in mainstream classrooms who would be rated as inattentive and hyperactive-impulsive on the basis of DSM-IV criteria for ADHD. The previous evidence presented and the results demonstrated here support this hypothesis. Standardised teacher rating scales (Conners, 2001) based on DSM-IV criteria for ADHD were implemented and a number of children were found to score outside the typical range on inattentive and hyperactive-impulsive subscales. The Classroom Observation Checklist scores were also corroborated by these ratings. The second hypothesis stated that it would be possible to differentiate two groups of typical children on the basis of attentional skills using the Classroom Observation Checklist. Again this hypothesis was supported, in that significant differences on attentional lapses, as measured by the observation checklist, were found between the two selected groups.

If these findings are reflective of ADHD behavioural symptoms being distributed across the population in varying degrees of severity, it implies that both the manifestations and underlying causes of these, such as impairments in cognitive functioning, will also be distributed in varying degrees across the typical population. Experiment 1 aims to assess this hypothesis by comparing the performance of the two groups of children selected using this study on measures of Executive Function. If the findings demonstrate that the groups significantly differ on these measures it will provide further support for the continuum theory of attentional difficulties together with a rationale for further investigating higher order cognitive function in this group.

Chapter 4 - Experiment 1 - A test of Barkley's (1997) Model of Inhibition in children with observed and rated attentional difficulties.

4.1 Introduction

Section 1.3.2.1 reviewed a number of Executive Function (EF) models which have been proposed to account for the symptoms of Attention Deficit / Hyperactivity Disorder (ADHD). Barkley (1997), Pennington and Ozonoff (1996), Sergeant et al. (1999), Quay (1997) and Sonuga-Barke (1994, 2003) have all proposed theoretical models to account for the cognitive impairments presented by children with ADHD. Although Quay (1997) and Sonuga-Barke (1994, 2003) propose that the cognitive impairments observed in ADHD have a motivational cause, thus implicating bottom-up processes, a number of these models explain ADHD as characterised by impairments in top-down processing, implicating Executive Function rather than reduced attentional capacity (Barkley, 1997; Pennington and Ozonoff, 1996; Sergeant et al. 1999). Barkley's (1997) model suggests that an inhibitory control deficit gives rise to the secondary cognitive difficulties documented in children and adults with attentional difficulties. These cognitive difficulties are reportedly responsible for the pattern of impaired academic and social function in children with ADHD. As these models imply, a deficit in EF is likely to have repercussions for working memory. The responsibilities of working memory that are executive in nature are dealt with by the central executive component of the model. As the central executive is responsible for organising executive resources in working memory it is likely that it is dependent on executive function (Barkley, 1997; 2001).

There has been recent empirical support for models suggesting that ADHD is characterised by executive function impairments. These investigations have provided particular support for inhibitory control as central to executive dysfunction, which is consistent with Barkley's (1997) model. Although a number of empirical investigations have been reported to test the inhibition model, due to the lack of consensus regarding the measurement of executive function (see section 2.4.2.1), the tasks used are varied making interpretation problematic. Despite this, however, some executive functions have been found to be consistently impaired in ADHD groups. The majority of these empirical investigations (see section 1.3.2.3 for a review) have reported impairments in ADHD groups on tasks designed to measure the various activities attributed to the executive function of response inhibition (Lawerence et al., 2002; Charman Carroll and Sturge, 2001; West et al., 2002 etc). The precise activities of response inhibition which were impaired, however, vary across these investigations with some on measures of interference control, some on measures of inhibition of a prepotent response and some on the inhibition of an ongoing response. The fact that a number of empirical investigations have consistently found deficits in ADHD groups on measures associated with response inhibition, both illustrates the importance of this executive function, and provides strong support for Barkley's (1997) hierarchical model.

Although measures of inhibition appeared to be the most reliable measures to differentiate ADHD children from typical controls, working memory measures which are also thought to reflect executive function, also emerged as important differentiating measures. All of the investigations reported which included a measure of working memory, with the exception of Adams and Snowling (2001) who were investigating children rated as hyperactive, found impairments on working memory in the ADHD group. Again, most investigations did not use both a measure of verbal and visuo-spatial working memory, making interpretations regarding specific working memory impairments impossible.

On measures of reconstitution the evidence for a deficit in fluency in ADHD groups was inconsistent. Scheres et al. (2004) and Berlin et al. (2004) reported impairments in ADHD groups on measures associated with verbal fluency, however, Lawrence et al. (2002); Adams and Snowling (2001); Shallice et al. (2002); Mahone et al. (2002) did not find evidence for this impairment. Again specific interpretations were made difficult as non verbal fluency and ideational fluency were not assessed in these investigations.

Only one of the investigations reviewed in section 1.3.2.3 used a measure of emotional self-regulation (Berlin et al., 2004) and on this measure the ADHD group was found to be impaired. This demonstrates that further empirical support for the utility of this measure in differentiating groups is required.

The findings of study 1 demonstrated that the behavioural symptoms associated with ADHD may be distributed across the population in varying degrees of severity. It was concluded that this implies that the hypothesised underlying causes of these behavioural symptoms, higher order cognitive function impairments, will also be distributed in varying degrees across the typical population. Experiment 1 was designed to investigate the extent to which the two groups of children who differ in their behavioural manifestations associated with inattention, hyperactivity and impulsivity, differ on measures of executive function which are the functions hypothesised to be under the control of the central executive component of working memory.

The aim was to administer tests of executive function in order to test Barkley's (1997) model. The intention of this investigation was to follow the methodology of Barkley et al.'s (2001) investigation as closely as possible, using similar tasks to assess executive function. In their investigation Barkley et al. (2001) used separate measures of non-verbal and verbal working memory, fluency tasks, a measure of emotional self-regulation, and a continuous performance task which included measures of both inhibition and inattention. Barkley et al. (2001) found that the ADHD group performed significantly worse than controls on these measures. The aim of experiment 1, therefore, was to ascertain whether children with observed and rated attentional difficulties would demonstrate a similar pattern of performance in comparison to controls on these tasks. If the groups significantly differ on these measures it will provide support for the utility of Barkley's (1997) inhibition model for differentiating between children with and without observed and rated attentional difficulties. This would also provide further support for the continuum theory of attentional difficulties and strengthen the rationale for investigating higher order cognitive function in this group.

It is hypothesised that children in the attentional difficulty (AD) group will perform significantly worse than children in the normal control (NC) group on all measures of Executive Function.

4.2 Method

4.2.1 Participants

Two groups of children (aged 8-9 years), identified in study 1. 24 children (14 males, 10 females) in the Attentional Difficulty (AD) group had been matched with children the 24 children in the Normal Control (NC) group for sex, age and non-verbal ability.

Table 4.1: Demonstrates the means and standard deviations of age and non-verbal ability for the AD and NC groups

	AD Group (N=24)		NC Group (N=24)	
	Mean	**SD**	**Mean**	**SD**
Age	8 years 6 months	6 months	8 years 4 months	6 months
Non-verbal ability	94.17	13.96	100.17	11.04

4.2.3 Design

A mixed design was used. The independent variable was group with two levels, attentional difficulty (AD) group or normal control (NC) group. The dependent variables were the scores on each of the tasks.

4.2.4 Measures

13 tasks and 1 subscale of a teacher rating measure were selected to assess functioning on the five executive functions identified by Barkley (1997). These were verbal working memory, nonverbal working memory, reconstitution, response inhibition and self-regulation. In addition, a measure of central executive function was administered in order to account for the different definitions of working memory used in the literature.

Response inhibition was assessed using the Conners' Continuous Performance Test (CCPTII) (Conners, 2000). This task was administered on a laptop computer and the object of the task was to monitor the letters appearing on the screen and to respond using the space bar to any letter with the exception of 'x'.

t-scores for hit rate, omission errors, commission errors, hit rate standard error, and variability of standard error were assessed.

Working memory was assessed using the nine tasks of the Working Memory Test Battery for Children (WMTB-C) (Pickering and Gathercole, 2001). Four verbal working memory tasks were used, digit recall, word list recall, nonword recall and word list matching, together these tasks constituted a Phonological loop component score on which groups were compared. Two nonverbal working memory tasks were used, these were block recall and mazes memory, these constituting the visuo-spatial sketchpad score on which groups were compared. The central executive tasks were listening recall, counting recall, and backward digit recall and constituted the Central Executive component score. Participants were provided with either spoken or visual stimuli which they were required to retain for immediate recall.

Reconstitution was assessed using fluency tasks. The three tasks used were, verbal fluency (Benton et al., 1983), non-verbal fluency, and ideational fluency. The tasks used to assess nonverbal fluency and ideational fluency were developed based on those used by Barkley et al. (2001). The verbal fluency task required participants to tell the examiner as many words they could think of in one minute beginning with a given letter. The non-verbal fluency task required participants to tell the examiner as many objects they could think of in two minutes which could be represented by a number of shapes. The ideational fluency task required the participants to tell the examiner as many purposes they could think of in a one minute period for a given object. Scores represented total correct responses.

Self-regulation was measured using the t score for the emotional lability subscale of the Conners' Teacher Rating Scale long version (CTRS:L) (Conners, 2001).

4.2.5 Procedure

Testing took place during a school term in four primary schools. A designated testing area was arranged to be used in each school, where distractions could be kept to a minimum. This room was often a library area, a quiet reading room, or a staff room. Children were tested individually by the experimenter on the 13 tasks designed to measure each of the five executive functions (Barkley et al., 2001). The measure of self-regulation had previously been collected as part of the selection measures outlined in study 1. The testing sessions were split into time periods of a maximum of 20 minutes and each child was tested on five different occasions. The children were tested according to testing guidelines and procedural advice and the tasks were administered in the same order to each of the participants.

The participants were given the opportunity to practice each of the tasks prior to the administration of the experimental conditions. For the standardised tasks there were a set number of practice trials which had to be completed accurately before testing began. For the fluency tasks the participants were given an example letter, shape or object and asked to generate responses until the examiner was satisfied that the object of the task had been understood. When practice trials had been completed successfully and the participant confirmed they understood what was required of them, testing began. The participants' progress was recorded on a score sheet during the working memory tasks, and all responses given on the fluency tasks were noted down. The scores on the Continuous Performance Test were saved to the laptop computer. These procedures provided the data to calculate a total score for each measure.

4.2.6 Analyses

Multivariate analysis of variance (Manova) was employed to assess the effect of group membership on the separate dependent variables both together and individually. The following dependent variables were assessed using Manova; phonological loop component score, visuo-spatial sketchpad component score, central executive component score, verbal fluency score, non verbal fluency score, ideational fluency score, omission errors, commission errors, hit rate, hit rate standard error, and variability of standard error. Prior to the Manova being implemented these eleven dependent variables were assessed for multicollinearity. It is recommended that if the correlation coefficients for any pair of dependent variables exceed 0.9 follow up analysis should be in the form of discriminant analysis (Brace et al., 2003). The Pearson's correlation coefficients exceeded 0.9, for one pair of dependent variables, variability of standard error and hit rate standard error. Scatterplots revealed linear relationships between the dependent variables, adhering to a further assumption for the use of Manova. (Appendix 6).

4.3 Results

4.3.1 Treatment of the data

The distribution of scores on each of the twenty-one dependent variables measured was examined. Normal distribution of scores was observed on all of the variables with the exception of self-regulation which was positively skewed. Although the variables, word list matching, block recall and omission errors were normally distributed, examination of boxplots revealed outliers. The outliers were amended to represent one score above the next highest or one score above the next lowest as appropriate (Tabachnick and Fidell, 2001).

The descriptive statistics (see table 4.2) revealed that the AD group scored lower than the NC group on the majority of the tasks undertaken. This was particularly the case for working memory tasks but less so for response inhibition tasks. The scores on the fluency tasks, however, demonstrated very little difference between the groups, and were within the normal range for verbal fluency (Gaddes and Crockett, 1975 cited in Spreen and Strauss, 1998). The variability of the scores for the AD group on the working memory and self-regulation measures are greater than for the NC group, and should be considered when interpreting the findings.

Manova was conducted on the eleven variables judged to be normally distributed. As the variable self-regulation score did not meet parametric assumptions, it was not included in the Manova analysis and was analysed using the Mann-Whitney test (Appendix 7).

The Box's M test revealed that the data did not violate the assumption of homogeneity of variance, as it was not significant. As the mean and standard deviation scores (table 4.2) suggest there was a significant effect of group on the combined dependent variable of executive function task score $F(11,36) = 15.895$, $p < 0.001$, *Wilks' Lambda* $= .171$, *partial* $\eta^2 = 0.83$.

Table. 4.2: Demonstrates the means and standard deviations for all of the Executive Function measures for each group

		AD Group (N=24)		NC Group (N=24)		Overall	
		Mean	SD	*Mean*	SD	*Mean*	SD
EF measures							
Verbal Working Memory (SSS)	*Digit Recall*	*106.45*	22.16	*114.52*	18.79	*110.08*	20.94
	*Word List Matching***	*85.09*	26.06	*104.63*	11.72	*93.88*	22.91
	*Word List Recall***	*100.69*	19.55	*119.00*	14.65	*108.93*	19.65
	*Nonword List Recall***	*108.15*	16.52	*130.48*	15.26	*118.20*	19.40
	PL Component Score**	*97.64*	25.57	*123.30*	14.76	*109.18*	24.83
Nonverbal Working Memory (SSS)	*Block Recall***	*88.97*	22.88	*110.19*	12.17	*98.52*	21.51
	*Mazes Memory***	*101.73*	12.33	*118.37*	13.29	*109.22*	15.17
	VSSP Component Score**	*93.24*	21.62	*117.11*	12.49	*103.98*	21.85
Central Executive (SSS)	*Listening Recall***	*99.27*	17.03	*124.18*	14.17	*110.48*	20.05
	*Counting Recall***	*89.30*	15.69	*114.04*	10.55	*100.43*	18.34
	*Backward Digit Recall***	*88.73*	13.84	*113.41*	13.78	*99.83*	18.46
	CE Component Score**	*89.45*	18.30	*124.37*	12.90	*105.17*	23.70
Reconstitution (Total Number of Responses Generated)	***Verbal Fluency***	*19.03*	6.92	*19.70*	5.19	*19.33*	6.16
	Nonverbal Fluency	*13.58*	4.84	*13.11*	3.71	*13.37*	4.34
	Ideational Fluency	*15.67*	5.35	*14.33*	3.69	*15.07*	4.69
Response Inhibition (t scores)	***Commissions (Inhibition)*****	*59.46*	6.65	*53.02*	7.05	*56.24*	7.52
	Omissions (inattention)	*56.88*	9.50	*53.02*	5.61	*55.43*	7.86
	Hit Rate (inhibition)	*48.81*	6.65	*49.88*	11.33	*49.34*	10.90
	Hit Rate Standard Error (inattention)	*55.48*	7.79	*51.20*	9.67	*53.34*	8.95
	Variability of Standard Error (inattention)	*54.69*	7.86	*51.98*	10.88	*53.34*	9.49
Self-regulation (t scores)	***TRS -Emotional Lability)****	*57.52*	13.60	*47.56*	5.32	*53.35*	11.91

(SSS) = Subtest Standard Score - The lowest possible subtest standard score is 55 and the highest possible is 145, with an average score of 100. Higher self-regulation scores indicate a difficulty in self-regulation. t-scores between 45 and 54 are classed as within the average range. **= significant group differences p<0.004, *= significant group differences p<0.05.

The univariate Anovas of each individual dependent variable showed that the NC group significantly outperformed the AD group on the majority on the measures employed, as table 4.2 suggests, even when a Bonferroni adjusted alpha level of 0.004 was applied. The groups differed significantly on the phonological loop component score $F(1,46) = 20.69, p<0.004$, *partial* $\eta^2 = 0.31$, the visuo-spatial sketchpad component score $F(1,46) = 36.482, p<0.004$, *partial* $\eta^2 = 0.44$, the central executive component score $F(1,46) = 64.964, p<0.004$, *partial* $\eta^2 = 0.58$, and on commission errors $F(1,46) = 10.579, p<0.004$, *partial* $\eta^2 = 0.19$. It should be noted, however, that the Levene's test of equality of error variances was significant for the central executive component score, therefore caution is advised when interpreting these findings. This suggests that distribution of scores within groups was highly variable. There was also a significant difference between the AD and NC groups on the measure of self-regulation $U = 174.500, z = -2.391, p = 0.017$, *two-tailed.*

On the continuous performance test measures there were no significant differences between the groups on omission errors, hit rate, hit rate standard error, or for variability of standard error. Interestingly no significant differences emerged between the groups on any of the fluency tasks, verbal fluency, non verbal fluency, and ideational fluency. Caution is advised, however, when interpreting the findings for the ideational fluency, omission error, and variability of standard error scores, as the Levene's test of equality of error variances was significant indicating a high level variability in scores within the groups. This may indicate sub-groups within the groups scoring at each end of the range of scores. This might be an indication that there are differences within the AD group based on the predominance of difficulties associated with inattention or hyperactivity-impulsivity.

The discriminant analysis was performed with group as the dependent variable and phonological loop component score, visuo-spatial sketchpad component score, central executive component score, verbal fluency score, non verbal fluency score, ideational fluency score, omission errors, commission errors, hit rate, hit rate standard error, and variability of standard error as predictor variables. A single discriminant function value was calculated. The value of this function significantly differed for the AD and NC groups *chi-square* =

71.587, df =11, p=0.001. The correlations between predictor variables and the discriminant function suggested that the three working memory component scores; central executive component score, visuo-spatial sketchpad component score and phonological loop component score respectively, were the best predictors of group membership. These scores were negatively correlated with the discriminant function value, suggesting that participants scoring lower were more likely to be part of the AD group. The next best predicators were commission errors and hit rate standard error. These were positively correlated suggesting that participants making more of these errors were more likely to be part of the AD group. Overall the discriminant function successfully predicted outcome for 100% of cases.

The analyses suggest that both storage and executive aspects of working memory contribute to the differences between the groups. It seems, however, as predicted that storage aspects alone cannot fully explain the differences between the groups. The order of the factor loadings clearly identifies the central executive component score as the best factor to differentiate the groups, emphasising the importance of the executive aspects of working memory in differentiating the two groups tested here. The next best predictors are the storage only factors of the phonological loop and visuo-spatial sketchpad scores. This finding confirms that storage processes are detrimentally affected in the AD group, however, the following predictor is the commission error measure of inhibitory control, again, clearly identifying the importance of executive attentional mechanisms in differentiating the groups.

In order to assess whether differences between the groups could be accounted for by differences in non-verbal ability scores, Multivariate analysis of covariance (Mancova) was performed. Homogeneity of regression and linear relationships between the covariate and dependent variables were confirmed. The variable non-verbal ability score was entered into the analysis as a covariate. The analyses showed that non-verbal ability score could not explain the differences between the groups on executive function as there was no significant effect of non-verbal ability score on the combined dependent variable of executive function task score (Appendix 8).

Qualitative Analysis

On inspection of the type of responses provided on the fluency tasks children in the AD group seemed to generate more varied and imaginative ideas, whereas children in the NC group were more likely to produce ideas within categories. Children in the AD group also appear less apprehensive regarding producing ideas that may have been viewed as socially unacceptable. 29 of the participants tested, provided responses on the fluency tasks which could be described as socially acceptable, or in no way socially unacceptable. The remaining 19 participants tested on the fluency tasks did produce at least one response which may be regarded as socially unacceptable. Of these participants, 15 belonged to the AD group and 4 belonged to the NC group. (Appendix 9 – examples of this data).

The 'socially unacceptable' responses were generally given on the ideational fluency task, and were most often associated with the uses of a brick and sometimes the uses of a rope. During the ideational fluency task, the occurrence of responses, which could be described as socially unacceptable, was 19 within the AD group and 6 within the NC group. The responses included purposes to damage objects or other people, e.g. 'smash things up', 'kill people', 'break someone's arm', 'strangling', 'whipping' and 'gagging'. During the verbal fluency task these responses occurred 13 times within the AD group, however, none of these responses were generated by the NC group. The socially unacceptable responses were again associated with causing damage, particularly to other persons, e.g. slap, spit, shoot, shot, and suffocate. These findings suggest that although the groups did not differ in the number of ideas they were able to generate on the fluency tasks, they did appear to differ in the type of response they were likely to give.

The mean scores for the AD group, although generally below the normative mean, were all within 1 standard deviation of the normative mean. The mean scores for the NC group were generally above the normative mean, and usually within 1 standard deviation above the normative mean. This demonstrates that although the groups significantly differed, scores for both groups were within the typical range of scores on standardised tests.

4.4 Discussion

4.4.1 Overall Findings

The results suggest that children in the attentional difficulty group overall performed at a lower level than children in the control group on measures of executive function, providing support for the hypothesis. Interestingly, however, the scores on standardised tasks remained in the typical range for both groups. Although overall differences between the groups emerged for executive function, follow up analysis revealed that there were no significant differences between the groups on fluency measures, and a number of the continuous performance test measures. Further analysis of the fluency results suggested that any differences between the groups reflected the type of response generated rather than the total number of responses generated. The results from the continuous performance test appeared to reflect a lowered performance by the attentional difficulty group on a measure of inhibition yet not on measures of attentional capacity. This is consistent with recent views of attentional difficulties as associated with attentional control rather than attentional capacity.

As previously noted, the scores on the standardised tests were found to be in the typical range for both groups providing support for the idea that attentional skills may lie on a continuum. Although significant differences were not found on all executive function tasks, it seems that children rated as inattentive perform at a significantly lower level than children rated as having good attentional skills on a number of executive function measures. The pattern of findings would be consistent with a theory of differences between the groups in the development of higher order cognitive processes (Zelazo and Frye, 1998).

The analyses also revealed the magnitude of the differences between the groups, thus revealing which measures had been the most useful in discriminating the groups. The central executive component score was revealed to be the most reliable discriminating measure (*partial* $\eta^2 = 0.58$), followed by the visuo-spatial sketchpad component score (*partial* $\eta^2 = 0.44$).

These findings are consistent with the results of empirical investigations of ADHD groups. The majority of the empirical findings reviewed in section 1.3.2.3

(e.g. Berlin et al., 2004; Muir-Broaddus et al., 2002; Lawrence et al., 2002) reported significant differences between ADHD children and matched controls on an array of tasks proposed to measure executive function. The particular tasks on which the group performance significantly differed, however, varied between investigations. This could be accounted for by methodological factors, such as the different tasks used or the different criteria applied for the matching of participants.

4.4.2 Response Inhibition

Commission errors, identified by Barkley et al. (2001) as measuring inhibition differentiated the groups, whereas, the measures which Barkley et al. (2001) suggested measured inattention did not. These findings support the contention that behavioural manifestations associated with ADHD are caused by attentional regulation or inhibitory control dysfunction rather than a general problem of attentional capacity. This is the premise of not only Barkley's (1997) Inhibition model but most of the recent models of cognitive function in ADHD reviewed in section 1.3.2. A further measure of inhibition, hit rate, however, did not differentiate the groups. An explanation for this is that both groups scored below average, indicating higher than average impulsivity, and this may have masked any impulsivity on the part of the AD group. Further, this measure may more strongly reflect motor impulsivity rather than cognitive impulsivity or inhibition. It may be the case that motor control is relatively unaffected in the AD group compared to groups with ADHD. This would explain why the groups assessed here do not differ on this measure.

4.4.3 Working Memory

The emergence of working memory measures as most useful in discriminating the groups was predicted by all but one of the empirical investigations reviewed in section 1.3.2.3. Further, in the review of the current cognitive models of ADHD (section 1.3.2) working memory featured highly. This would also be supported by Pennington and Ozonoff (1996) who suggested that executive tasks are characterised by those which have both high working memory and inhibitory control demands, or those with a high demand for either. They suggest that working memory may be demanded for the overcoming of inaccurate prepotent responses. Pennington and Ozonoff's (1996) proposal that working memory and inhibition are two dimensions which are critical for understanding executive function provides the argument for investigating working memory task performance in more detail in children with attentional difficulties. The role of working memory in attentional difficulties has been unclear in previous investigations as the tasks employed have not been clearly specified, therefore, this problem should be addressed. The finding that the central executive and visuo-spatial component scores were particularly effective in discriminating the groups, together with previous findings, emphasises the dependency on EF for the adequate performance on these tasks. These findings provide support for the central executive (Baddeley and Hitch, 1974; Baddeley, 2000) as a construct which is responsible for executive function task performance.

4.4.4 Reconstitution

The finding of no significant differences between the groups on measures of reconstitution is contrary to the hypothesis. While the non-significant finding was not predicted a priori, this finding does replicate previous studies that also failed to find evidence of impairment on fluency measures (Lawrence et al., 2002; Adams and Snowling, 2001; Shallice et al., 2002; Mahone et al., 2002). Further, the majority of empirical investigations did not assess nonverbal fluency and ideational fluency, making interpretations problematic. An interpretation of these findings, particularly with reference to verbal fluency, is that this ability is more heavily associated with language ability than inhibitory control. Support for this interpretation comes from an investigation by Cohen et al. (1996). They compared verbal fluency in three groups of children, a group of typical children, a group of children with developmental dyslexia and a group of children with ADHD. The verbal fluency task was found to be clinically useful for differentiating groups based on language disorder. The language disorder subgroup of the dyslexic group performed significantly worse on the task in comparison to the visual spatial subgroup and the ADHD group, who both performed within the average range. These findings suggest that verbal fluency ability is dependent on language ability. An explanation for the findings presented here, therefore, is that the AD group has adequate language abilities to perform this task. This hypothesis is supported by the finding that verbal fluency was in the normal range for both groups (Gaddes and Crockett, 1975 cited in Spreen and Strauss, 1998).

The qualitative differences between the groups may also be linked to a difference in levels of externalising emotional behaviour associated with aggression. Groups differed on the measure self-regulation and this difference may have been due to ratings of aggression. There was a high level of variability in these scores perhaps due to a number of children within the AD group gaining high ratings for emotional lability, while others were rated as manifesting typical emotional responses.

A further explanation for the non significant finding on fluency measures, centres on the inhibitory dysfunction account of ADHD. The fluency tasks administered here do not seem to be reliant on inhibitory control to the same extent as the other executive function tasks administered. There are no demands for the inhibition of an ongoing response as the task does not have dual demands and there is little need for interference control. It may be the case, however, that the inhibition of a prepotent response is demanded for this task and may explain firstly why the AD group is equally efficient at producing words or ideas as the control group, and secondly why the AD group appear to have difficulties inhibiting responses which are, arguably, socially unacceptable. Pennington and Ozonoff (1996) in their review of EF investigations of ADHD concluded that verbal tasks are not very sensitive to ADHD, as none of the investigations they reviewed found a significant group difference.

The qualitative differences between the groups on measures of fluency could be explained by the Supervisory Attentional System (SAS) (Norman and Shallice, 1980). The task requires strategy application, the ultimate objective of the SAS. The qualitative analysis revealed that the groups used different strategies whilst undertaking the task. The NC group generally seemed to provide responses in categories, such as, objects in the testing room, whereas the AD groups' responses were more varied and did not seem to belong to categories. These observations may reflect a difference between the groups on strategy application which has been suggested as a manifestation of underlying problems of SAS function (Burgess, 2000). It could be concluded therefore, that children in both groups have adequate language ability to perform the fluency tasks, however, they differ on strategy application. If the AD group have difficulties on strategy generation performance may diminish on longer or more complex tasks, such as random generation tasks used by Baddeley (1996). These interpretations have clear implications for central executive and SAS functioning in the AD group. These hypotheses could be addressed by using tasks which have increasing demands for complex strategies.

4.4.5 Self-regulation

The finding of a significant group difference on the measure of self-regulation is consistent with the findings of Berlin et al. (2004) who found impairments in an ADHD group on this measure. This provides further empirical support for the utility of this measure in differentiating groups, although, as noted above, the reasons for the large degree of variation in scores in the AD group would need to be clarified.

4.4.6 Implications of the findings for Barkley's (1997) Inhibition Model, the central executive and the SAS

These findings demonstrate that Barkley's model provides a relatively good framework for characterising the cognitive difficulties experienced by children with observed and rated attentional difficulties. The findings have suggested, as Barkley (1997) asserted, that response inhibition is a key construct in cognitive accounts of attentional difficulties. Some anomalies have emerged, particularly with reference to measures of fluency. These anomalies, however, are supported by previous empirical findings and further can be explained with reference to the importance of response inhibition, thus do not seem to discredit Barkley's (1997) model in any serious ways.

Although the findings do not discredit Barkley's model, the findings could equally be explained with reference to the central executive of the working memory model (Baddeley and Hitch, 1974; Baddeley, 2000) and the Supervisory Attentional System (SAS) (Norman and Shallice, 1980). The central executive and the SAS are proposed to be responsible for the organisation of executive resources. The findings presented here make it clear that the differences between the groups are dependent on differences in the application of these executive resources.

4.4.7 Summary of findings

In summary, this experiment has provided support for Barkley's model in differentiating children with and without observed and rated attentional difficulties at a lesser severity to those with ADHD, or those children lower on the attentional skills continuum. Attentional regulation, termed here as inhibition, rather than attentional capacity appears to characterise the AD group, although the activities of response inhibition to which this applies remains unclear. Although the commission errors measure on the continuous performance test appeared to provide a measure of inhibition of an ongoing response, this measure could equally demonstrate inhibition of a prepotent response. The validity of tests of fluency for the measurement of executive function has been raised and the findings add to the body of literature already addressing this point.

Working memory measures, particularly central executive and visuo-spatial sketchpad measures have emerged as useful measures for differentiation between children with and without rated and observed attentional difficulties. These findings, together with the relative importance of working memory to executive function attributed by Pennington and Ozonoff (1996) provide a rationale for the investigation of working memory in children with attentional difficulties in more detail. The aims of experiment 2, therefore will be to investigate visuo-spatial working memory in children with attentional difficulties.

Chapter 5 - Experiment 2 - Visual and Spatial Working Memory in Children with attentional difficulties compared to children with good attentional skills.

5.1 Introduction

Experiment 1 demonstrated that the Attentional Difficulty (AD) and Normal Control (NC) groups differed on a range of tasks proposed to measure executive function including measures of working memory. The AD group performed at a significantly lower level than the NC groups on central executive, phonological loop and visuo-spatial sketchpad tasks. The central executive and visuo-spatial sketchpad component scores emerged as the best discriminators for group membership. These findings were interpreted as supporting the hypothesis of an association between lowered working memory task performance, particularly for central executive and visuo-spatial sketchpad tasks, and attentional difficulties. The findings confirm results of executive function investigations of ADHD using measures of working memory (Barkley et al., 2001). The findings also confirm the idea that working memory and executive function have strong links as Pennington and Ozonoff (1996) have suggested. Experiment 2 aims to investigate performance on visuo-spatial working memory tasks in more detail.

Compared to the number of studies investigating executive function in children with attentional difficulties, there have been relatively few that have closely examined working memory function (see section 1.3). Further, these investigations have not systematically assessed the involvement of components of working memory. Roodendrys et al. (2001) looked only at the phonological loop and the central executive as the main aim of their investigation was to examine working memory differences between children with ADHD and children with reading disability. An investigation by Karaketin (2004), however, focussed on all three components. Although these investigations have provided some fairly clear evidence for the idea of central executive difficulties being associated with ADHD and conversely that phonological loop difficulties are not associated with ADHD, they have not provided clear evidence as to whether the visuo-spatial sketchpad (VSSP) is affected. Research by Barnett et al. (2001) did, however, find lowered performance on spatial working memory tasks in ADHD children in comparison to controls. It should be noted though that Barnett et al. (2001) did not compare performance on their spatial working memory task with performance on visual or verbal tasks, and could, therefore, but accounted for by a general impairment in working memory capacity, rather than being specific to spatial working memory.

Not only have previous investigations not provided specific evidence of impairments in working memory in children with attentional difficulties, very few have used a specific model of Working Memory, such as the model developed by Baddeley and Hitch (1974). Still fewer studies have investigated working memory as a core deficit in attentional disorders. Theoretical accounts of cognitive impairments in ADHD (Pennington and Ozonoff, 1996) see working memory as critical to executive function. As Sergeant et al. (2003) suggest, tasks such as the Stroop task, which are proposed to measure inhibition, also involve working memory. Despite limited specific evidence of a link between ADHD and impaired working memory, the working memory model could emerge as extremely useful in explaining attentional difficulties in children.

The findings of Experiment 1 suggested that the visuo-spatial sketchpad component score was a good discriminator of group membership. A large body of research has addressed the question of whether visual information and spatial information are retained by separable cognitive components or resources of the working memory system, and have concluded that it is likely this is the case (see section 1.3.3.2.1). Support for separable systems comes from a variety of sources, including studies of patients at different stages of Parkinsons Disease (Mollion et al., 2003), studies of brain structure and function in brain-damaged adults (Luzzatti et al., 1998), and from dual-task interference methodology or comparisons of performance on visual and spatial tasks (Baddeley and Lieberman, 1980 cited in Baddeley, 1986; Klauer and Zhao, 2004). This literature provides a good model for which to investigate working memory in the attentional difficulty group.

The tasks used in this experiment were developed with reference to Logie's (1995) revised model of visual working memory (see figure 5.1). Logie proposed that the visuo-spatial sketchpad comprised two inter-dependent components. A passive visual storage component known as the 'visual cache', storing visual form and colour information is closely linked to the visual perceptual system, and an active spatial maintenance component known as the 'inner scribe', storing movement sequences. The Visual Buffer served to maintain conscious visual imagery for short periods for both of these components should the central executive be required for more complex visual or spatial tasks.

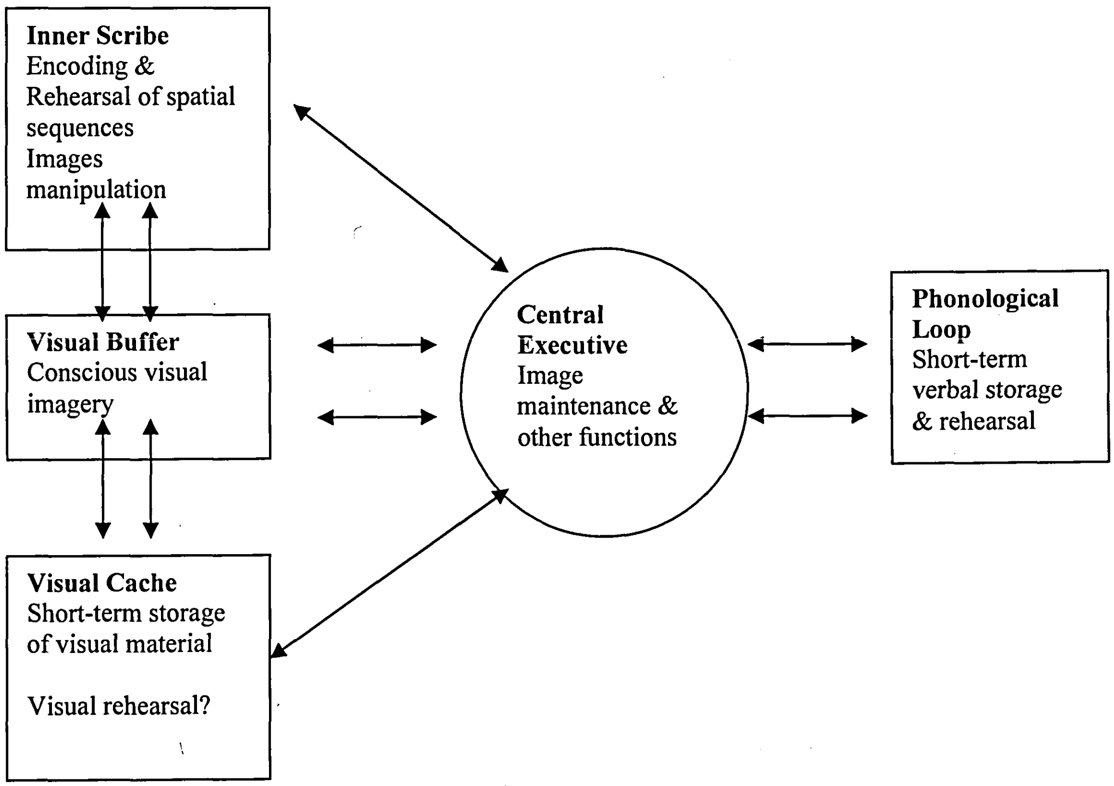


Figure 5.1: Logie's (1995) Working Memory Model including dissociation of the visual and spatial components of the Visuo-Spatial Sketchpad

Findings that pattern (visual) memory develops much more rapidly across age than block sequence (spatial) memory (Logie and Pearson, 1997) were consistent with Logie's (1995) model that different cognitive systems deal with static visual patterns and sequences of targeted movements. An alternative to Logie's theory was proposed by, Pickering et al. (2001). They hypothesised that the subcomponents of the visuo-spatial sketchpad may operate on information that is either, static or dynamic in nature rather than visual or spatial. The findings from the developmental study were consistent with their theory, with performance on dynamic tasks increasing more steeply with age. Another view was presented by Cornoldi and Vecchi (2000 cited in Vecchi et al., 2001). They make a distinction between visuo-spatial tasks requiring maintenance only, ('passive' tasks), and those which require manipulation in addition, ('active' tasks). They propose that this distinction may be helpful in understanding differences in visuo-spatial ability in specific populations.

The theoretical explanations for the fractionation of the visuo-spatial sketchpad discussed above (Logie, 1995; Pickering et al. 2001; Cornoldi and Vecchi, 2000 cited in Vecchi et al., 2001) and in section 1.3.3.2.1, appear to be fairly diverse. They have in common however, that dissociation within the visuo-spatial sketchpad is likely, although of different possible kinds. The implications are that the demands associated with spatial (Logie, 1995), dynamic (Pickering et al. 2001) or active (Cornoldi and Vecchi, 2000 cited in Vecchi et al., 2001) tasks are more heavily related to monitoring and manipulation. As Sergeant et al. (2003) have suggested these processes are associated with executive attentional control rather than merely control of memory which would be demanded for tasks that require maintenance only. These interpretations would lead us to the conclusion that spatial tasks, opposed to visual tasks, are more likely to demand central executive processes, such as the recruiting of executive attention. This interpretation would also be supported by the findings of Quinn (1994). Quinn demonstrated that memory for movement sequences and spatial processing may be dealt with by the same system, whereas other types of visuo-spatial information are dealt with by a different system, thus supporting models arguing for separable systems (Logie, 1995). Further to this, however, Quinn found that the requirement to move to a previously specified sequence of targets disrupted memory for spatial locations. These demands are common to spatial tasks, whereas, visual tasks do not have this requirement. This may implicate greater demands for executive attention recruited by the central executive, for spatial tasks.

These theoretical and empirical findings provide a good framework, therefore, on which to base the proposed investigation of visuo-spatial working memory in children with attentional difficulties. The majority of the empirical investigations on this topic have focussed on either adults or typically developing children. No studies, however, appear to have compared visual and spatial working memory in children with attentional difficulties without a clinical diagnosis of ADHD, or have investigated a dissociation in these types of populations.

Experiment 2 will investigate the visuo-spatial sketchpad using the sample of children used in previous studies rated as having attentional difficulties compared to controls. The intention is to assess whether the visuo-spatial sketchpad is an important factor contributing to the observed differences in working memory task performance between the attentional difficulty and normal control groups observed in experiment 1. To achieve this aim three task conditions have been developed. Separate visual and spatial tasks were designed with both a static and dynamic condition. These four tasks each have two further conditions a memory and non-memory condition allowing comparisons between groups in terms of memory load. In addition, each of the memory tasks will be performed under an articulatory suppression condition allowing comparisons to be made with regard to phonological loop functioning.

Logie's (1995) model of the visuo-spatial sketchpad suggests that visual and spatial working memory tasks demand separate systems for their adequate completion. Cornoldi and Vecchi (2000 cited in Vecchi et al., 2001) suggest that this dissociation may apply to passive and active demands associated with the tasks and Sergeant et al. (2003) suggest that working memory requires executive attention. It is suggested therefore that spatial tasks in comparison to visual tasks may have heavier demands for executive attention. It is hypothesised therefore that there will be no difference between the groups on visual tasks, but the AD group will perform at a lower level than the NC group on spatial tasks.

Pickering et al. (2001) suggested that the hypothesised fractionation of visual and spatial within the visuo-spatial sketchpad may be explained in terms of the respective static and dynamic properties of tasks used to measure them. Again, the implication from the previous literature (Sergeant et al., 2003) is that the dynamic tasks have heavier demands for executive attention and therefore, the central executive. A further hypothesis is, therefore, that there will be no difference between the groups when the task stimulus is static, but the AD group will perform at a lower level than the NC group when the task stimulus is dynamic.

5.2 Method

5.2.1 Participants

All of the forty-eight children who took part in experiment 1 were to have taken part in experiment 2, however, as a result of illness or absence only forty-four of these children could be re-tested. Each of the groups now consisted of 13 males and 9 females. For the AD group the mean age was 9 years 3 months (SD = 6 months), and the control group 9 years 0 months (SD = 6 months). The minimum and maximum ages overall and within each group were 8 years 5 months and 10 years 2 months. One-way Anovas demonstrated, despite attrition, that the attentional difficulty group did not differ significantly from the control group either for age $F(1,42) = 3.131, p>0.05$, or non-verbal intelligence $F(1,42) = 0.49, p>0.05$.

5.2.2 Design

A mixed experimental design was utilised. The between participants variable comprised two groups. The experimental group consisted of children rated as having attentional difficulties (AD group) and the control (NC) group consisted of children rated as having good attentional skills. The within group variable of format had two levels, perception (this was the term used to refer to the non memory condition) and working memory. The second within group variable, condition, had two levels, static and dynamic. There were also two task types, visual and spatial, yielding eight different conditions which both groups completed. In addition to these conditions there was also an articulatory suppression condition on the working memory formats of both the visual and spatial tasks. Both groups, therefore, completed twelve tasks in total. Counterbalancing of task presentation of the initial eight tasks was implemented to eliminate any practice effects. The presentation of the four articulartory suppression conditions, which took place at a final testing session a few months after initial testing had taken place, were also counterbalanced. Half of the participants undertook the visual tasks first and half the spatial tasks, perception tasks were always completed first followed by working memory tasks due to the added complexity of the working memory format, and for the same reason static tasks were always followed by dynamic tasks.

5.2.3 Measures

5.2.3.1 The Tasks

The twelve tasks used in the experiment are shown in figure 5.2 below. These tasks were designed and developed specifically for this experiment. Pilot studies using children in the same age range as the experimental groups were undertaken. This ensured that amendments could be made to the tasks where problems arose, including floor and ceiling effects. As described in section 2.4.3.2 the tasks were computer administrated. A Toshiba Satellite Pro M10 laptop computer with an Intel Pentium 1.7GHz processor with 512 MG RAM and 14" screen size was used to present the tasks. Participants positioned themselves approximately 45cm (18") away from the screen.

Table 5.1: The conditions and task requirements of the six visual and six spatial tasks

	Task Condition	Task Requirements
Visual Tasks	Visual Perception Task – Static (VPS)	Matching
	Visual Perception Task – Dynamic (VPD)	Matching and Appearance Order
	Visual Working Memory Task – Static (VWMS)	Matching and WM
	Visual Working Memory Task - Dynamic (VWMD)	Matching, WM and Appearance Order
	Visual Working Memory Task – Static with Articulatory Suppression (VWMS/AS)	Matching and WM with Articulatory Suppression
	Visual Working Memory Task - Dynamic with Articulatory Suppression (VWMD/AS)	Matching, WM and Appearance Order with Articulatory Suppression
Spatial Tasks	Spatial Perception Task – Static (SPS)	Identifying Location
	Spatial Perception Task – Dynamic (SPD)	Identifying Location and Order Recall
	Spatial Working Memory Task - Static (SWMS)	Identifying Location and WM
	Spatial Working Memory Task – Dynamic (SWMD)	Identifying Location, WM and Order Recall
	Spatial Working Memory Task - Static with Articulatory Suppression (SWMS)	Identifying Location and WM with Articulatory Suppression
	Spatial Working Memory Task - Dynamic with Articulatory Suppression (SWMD)	Identifying Location, WM and Order Recall with Articulatory Suppression

Figure 5.2: An example of the visual task stimuli

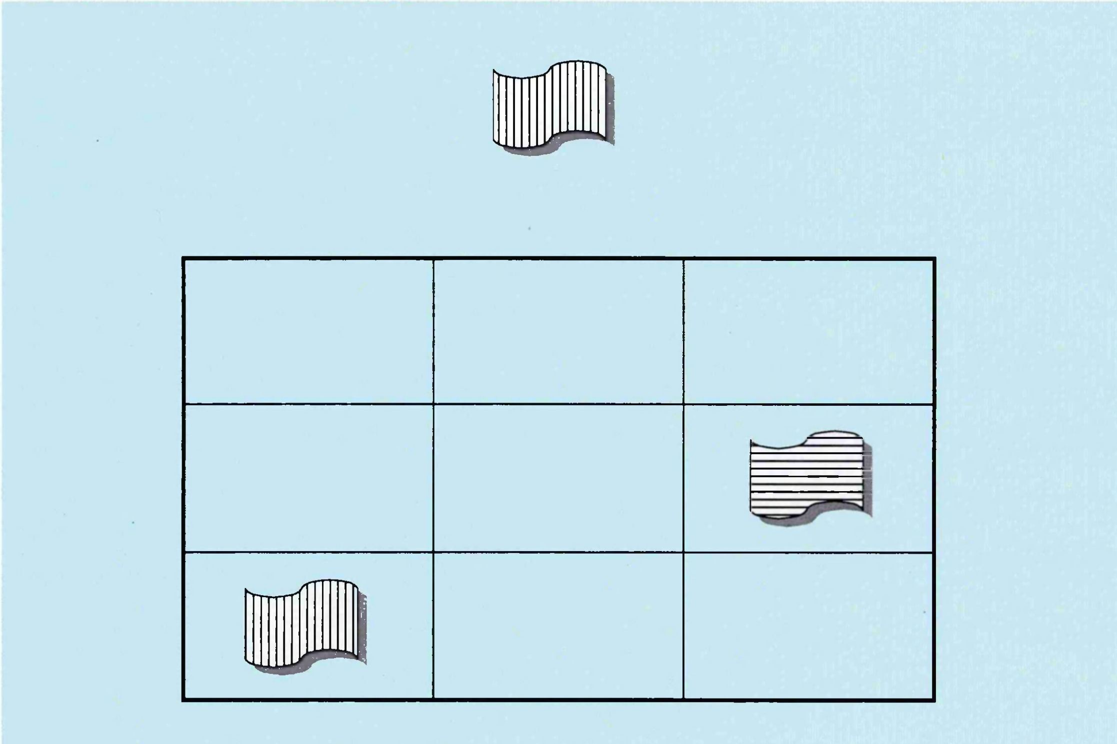


Figure 5.3: An example of the spatial task stimuli

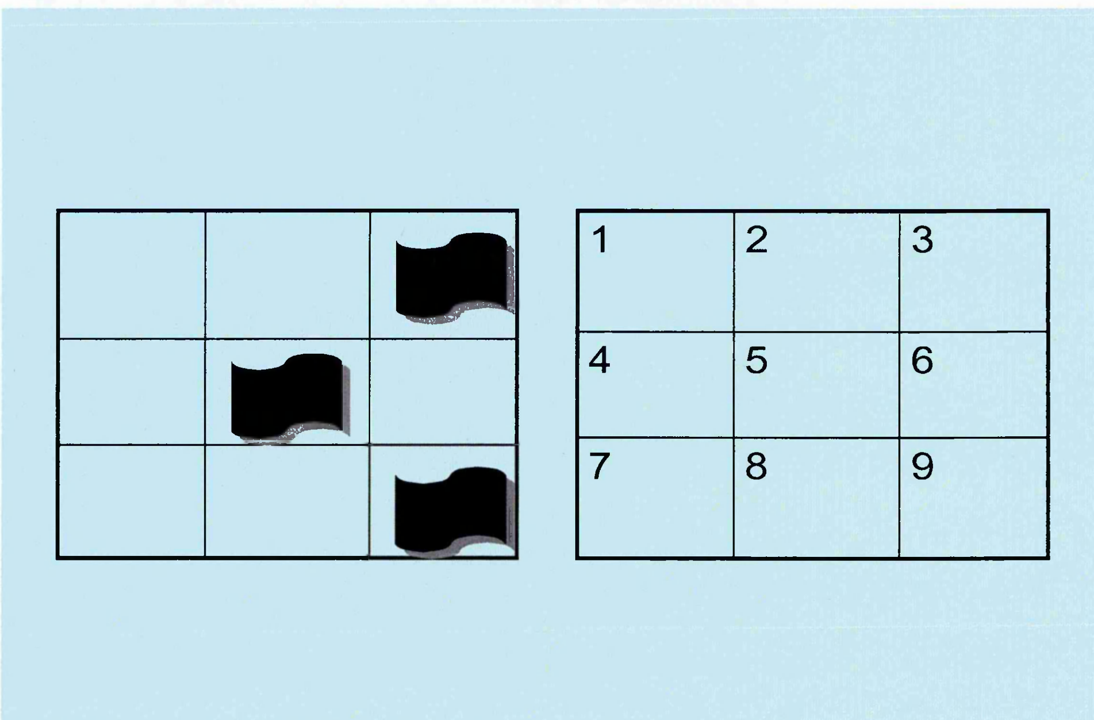


Figure 5.2 shows an example of the visual task stimuli, and figure 5.3 shows an example of the spatial task stimuli.

5.2.4 Procedure

Each child was collected from the classroom and taken to a pre-designated area in the school that minimised any visual or auditory distraction; this was often the library area or an area between classrooms. The child was asked to sit on a chair in front of a desk and the researcher would sit alongside the child in order to explain the rules and purpose of each task.

Each participant was asked to sit in front of the computer placed on a table at a typical height for a school table, thus ensuring the screen was in the line of vision for each participant. Each participant sat approximately 45cm (18") away from the screen. The researcher asked participants to indicate when they could clearly see the images on the screen.

Each participant was given a few minutes to undertake some practice trials on each of the tasks. When the researcher was satisfied that each participant understood the tasks and was able to undertake them adequately, testing commenced. Each participant was presented with twelve tasks in total to encompass all of the conditions of the experiment. The child's response on each was recorded on to score sheets (Appendix 10 – for examples of the score sheets).

The visual discrimination tasks required the participant to consider a target shape marked with a pattern, the target shape remained on screen for five seconds. The participant was required to pick out the matching shape from an array displayed in a three by three grid positioned below the target shape. The array of shapes in the grid increased in number as the task proceeded, for example in the first block participants were presented with two shapes to compare to the target shape, increasing to three in block two, the number of shapes in the grid increased up to block eight where nine shapes were presented in the grid thus filling the grid. In the perception condition the target shape remained on the screen at all times. In the working memory condition the target shape appeared alone and disappeared after five seconds, the comparison array then appeared and remained on screen for five further seconds. In the dynamic condition the same conditions applied on the perception and working memory conditions, however, the array of shapes appeared one at a time at a rate of one per second. The participant was required to both, select the matching shape and tell the examiner in which order the matching shape appeared (E.g. First, second, third, etc.). The participant was required to point to the matching shape, the selection was verified by the examiner and the participant was asked to reconfirm this. Although every effort was made to ensure that the perception versions of the tasks did not have a memory element, it should be noted that the visual perception dynamic task may have had a slight memory load for order requirements. This possibility was addressed by the analysis of the scores excluding order recall errors.

The spatial location task required the participant to consider an array of filled shapes in a target grid. Again a three by three grid was utilised and the number of shapes in the grid increased from one in block one to eight in block eight as the task proceeded. The task requirements were to indicate the location of the shapes in a similar grid. Again, in the perception condition the target grid remained on screen at all times, whereas, in the working memory condition the target grid was removed when the response grid emerged. In the dynamic condition the target shapes appeared one at a time at a rate of one per second and the participant was required to both recall the location of the shapes and recall the sequence the shapes appeared in. The response grid was labelled with numbers, and the participant was required to both point to the locations in the grid and also tell the examiner the corresponding numbers, this was to minimise any effect of motor skills and served to reconfirm selections. For both tasks the response grids remained on screen until the participant provided a correct or incorrect response or indicated that they could not answer.

The concurrent articulatory suppression conditions were administered in the same environment with both groups of participants. The articulatory suppression condition was intended to assess the impact of verbal recoding of the visual or spatial information on performance of the working memory tasks. If verbal recoding did feature highly in performance of one of the tasks or conditions then the articulatory suppression procedure should have a negative effect on task score in comparison to the scores without articulatory suppression, but remain unaffected on the other task or condition. A similar procedure was followed as outlined for the visual and spatial tasks, however the articulatory suppression condition required the participants to repeat the word 'the' continually during the encoding phase of the working memory tasks.

In total, testing took place over three sessions lasting approximately twenty minutes per session. At the end of each testing session each participant was congratulated on their performance and thanked for taking part before being returned to their classroom.

5.2.4.1 Scoring

Each task consisted of 8 blocks with 6 trials in each block. Each participant started each task at trial 1, block 1. If the participant got four correct in a block, they could move on to the next block and receive credit for the trials they did not complete. The task was discontinued if the participant got three trials incorrect within a block. The use of blocks of six trials, the move on rule and the discontinue rule, are in line with similar tests, such as the Working Memory Test Battery for children (Pickering and Gathercole, 2001). On the dynamic conditions two sets of scores were calculated. For the spatial task a score based on getting both location and sequence correct was collected in addition to a score for location only, which excluded errors on sequence. The discontinue rule was not applied if the participant achieved four correct responses in a block on the location task, even if three incorrect sequences had been provided. For the visual task a score based on getting both pattern discrimination and order of appearance correct was calculated in addition to a score for discrimination only, which excluded errors on order of appearance. Again, the discontinue rule did not apply if it was possible that the participant could achieve four correct discriminations in a block regardless of whether more than three incorrect order appearance answers had been given. One point was awarded per correct trial, and a score for each of the tasks was calculated.

5.3 Results

5.3.1 Treatment of data

Histograms and boxplots were produced to assess the distribution of the scores on each of the tasks administered. In general the histograms demonstrated normal distribution of scores for each of the sixteen variables to be tested in the analyses. Boxplots, however, did reveal outliers on some of these variables.

With reference to Tabachnick and Fidell (2001), and Howell (2002) the outliers were assessed. It was concluded that the low scores were achieved by children within the AD group who appeared to have had great difficulty completing the tasks, and high scores by children in the NC group who had completed the tasks with great ease. Low scores were amended to represent a score one point below the next lowest score, and high scores to represent a score one point higher than the next highest score (Tabachnick and Fidell, 2001). Analyses were performed on the data prior to the amendment of outliers and compared with analyses performed after the amendment of outliers. The analyses were consistent with each other suggesting that amending the outliers had not changed any legitimate trends in the data (Appendix 11).

5.3.2 Analyses

In total the participants undertook twelve versions of the tasks. From these twelve sets of scores three sets of analysis were produced. These analyses are set out separately for ease of interpretation. The first set of analyses tested the hypotheses relating to Logie's (1995) model of visuo-spatial working memory, comparing visual and spatial task performance in children with and without attentional difficulties, and Pickering et al.'s (2001) dynamic and static distinction based on the static and dynamic conditions. The second set of analyses again assessed these hypotheses. In this analysis, however, the score with order recall errors excluded were used. The purpose of this analysis was to assess the impact of the task demands that are often associated with dynamic tasks, such as order recall. A final set of analyses, again compared the two groups, however, here the working memory task with articulatory suppression scores were used. The purpose of this was to assess whether a verbal recoding strategy was being used to complete the tasks.

5.3.2.1 Analysis 1 - Analysis of Visual and Spatial Task Scores in static and dynamic condition in children with attentional difficulties and control children.

The primary purpose of this experiment was to compare the performance of children with and without attentional difficulties on the visual and spatial tasks. Two task formats, perception and working memory, were used and two task conditions were incorporated, static and dynamic. This yielded eight scores for each group. The mean and standard deviations of the scores for each of the tasks are presented below in table 5.2.

Table 5.2: Mean scores of number of correct trials (and standard deviations) on the eight tasks undertaken

Task Type	AD Group (N=22)	NC Group (N=22)	Overall (N=44)
Visual Perception Static (VPS)	33.95 (8.79)	37.18 (5.81)	35.57 (7.54)
Visual Perception Dynamic (VPD)	21.32 (9.93)	26.36 (8.23)	23.84 (9.37)
Spatial Perception Static (SPS)	27.05 (8.34)	32.77 (4.58)	29.91 (7.25)
Spatial Perception Dynamic (SPD)	16.95 (7.56)	24.00 (5.43)	20.48 (7.42)
Visual Working Memory Static (VWMS)	27.59 (9.27)	32.18 (7.63)	29.89 (8.70)
Visual Working Memory Dynamic (VWMD)	19.59 (9.09)	24.91 (8.46)	22.25 (9.09)
Spatial Working Memory Static (SWMS)	19.09 (7.47)	27.27 (4.03)	23.18 (7.23)
Spatial Working Memory Dynamic (SWMD)	15.55 (6.97)	18.32 (5.28)	16.93 (6.27)

Figure 5.4: Line graph demonstrating mean task score and standard error of the mean for the AD and NC groups on each condition of the visual task.

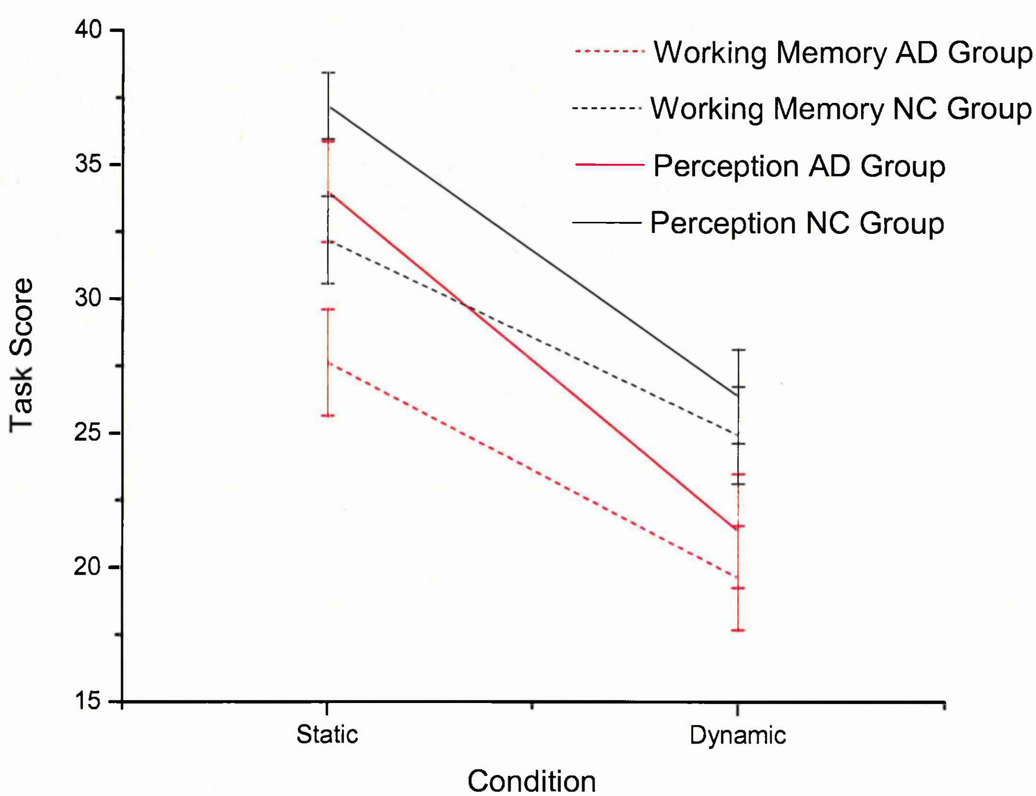
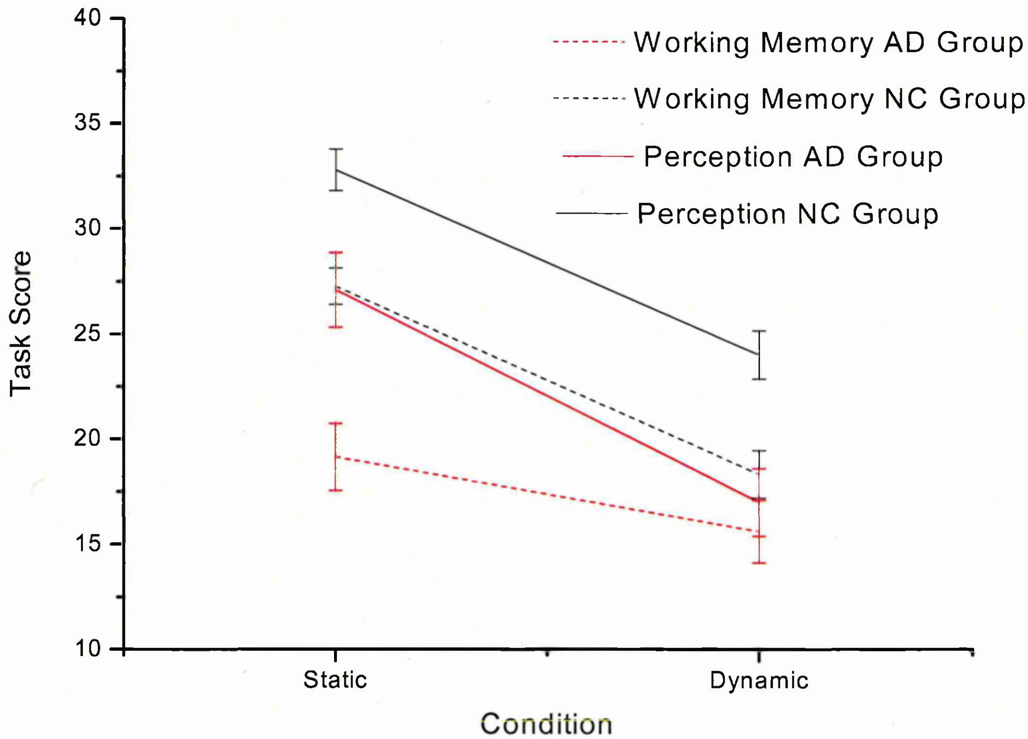


Figure 5.5: Line graph demonstrating mean task score and standard error of the mean for the AD and NC groups on each condition of the spatial task.



As table 5.2 and figures 5.4 and 5.5 demonstrate the NC group achieved higher scores than the AD group on all of the tasks. The standard deviations for the AD group scores are slightly larger than the NC group scores suggesting more variation in scores. Overall, higher scores were gained on the perception tasks in comparison to the working memory tasks. Although the visual and spatial tasks cannot be directly compared as they have differing task demands, they are comparable in terms of the number of stimuli presented and overall lower scores were recorded for spatial tasks in comparison to visual tasks.

On the perception tasks higher scores were gained on those in a static (VPS = 35.14, SPS = 29.91) rather than dynamic format (VPD = 23.84, SPD = 20.48). There seems to be slightly less deviation amongst the scores on the spatial tasks in comparison to the visual tasks. A similar pattern of results emerged for the working memory tasks, in that higher scores were gained for the static tasks (VWMS = 29.89, SWMS = 23.18), with much lower scores for the dynamic tasks

(VWMD = 22.25, SWMD = 16.93). Again there is slightly less deviation amongst the scores for spatial tasks in comparison to visual tasks. The general trend is that, overall, children perform best on the perception formats and static conditions and less well on the working memory formats and dynamic conditions.

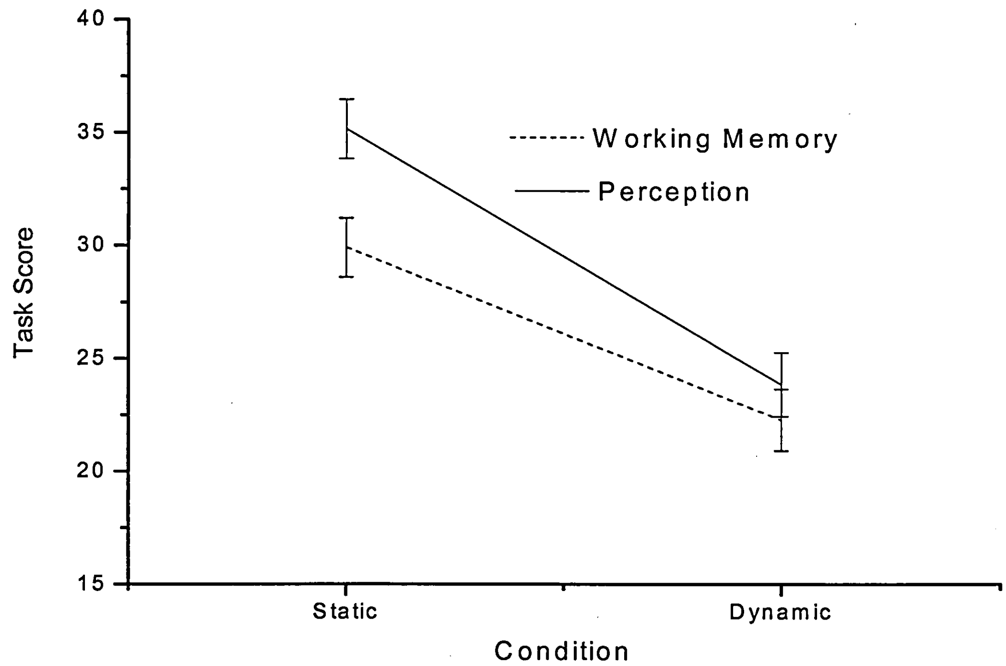
When scores for the AD group and NC group were examined separately a similar pattern emerged. The participants performed at a higher level on the static tasks and the perception formats compared to the dynamic tasks and the working memory formats. This pattern occurs for both the visual and spatial tasks. The mean scores for the NC group, however, are somewhat higher on all tasks than those for the AD group.

As the descriptive statistics have demonstrated, the AD group children performed at a lower level when compared to NC group children on all of the eight tasks administered. The scores for each task type (visual/spatial) were analysed separately using mixed 2x2x2 analyses of variance (Anovas). The within participants variables were task format, perception or working memory; and task condition, static or dynamic, and the between participants variable was group, either AD or NC group.

Visual Tasks

The mixed Anova revealed that for the four visual tasks overall there was a close to significant main effect of group $F(1,42) = 4.069$, $p = 0.05$. The effect size (*partial* $\eta^2 = .088$), however, suggested that there was not a substantial difference between the groups on the visual tasks. There was a significant main effect of task format (perception or working memory), $F(1,42) = 24.259$, $p<0.001$, *partial* $\eta^2 = .366$, reflecting better scores for the perception versions of the tasks. There was also a significant main effect of condition (static or dynamic) $F(1,42) = 169.460$, $p<0.001$, *partial* $\eta^2 = .801$, indicating better performance on the static tasks in comparison to the dynamic tasks. A significant condition by format interaction was also found, $F(1,42)=11.503$, $p<0.01$, *partial* $\eta^2 = .215$.

Figure 5.6: A line graph showing the significant interaction between format and condition with standard error of the mean for each condition.



There were no significant interactions of format by group, condition by group, or format by condition by group.

The main effects of task format and condition suggested that the scores were significantly better on perception versions of the task in comparison to working memory versions, and better on static in comparison to dynamic versions.

Four paired-samples t-tests were used to test the interaction of condition by format. When the Bonferroni correction was applied, significant differences were observed between the VPS and the VPD task scores *t(43) 13.859, p<0.0125*, and the VWMS and the VWMD task scores *t(43) 7.290, p<0.0125*, indicating better performance on the static versions of both the perception and working memory tasks. There was also a significant difference between the scores on the VPS and the VWMS tasks *t(43) 7.440, p<0.0125*, indicating better performance on the perception version of the static tasks. There were no significant differences between the VPD and the VWMD tasks, indicating no differences between scores on the dynamic versions of the task dependent on format. These analyses revealed that the interaction represents a greater difference between working memory and perception tasks for static than for dynamic conditions. The dynamic condition was difficult in both task formats (Appendix 12).

Spatial Tasks

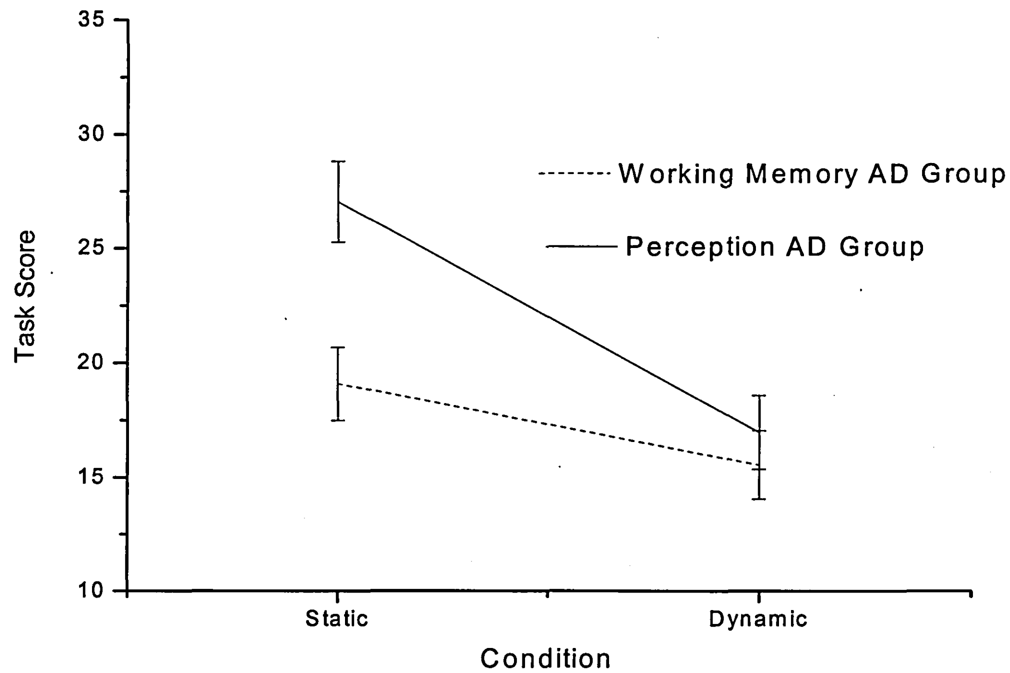
For the spatial tasks the mixed Anova revealed a significant main effect of group $F(1,42) = 13.230, p<0.01$, partial $\eta^2=.240$, in that the children with attentional difficulties performed at a significantly lower level than NC children on the spatial tasks. Follow up one-way Anova analyses revealed a significant differences between the groups scores on the SPS task $F(1,42)=7.973, p<0.01$, a significant difference on the SPD task $F(1,42)=12.594, p<0.01$, a significant difference on the SWMS task $F(1,42)=20.452, p<0.001$, but no significant difference between the groups on the SWMD task.

There was a significant main effect of task format (perception or working memory), $F(1,42) = 70.752, p<0.001$, partial $\eta^2=.628$, reflecting better scores for the perception versions of the tasks. There was also a significant main effect of condition (static or dynamic) $F(1,42) = 155.029, p<0.001$, partial $\eta^2=.787$, indicating better performance on the static tasks in comparison to the dynamic tasks.

A significant condition by format interaction was found, $F(1,42)=9.295, p<0.01$, partial $\eta^2=.181$, and a significant format by condition by group interaction was also found, $F(1,42) =10.388, p<0.01$, partial $\eta^2=.198$. The interactions of format by group and condition by group were not significant.

In order to test the interaction of format by condition by group, it was necessary to perform a 2x2 repeated measures Anova on the data for each group separately. Within the AD group there was a significant main effect of format $F(1,21)=39.593, p<0.001$, partial $\eta^2=.653$, indicating better scores on the perception task in comparison to the working memory task, a significant main effect of condition $F(1,21)=73.736, p<0.001$, partial $\eta^2=.778$, indicating better scores on the static condition in comparison to the dynamic condition, and a significant interaction of format by condition $F(1,21)=19.844, p<0.001$, partial $\eta^2=.486$.

Figure 5.7: Line graph demonstrating the interaction of format by condition within the AD group on the spatial tasks.



Within the NC group there was a significant main effect of format *F(1,21)=33.327, p<0.001, partial* η^2*=.613,* indicating better scores on the perception in comparison to the working memory format, a significant main effect of condition *F(1,21)=82.195, p<0.001, partial* η^2*=.797,* indicating better scores on the static in comparison to the dynamic condition, but no significant interaction of format by condition.

These post hoc analyses can explain the overall significant interaction of condition by format, and the significant format by condition by group interaction, as the format by condition interaction was only significant within the AD group (see figure 5.7). Again, overall and within the AD group only, scores on the dynamic perception task were much lower in comparison to the static condition whereas the scores were low on both conditions of the working memory task. Again, it appears that the working memory format and the dynamic condition have a cumulative detrimental effect on children with attentional difficulties. (Appendix 12).

Summary of results

Overall children with attentional difficulties obtained lower scores in comparison to NC children on all of the tasks administered, however, a significant main effect of group was found only for spatial tasks. Post hoc testing revealed significant differences between the groups on each of the spatial tasks with the exception of one. The analysis of the spatial working memory dynamic task indicated no difference between the groups, with both groups scoring at a low level on this particular task. This finding suggests that the combination of the spatial task in the working memory format and in the dynamic condition was challenging for both groups of children, not just for the AD group. This supports the hypothesis that children with attentional difficulties would gain lower scores on spatial tasks in comparison to NCs, and not differ on visual tasks.

Working memory formats yielded lower scores in comparison to perception formats. It follows that the extra exposure to the stimuli in the perception condition, during both encoding and recall stages, would give an advantage over the working memory condition in which exposure to the stimuli only occurred in the encoding stage of the task. The analysis indicated that there were no significant differences between the groups on visual perception tasks, yet differences did emerge on spatial perception tasks with NC children gaining significantly better scores. This suggests, as per the hypothesis, that children with attentional difficulties gain lower scores on both perception and working memory tasks in comparison to controls.

Overall dynamic conditions yielded lower scores compared to static conditions. Differences between the groups on the dynamic condition, however, occurred only on spatial tasks, and not on visual tasks. Further, differences between the groups were observed on spatial tasks in the static condition. Although dynamic condition differentiated the groups this only occurred within the spatial tasks, therefore, does not fully support the hypothesis that dynamic condition differentiates the groups in all situations.

On both the visual and spatial tasks there was a significant interaction of condition by format and on the spatial tasks there was also a significant interaction of condition by format by group. This interaction indicated that within the AD group only, there was a greater difference between working memory and perception tasks for static than dynamic conditions. It appears that the working memory format and the dynamic condition have a cumulative detrimental effect on children with attentional difficulties.

5.3.2.2 Analysis 2 - Analysis of dynamic task scores disregarding order recall errors

In order to address the possibility that any differences between the groups were due to the higher task demands of recalling order, rather than the actual presentation demands of the dynamic condition, a score for the dynamic tasks was calculated which did not penalise the participant if they provided an incorrect order. These scores were analysed, comparing them to the static scores in the same way as in the previous analysis. Table 5.3 demonstrates the mean and standard deviation scores.

Table 5.3: Table to demonstrate the mean scores of number of correct trials (and standard deviations) on the eight tasks undertaken - Static versions and dynamic versions when order recall errors were disregarded

Task Type	AD Group (N=22)	NC Group (N=22)	Overall (N=22)
Visual Perception Static (VPS)	33.95 (8.79)	37.18 (5.81)	35.57 (7.54)
Visual Perception Dynamic (VPD)	30.05 (8.24)	34.05 (6.78)	32.05 (7.72)
Spatial Perception Static (SPS)	27.05 (8.34)	32.77 (4.58)	29.91 (7.25)
Spatial Perception Dynamic (SPD)	16.95 (7.56)	24.00 (5.43)	20.48 (7.42)
Visual Working Memory Static (VWMS)	27.59 (9.27)	32.18 (7.63)	29.89 (8.70)
Visual Working Memory Dynamic (VWMD)	25.05 (8.60)	30.05 (7.42)	27.55 (8.33)
Spatial Working Memory Static (SWMS)	19.09 (7.47)	27.27 (4.03)	23.18 (7.23)
Spatial Working Memory Dynamic (SWMD)	18.64 (7.66)	24.68 (4.49)	21.66 (6.91)

Table 5.3 clearly demonstrates that the difference between the static and dynamic scores was less marked when the scores for correct order were excluded for the dynamic tasks. This served to compare only the effect of differing presentation, rather than both differing presentation and differing task demands. Again, AD children achieved lower scores in comparison to NCs, and the visual task and working memory format advantage was still apparent.

The standard deviations overall and particularly in the AD group were quite large suggesting a large amount of variation in the scores. These data were then compared with the static task data in the same way as the previous analysis with 2x2x2 mixed Anovas (see appendix 13).

Visual Tasks

The 2x2x2 mixed Anova for the visual tasks revealed that the main effect of group was close to significance $F(1,42) = 3.748$, $p = 0.06$. The effect size (*partial* $\eta^2 = .082$), however, suggested that there was not a substantial difference between the groups on the visual tasks. There was, however, a significant main effect of task format (perception or working memory), $F(1,42) = 45.559$, $p<0.001$, *partial* $\eta^2 = .520$, reflecting better scores for the perception versions of the tasks. There was a significant main effect of condition (static or dynamic) $F(1,42) = 36.689$, $p<0.001$, *partial* $\eta^2 = .466$, indicating better performance on the static tasks in comparison to the dynamic tasks. There were no significant interactions of format by group, condition by group, or format by condition by group. These significant main effects and non significant interactions do not represent different results in comparison to the analysis of the static and original dynamic tasks. However, contrary to those results, no significant interactions of condition by format were observed.

Spatial Tasks

For the spatial tasks a significant main effect of group was found $F(1,42) = 12.546$, $p<0.01$, *partial* $\eta^2 = .230$, in that the children with attentional difficulties performed at a significantly lower level than NC children on the spatial tasks. A one-way Anova revealed a significant difference between the groups on the spatial perception dynamic task $F(1,42)=7.669$, $p<0.01$, as found previously, and a significant difference between the groups on the spatial working memory dynamic task $F(1,42)=10.209$, $p<0.01$. The significant difference between the groups on the spatial working memory task in the dynamic condition was not found when order recall errors were taken into account in the previous analysis. This suggests that if the complexity of the task demands were reduced children in the NC group would perform at a higher level, whereas children in the AD group would not achieve the same level of improvement.

There was a significant main effect of task format (perception or working memory), *$F(1,42) = 76.713$, $p<0.001$, partial $\eta^2=.646$*, reflecting better scores for the perception versions of the tasks. There was also a significant main effect of condition (static or dynamic) *$F(1,42) = 51.788$, $p<0.001$, partial $\eta^2=.552$*, indicating better performance on the static tasks in comparison to the dynamic tasks. A significant condition by format interaction was found, *$F(1,42)= 8.469$, $p<0.01$, partial $\eta^2=.168$*, and the format by condition by group interaction, *$F(1,42) = 5.090$, $p<0.05$, partial $\eta^2=.108$*, was also significant. In line with the order recall data the interactions of format by group, and condition by group were not significant.

In order to assess the interactions of format by condition and format by condition by group, it was necessary to perform a 2x2 repeated measures Anova on the data for each group separately. In line with the previous analysis of dynamic tasks with order recall demands, within the AD group there was a significant main effect of format *$F(1,21)=34.018$, $p<0.001$, partial $\eta^2=.618$*, indicating better scores on the perception task in comparison to the working memory task, a significant main effect of condition *$F(1,21)=15.979$, $p<0.01$, partial $\eta^2=.432$*, indicating better scores on the static condition in comparison the dynamic condition, and a significant interaction of format by condition *$F(1,21)=13.237$, $p<0.01$, partial $\eta^2=.399$*.

Again in line with the dynamic order recall data, within the NC group there was a significant main effect of format *$F(1,21)=47.246$, $p<0.001$, partial $\eta^2=.692$*, indicating better scores on the perception in comparison to the working memory format, a significant main effect of condition *$F(1,21)=44.329$, $p<0.001$, partial $\eta^2=.679$*, indicating better scores on the static in comparison to the dynamic condition, but no significant interaction of format by condition.

These post hoc analyses can explain the overall significant interaction of condition by format, and the significant format by condition by group interaction, as the format by condition interaction was only significant within the AD group. Again, overall and within the AD group, the effect of the dynamic condition on the perception task was much more dramatically detrimental than on the working memory task. The cumulative effect of working memory format and dynamic condition is again apparent.

Summary of findings

The comparison of task scores on static tasks and dynamic tasks when order errors were excluded showed similar results to the previous analysis which took into account order recall errors. Overall the AD group gained lower scores on all tasks again, however the differences between the groups were less obvious. Working memory formats, and dynamic conditions caused lower scores on both visual and spatial tasks, overall and for the groups separately. Like the analysis of the order recall data the groups did not differ on any of the visual tasks, however, the groups significantly differed on the spatial tasks, including the spatial working memory dynamic task. Previously, both groups had scored at low levels resulting in no significant differences between the groups, however, when order recall errors were excluded the scores of the NC group improved. This finding highlights the fact that both the presentation and task requirements of the dynamic condition have an impact on the performance of these tasks. Again, there was a significant interaction of condition by format, and a significant format by condition by group interaction, as the format by condition interaction was only significant within the AD group. This was only true for the spatial tasks, the visual task data did not yield any significant interactions. Again, although true only for the spatial tasks, within the AD group, the effect of the dynamic condition on the perception task was much more dramatically detrimental than on the working memory task. The disproportionate effect of working memory format and dynamic condition is again apparent.

5.3.2.3 Analysis 3 - Analysis of Visual and Spatial task in dynamic and static condition with articulatory suppression demands in children with attentional difficulties and control children.

Verbal encoding at the presentation stage could provide a partial explanation for the pattern of results found in the previous analyses. Visual discrimination tasks may be easier to encode verbally in comparison to spatial location naming, and verbal recoding strategies could be more developed in the NC children (Pickering et al., 2001). The phonological loop is not usually reported as deficient in ADHD children, implying that there should be no difference between the groups on verbal recoding skills. It is sensible to test a verbal recoding explanation by utilising an articulatory suppression condition on the working memory task. The working memory tasks were undertaken by each participant for the second time under the articulatory suppression condition. The introduction of an articulatory suppression condition on the working memory tasks, overall, did not appear to have a differential effect on the pattern of results. The one finding that differed between analyses was associated with the main effect of group on the tasks. A main effect of group was found for the visual tasks and follow up analysis revealed that this was associated with a difference between the groups on all four visual tasks. The post hoc analyses of the main effect of group on the spatial tasks revealed differences between the groups on all four of the tasks, where previously differences occurred only on three. This further significant difference between the groups was observed on the spatial working memory dynamic task in the articulatory suppression condition.

The articulatory suppression condition data do not support a verbal recoding explanation for differences between the groups on spatial tasks yet no differences between the groups on visual tasks. A verbal recoding explanation would suggest that more complex verbal encoding was required for the spatial task and this is why the groups differed, whereas simple verbal recoding was required for the visual task, which both groups were able to perform. Should verbal recoding performance be responsible for the pattern of results, this analysis should have revealed no significant differences between the groups. Clearly this is not the case. In fact it appears that the articulatory suppression condition has increased the complexity of the task and perhaps increased loading on the central executive, resulting in lowered performance overall, and particularly in the AD group (see appendix 14 and 15).

Table 5.4 Summary of findings for analyses 1, 2 and 3

	Task Type	Results
Analysis 1 – Visual and spatial task performance.	**Visual Tasks**	• No main effect of group. • Main effect of format – lower scores on working memory formats. • Main effect of condition – lower scores on dynamic conditions. • Condition by format interaction – greater difference between working memory and perception tasks for static compared to dynamic condition, as dynamic seems to be difficult in both formats.
	Spatial Tasks	• Main effect of group – lowered performance by AD group on SPS, SPD, SWMS but not SWMD. Both groups scored low on SWMD. • Main effect of format – lower scores on working memory formats. • Main effect of condition – lower scores on dynamic conditions. • Condition by format interaction and condition by format by group interaction – condition by format interaction only significant in AD group. Dynamic condition lowered perception task performance but working memory was low in both conditions.
Analysis 2 – Order recall errors excluded	**Visual Tasks**	• Same findings as in analysis 1.
	Spatial Tasks	• Same findings as in analysis 1 with the exception of a further significant difference between the groups on SWMD due to higher performance by the NC group when order recall errors were excluded
Analysis 3 – Articulatory suppression conditions	**Visual Tasks**	• Same findings as in analysis 1 with the exception of a main effect of group and the AD group performing lower on both tasks.
	Spatial Tasks	• Same findings as in analysis 1 with the exception of a further significant difference between the groups on SWMD.

5.4 Discussion

5.4.1 Overall findings

Spatial task performance emerged as an important variable in differentiating AD and NC groups. The groups responded differently to the spatial and visual tasks. As predicted, AD children performed at a significantly lower level than the NC group on the spatial task in both formats with and without a memory element, but there were no significant differences between the groups on visual tasks. This pattern occurred in both static and dynamic conditions. Differences between the groups on the spatial working memory tasks occurred only on the static version, and the dynamic version in which order errors were excluded. The reason for this pattern of findings appeared to be due to the difficulty of both groups to complete the dynamic version of the spatial task. Overall, however, both perception and working memory formats of the spatial tasks differentiated the groups.

5.4.2 Differences between groups on task type: Visual versus Spatial

The finding that differences between the groups occur on spatial tasks, yet not visual tasks, was predicted and builds on the findings of Roodendry's et al (2001) and Karaketin (2004). They highlighted the lack of importance of the phonological loop, but failed to give a clear indication of the relevance of visuo-spatial working memory on attentional difficulties. These findings also build on the findings of Barnett et al. (2001). They demonstrated that compared to controls ADHD children were unable to hold multiple pieces of spatial information in memory simultaneously. Barnett et al. (2001) did not, however, compare visual and spatial tasks, as in this experiment.

Although, the differences on spatial yet not visual tasks also appear consistent with Logie's (1995) model that argued for separable systems for visual and spatial information, they may more realistically indicate differences in the demands for central executive processes. The findings do not necessarily indicate separable systems, and the delayed or impaired development of the spatial system in children in the AD group compared to those in the NC group. An explanation for the differential development of the separable visual and spatial systems which Logie has reported may be associated with the increase and decrease in the reliance on central executive processes for spatial and visual tasks respectively. This interpretation, however, is based on the tasks used here and it may be the case that the central executive demands of these tasks vary to a greater extent than those used in previous studies.

An alternative but consistent explanation for the findings may be related to the demands of the tasks, rather than to the task stimuli. The spatial task demands recall of stimuli and therefore manipulation, whereas, for the visual task recall of stimuli is only demanded for ordering of the stimuli, for the correct identification of the matching pattern only recognition skills are demanded. Although this could be construed as a limitation of the experiment, it does provide further evidence that the groups differ dependent on manipulation requirements, thus executive attention requirements, under the control of the central executive.

5.4.3 Differences between the groups on task condition: Dynamic versus Static

The finding that differences emerged between the groups on both static and dynamic spatial tasks is contrary to the hypothesis but can be explained with reference to findings by Quinn (1994). Quinn suggested that interference or disruption in spatial processing, which according to Sergeant et al. (2003) would require monitoring and therefore executive attention, is caused by both movement to a specified targeted sequence and by knowing the target sequence in advance.

According to this definition it is a possibility that interference occurred, even in the static version, as the participants were induced to use a sequential method of output of the positions of targets. This interpretation would also explain why the NC group performed so poorly on the Dynamic Spatial Working Memory task in addition to the AD group. As sequence was demanded on both input and output thus the demands for executive attention would be very high. On visual tasks although order recall was required on the dynamic version of the task, the participant did not necessarily need to maintain an entire sequence. Sequence would only be retained until the target appeared, and furthermore, sequence would not be required at the output stage only at the encoding stage and not necessarily for a full sequence of targets. This would imply that demands for monitoring and therefore, executive attention and thus inhibitory control are much lower for the whole range of visual tasks.

5.4.4 Implications for Barkley's (1997) Inhibition model

Overall the findings suggest that the groups differ in performance on tasks where the demands for executive attention, thus inhibition, are high. The central executive has the responsibility for recruiting these resources. If executive attentional resources are not available a reduction in performance on tasks demanding the central executive will result. Although this experiment did not directly test inhibitory control the interpretations regarding the unavailability of executive attentional mechanisms could be consistent with Barkley's (1997) inhibitory control hypothesis. Barkley's hypothesis suggests that an impairment in response inhibition results in inadequate working memory processing. The differences between the groups could be explained as a difference in ability to resist interference or distraction from active properties of tasks, due to the inability of the central executive to recruit attentional resources such as inhibitory control.

5.4.5 Implications for the fractionation of the visuo-spatial sketchpad

According to Logie's (1995) model the spatial task would rely most heavily on the Inner scribe of the VSSP, as it is involved in encoding and maintenance of sequences of spatial locations. Logie's model suggests that this encoding of spatial locations (static) and retention of spatial sequences (dynamic) can take place independently. The visual buffer which employs the assistance of the central executive will only become involved if a cognitive strategy is employed to assist recall. The difference between the AD and NC groups could be explained as an inability in the AD children to use strategies to recall spatial locations and sequences which depend on the central executive and its responsibilities to recruit inhibitory control mechanisms. The strategies demanded for the recall of spatial locations and sequences may be more complex than the strategies demanded for the recall of the visual stimuli, thus placing heavier demands on the central executive for inhibitory control.

These interpretations would be supported by the findings of Smyth and Pelky (1992) who investigated short-term retention of spatial information using an interference paradigm. The results were interpreted in terms of place-keeping functions, which are said to demand the central executive, in spatial memory sequences. Further, Quinn and McConnell (1996) investigating visual memory suggested that maintenance of order may be a central executive attribute rather than dependent on the visuo-spatial sketchpad. It seems that in the present experiment the order demands in all versions of the spatial task are much greater than those in any version of the visual task.

The literature on the fractionation of the visuo-spatial sketchpad has been useful in the investigation of the differing working memory abilities of children with and without attentional difficulties. It should be noted, however that as an interaction between group and modality has not been tested here a dissociation between visual and spatial can not be asserted. The fact that children in the attentional difficulty group were found to perform at a significantly lowered level than children in the control group on most of the spatial tasks was interpreted as reflecting the heavier demands of these tasks on the central executive, for executive attentional mechanisms such as inhibitory control. This may be true of only the tasks used here to measure spatial working memory or, more likely, common to a wide range of tasks currently used to measure spatial working memory. An example of a widely used spatial task is the Corsi blocks task, and the spatial task used in this experiment is based on this task.

5.4.6 Working Memory and Executive Function

The findings reported here clearly illustrate the association between working memory, in particular the central executive, and executive function. As Sergeant et al. (2003) have suggested it is the responsibility of working memory, specifically the central executive, to recruit executive attention such as inhibition. This is where working memory and executive function are linked.

The relative demand for executive resources on the visual and spatial tasks can be explained with reference to Cornoldi and Vecchi's (2000 cited in Vecchi et al., 2001) *distributed 'continuum' model*. It may be the case that the task demands for the visual task would be passive retention only, whereas for the spatial task active rehearsal may be involved. If the spatial task implemented here could be described as an active task and the visual task as passive, it would follow, according to Cornoldi and Vecchi's theory that the spatial task demands domain independent techniques and interconnections between different sensory systems. These describe responsibilities commonly attributed to the central executive, and thus implicated executive function.

The findings could also be interpreted in terms of a SAS (Norman and Shallice, 1980) failure. The difference between the groups may be in terms of their ability to generate strategies, which is in turn reliant on executive attentional mechanisms. It is plausible that the spatial task has heavier demands in comparison to the visual task for strategy generation and it is on this ability that the groups differ. This interpretation would also implicate the central executive as the SAS has been hypothesised as constituting one activity the central executive is responsible for (Baddeley, 1996).

The executive function explanations for the findings would be supported by previous studies by Karatekin (2004) and Roodendrys et al (2001). These studies indicated no deficit in ADHD children on tasks involving the slave systems, yet detrimental performance occurring on central executive tasks. In these investigations also executive function is implicated.

5.4.7 Conclusions

This investigation has succeeded in systematically examining a number of variables which have been proposed to account for developmental differences in visuo-spatial working memory (Logie, 1995; Pickering et al., 2001). It has built on findings from previous studies (Roodendry's et al, 2001, Karaketin, 2004) to provide a more specific account of the differences between AD and NC children on visuo-spatial working memory. It has clearly demonstrated that the properties and task demands inherent in spatial tasks, such as movement to a series of targets (Quinn, 1994), and the demands of using sequential processing of the stimuli, are important in differentiating the visuo-spatial abilities of children with attentional difficulties from control children.

It has been demonstrated that the control group can perform adequately on both the visual and spatial tasks. It may be that the children with attentional difficulties performed more poorly on the spatial tasks as they are more *difficult* for them, due to the fact that they rely on different or more components of the cognitive system, such as inhibitory control (Barkley, 1997), than the visual tasks (Logie and Pearson, 1997). This is consistent with both a dissociation theory and the central executive explanation.

There may be a developmental explanation for the findings. Children in the attentional difficulty group may not have developed the skills required for spatial working memory tasks to the same extent as control children. This idea is supported by Logie and Pearson's (1997) findings suggesting spatial working memory develops more slowly than visual working memory. The reason for this may be that spatial working memory places heavier demands on the central executive. An experiment examining performance on the spatial working memory task in children of different ages rated as having attentional difficulties would confirm whether this is the case.

Central executive responsibilities such as the recruitment of executive attention and inhibitory mechanisms have been highlighted as factors that may differentiate the groups examined here. Experiment 3, therefore, will examine further this aspect by investigating executive function on central executive tasks.

Chapter 6 - Experiment 3 - A comparison of children with and without attentional difficulties on 'real life' central executive tasks: An examination of executive attentional demands.

6.1 Introduction

The findings of experiment 2 were interpreted as indicating that the groups differ on tasks that have heavier demands for executive attentional mechanisms, such as inhibition, which are recruited by the central executive. Evidence to support this interpretation was drawn from Logie's (1995) model of the visuo-spatial sketchpad, and the assertions made by Sergeant et al. (2003) and Pennington and Ozonoff (1996) concerning the demand for executive attentional mechanisms for working memory. It was also thought that the findings were consistent with Barkley's (1997) inhibition model. It was concluded that a problem associated with inhibitory control could explain the lowered performance of the attentional difficulty group in comparison to the control group on the spatial working memory task. These interpretations would predict lowered performance in the attentional difficulty group on tasks that demand the central executive. This implication has been derived from empirical investigations using ADHD groups (Roodendrys et al., 2001; Karatekin, 2004). The relationship between central executive control and inhibitory control in these groups, however, remains unclear.

The executive nature of the central executive has only relatively recently been addressed by Baddeley (1996) where he proposed that the central executive could be fractionated into a number of responsibilities. As reviewed in section 1.3.3.2.2 Baddeley (1996) suggested, based on empirical findings, that the central executive is responsible for at least four activities. The first of these is the integration and coordination of information for two separate tasks or the integration of information from the phonological loop and the visuo-spatial sketchpad; the second is strategy generation and the capacity to switch retrieval strategies; thirdly, selective attention to one stimulus whilst inhibiting the disrupting effect of another, and finally, the retrieval and integration of information from long term memory. Common to each of these functions are the demands for executive attention leading to comparisons being made between the central executive and the supervisory attentional system (SAS) proposed by Norman and Shallice (1980). The SAS is proposed to be responsible for the allocation of attention in novel situations. This is achieved via the inhibition of irrelevant schemas, monitoring and strategy development (Norman and Shallice, 1980).

The findings of experiment 2 provided support for the SAS model as it was able to more fully explain the findings in comparison to the EF models and the central executive. The SAS describes in more detail the central executive or executive attentional mechanisms as they are termed in the EF literature, particularly inhibition, monitoring and strategy development mechanisms. Although attempts have been made to fractionate the central executive (Baddeley, 1996) this seems to be based more on task type rather than on executive attentional mechanisms. Only relatively recently has interest in examining the executive nature of the central executive increased with Bayliss et al. (2005) assessing the development of complex span performance. Development was found to be related to both general speed of processing and storage ability. General speed of processing seemed to be associated with the speed with which stored items could be reactivated, providing evidence of a link between executive function and working memory as it implicates the development of executive attentional mechanisms in working memory performance.

The activities attributed to the SAS can also be likened to those described by Barkley (1997) as encompassed by the response inhibition function in his model. These three processes are inhibition of a prepotent response, interruption of an ongoing response and interference control. These processes would be achieved by the SAS by the interruption of one behaviour and the initiation of another. The SAS, however, describes more precisely how these objectives are achieved. It is suggested that a number of subordinate processes are involved. These are the monitoring of current and intended behaviour which can induce activation of attentional mechanisms, and the modulation of action selection in order that appropriate actions are biased for selection with the ultimate objective of the SAS being to generate strategies for solving novel problems. The two inhibitory processes in Barkley's (1997) model could be likened to the modulation processes in the SAS model, whereas the interference control processes could be compared to the monitoring functions of the SAS. Barkley's hypothesis suggests that an impairment in response inhibition results in inadequate working memory processing, the SAS goes further to explain how this may occur. These processes could underlie the central executive functions proposed by Baddeley (1996).

Empirical investigations have attempted to assess executive function (see section 1.3.2.3 for a review) by examining failures made by patients with frontal lobe dysfunctions, and children with developmental disorders attributed to frontal lobe abnormalities. Although these investigations have not had the specific aim of assessing the activities Baddeley (1996) has attributed to the central executive, the results of investigations assessing differences between typical and atypical groups on dual-tasks, switching tasks and problem-solving tasks can be used to hypothesise about the first three activities of the central executive. Of particular relevance is an investigation by Cepeda et al. (2000) who implemented a task switching paradigm. They found that ADHD children experience deficient performance on switching trials, whereas medicated ADHD children and NC children did not demonstrate this deficient performance. There were no differences in performance between the groups on the individual tasks that did not require switching. These findings can be taken to indicate that children with ADHD have difficulties associated with the selective attention or inhibitory function of the central executive. Further, Siklos and Kerns (2004) demonstrated that ADHD children performed at a lower level than controls during an investigation of multitasking. This evidence was suggested to indicate that the ADHD group had difficulties associated with strategy generation and they suggested a failure of the SAS to explain their results. These findings, however, can also be taken as indicating a difficulty associated with the central executive function associated with the integration of information from two separate tasks, as these were the requirements of the task Siklos and Kerns administered.

Children with ADHD have been consistently shown to have impairments in executive functioning on laboratory tasks such as continuous performance tasks (e.g. West et al., 2002 Shallice et al., 2002) (see section 1.3.2.3), and the children in the AD group have been shown in experiment 1 to perform at a lower level compared to the NC group on measures of executive functioning. Less consistent are the findings on tasks which are more similar to the tasks children are asked to complete in everyday situations such as at home and at school. Lawrence et al. (2002) asked children to take part in computer games and a trip to the zoo. Inhibitory, working memory, and monitoring demands associated with following instructions and planning were placed on ADHD and control groups in the two different situations. The findings demonstrated that children with ADHD had working memory impairments on the computer game but not during the trip to the zoo, suggesting that working memory impairments may not be observed on 'real life' tasks. As an ultimate aim of this thesis is to provide some basis for intervention to improve academic achievement in the attentional difficulty group it is of particular importance to assess executive function and working memory on tasks that the children may be asked to complete either at home or school. Further, it may be the case that the difficulties identified in children with attentional difficulties in experiments 1 and 2 do not emerge on tasks they are familiar with. By using 'real life' tasks the ecological validity of the findings will be increased.

With reference to the literature (see section 2.4.4.1) a number of measures thought to characterise executive attentional control mechanisms and would therefore be required on central executive tasks, were selected. These were inhibition, monitoring and strategy application. Inhibitory control mechanisms feature highly in models of EF, and are seen as necessary for executive functioning (Barkley, 1997; Pennington and Ozonoff, 1996). Inhibitory mechanisms are proposed to interrupt ongoing actions and to stop incorrect prepotent responses. They are explicitly referred to in these models and it is suggested that they are required for working memory (Sergeant et al., 1999). It has also been suggested here that they could be likened to the modulation processes of the SAS (Norman and Shallice, 1980). Sergeant et al. (1999) also suggest that monitoring will demand executive attention, although they do not provide a clear definition of this mechanism. Monitoring mechanisms will, clearly, be demanded for tasks involving a memory element. The monitoring of information could be a function of the central executive, and is also described in the SAS. The interference control processes described by Barkley (1997) may also be achieved by monitoring processes. Strategy application, although not specifically referred to in EF models or the working memory model, is reported as the ultimate result of the SAS. Here strategy application will be inferred from measures of performance such as completion time and correct responses. It is assumed that strategy application will demand both inhibition and monitoring. Motor control has been included in some EF models and is reported (Barkley, 1997) to be dependent on attentional mechanisms and will, therefore, be assessed.

Experiment 3, therefore, investigated the executive nature of the central executive using a number of familiar or 'real life' tasks designed to tap on to the first three proposed (Baddeley, 1996) functions of the central executive. These were the integration and coordination of information measured using a dual-task paradigm with three conditions; strategy generation and the capacity to switch retrieval strategies measured using a switching task with four conditions; and selective attention and inhibition measured using two problem-solving tasks. It was considered that the fourth activity identified by Baddeley, the retrieval and integration of information from long term memory, would be required for each of these tasks. Each of the tasks had control or lower level conditions which did not have heavy demands on the central executive. This series of experiments aimed to assess whether the groups differed in their task performance on each task proposed to assess a function of the central executive, and more specifically to measure the executive attentional control on these tasks. This would provide more specific information regarding executive function difficulties in the attentional difficulty group.

Consistent with the findings of Roodendrys et al. (2001) and Karaketin (2004) it was hypothesised that the AD group would make more errors in comparison to the NC group on the central executive conditions of each set of tasks but would not differ on the control conditions. It was also hypothesised that a lowered performance on central executive conditions would be reflected in significant differences between the groups on the measures of inhibition, monitoring and strategy application, consistent with Sergeant et al.'s (1999) proposal that working memory is dependent on executive attentional resources. There would be no significant differences between the groups on the measures of monitoring, inhibition, strategy application, and motor control on the control conditions of the tasks.

6.2 Method

6.2.1 Participants

The same 44 children who took part in experiment 2 went on to take part in this experiment. The mean age of the attentional difficulty (AD) group was 9 years 7 months (SD = 6 months), and the mean age of the control (NC) group was 9 years 4 months (SD = 6 months).

6.2.2 Design

A mixed experimental design was utilised. The experimental group consisted of children rated as having attentional difficulties (AD group) and the control group (NC group) consisted of children rated as having good attentional skills. The within groups variables were the conditions on each of the tasks, central executive condition and control conditions which did not load on the central executive, yielding up to four within participants levels. Counterbalancing of task presentation was implemented to eliminate any practice effects. All of the participants were presented with the control or lower level of difficulty tasks prior to the experimental or higher level of difficulty tasks. Where there was more than one control or baseline condition the order of presentation of these conditions was counterbalanced across the participants. As the pairs game was common to both the dual and switching tasks these were undertaken on separate sessions to reduce any practice effects. Pilot studies were carried out with children in the same age range as the children in the AD and NC groups using each of the tasks. These studies revealed that performance on the control conditions was almost error free as expected. More errors were made on the experimental conditions, however, the participants were able to understand the rules and complete the tasks. Data conforming to parametric assumptions was analysed using Manova, Anova and t-tests. Data which did not conform to parametric assumptions was analysed using Mann-Whitney U Tests, Friedman Tests and Wilcoxon Signed Ranks Tests.

6.2.3 Measures

Table 6.1: An overview of the three central executive tasks, their conditions and the measures of executive function taken on each.

CE Tasks/ CE Function	Conditions		Measures of Executive Function
Task 1 Switching - Pairs Game / Selective attention/inhibition	Experimental	Combination of Rules - Switching Condition	Monitoring • incorrect rule used • requests for reiteration of rule Strategy Application • completion time Inhibition • turning too many cards over • matching errors Motor • dropping cards/turning too many over due to motor control.
	Control	Animal Rule – Non-switch condition	
	Control	Colour Rule – Non-switch condition	
	Control	Number Rule – Non-switch condition	
Task 2 Dual-Task; Pairs Game and Jigsaw / Integration and coordination	Experimental	Pairs and Jigsaw together under time constraint	Monitoring • Looks toward timer • requests for instructions Inhibition • turning too many cards • undertaking both tasks (y/n) • incorrect match Strategy Application • correct match • number pieces fitted together • pieces placed correctly near edge • Total correct pieces selected. Motor • Too many pieces turned • Pieces dropped.
	Control	Jigsaw under time constraint.	
	Control	Pairs under time constraint	
Task 3 Problem-solving Tasks / Generation of novel responses		Problem-solving Eggs and Baskets Farmer task	Monitoring • Requests for reiteration of instructions Strategy Application • Correct moves • Total moves • Solution time Inhibition • Incorrect moves

Inhibition is the process which stops the participant making an inaccurate response via the modulation of action selection. Monitoring describes the processes responsible for holding necessary information in mind, this is primarily a memory component and serves to control interference. Strategy application is the result of these processes, and represents how successful the participant has been at the task with completion time and correct response measures. Motor error describes errors made as a result of poor motor control, such as dropping cards.

6.2.4 Overview of the procedure

Each participant was collected from the classroom and taken to a pre-designated area in the school that minimised any visual or auditory distraction, often the library area or an area between classrooms. They were asked to sit on a chair in front of the desk and the researcher would sit alongside in order to explain the rules and purpose of each task. To eliminate the possibility of colour-blindness having an effect on the results of the switching and dual tasks, each child was shown the different coloured cards used in the tasks and asked to name each colour prior to the study commencing. None of the children experienced any difficulties naming the colours blue, red, green and yellow. The participants were given a few minutes to practice and become familiar with each of the conditions of the switching task and the control conditions of the dual task. The participants did not practice the dual condition of the dual task or the problem-solving tasks as spontaneous responses were assessed on these tasks which would be affected if practice trials were allowed. Data collection commenced only when it was clear that the rules had been understood. The length of time required to complete all tasks necessitated breaking them up into two sessions.

6.2.4.1 Semi-structured interview

At the end of each of the two testing sessions each child was asked some simple questions about the tasks they had undertaken in that session. At the end of the final session they were asked some overall questions about the games they had completed (see Appendix 16 for the semi-structured interview questions).

6.2.5 Task 1 - A comparison of children with attentional difficulties and matched controls on a Switching task, proposed to measure the CE function of selective attention or inhibition.

6.2.5.1 Materials

The switching task consisted of a pairs game which was developed for use in this experiment. 27 cards were used for the pairs task, and on every card a different combination of the three dimensions appeared; colour, animal and number. Three types of colour were used; green, orange and blue; three types of animal, dog, cat, and elephant; and one, two or three animals on a card. Three rules were developed which were based on matching according to these three dimensions. Figure 6.1 shows an example of the pairs cards used in the task.

Figure 6.1: An example of the pairs cards used in the switching task

The participants were required to undertake the pairs game under four conditions. The first three conditions required the participants to match the pairs according to a specified rule, such as match animals. A correct match would be achieved if both cards had the same animal on them, regardless of the number of animals on each card, and regardless of the colour of each card. The same procedure was undertaken using colour and number rules. A final condition was the switching condition where participants were asked to switch the rule they were matching under after every match. They were informed to start matching using a particular dimension such as animal, and move on to matching using colour, then number, rotating the rule as matches were made. They were required to keep in mind each rule and apply them in the correct order. The participant was given the order in which they should apply these rules, for example, animal, then colour, then number. The minimum possible score on each of the executive function measures was zero, and there was an unlimited maximum score on each measure (Appendix 17 for the operationalisation of the measures).

6.2.5.2 Procedure

Each child was shown the cards and the researcher explained the different categories to the child and the three different rules which could be used to match the cards. The general rules of the pairs game were also explained to the child, that they could only turn over two cards at a time and these must be turned face down again unless a match was made. If a match was made the matching pair should be placed to the side away from the unmatched cards. When the child had indicated that they understood the categories, the matching rules and the general rules of the pairs game the cards were placed face down in front of the child. They were given a few minutes to practice each of the rules in turn. When it was clear to the researcher that the child understood each of the rules, testing commenced using one of the rules. The child was informed that they would be timed, but there would be no time constraint, and the number of correct matches would be counted. A number of measures of the child's performance were taken during the period in which they undertook each of the four versions of the pairs game. Testing ceased when three cards remained due to the possibility that the remaining three cards would be impossible to match. The child was congratulated on their performance after each condition. When all three control conditions had been undertaken and measures recorded the child was informed of the switching condition. They were told that this task might be more difficult as all three of the rules they had previously used would be used in this version. The child was informed that they would be required to start with the animal rule. Once they had made a match using this rule they should move on to the colour rule, and once a match had been made using this rule they should apply the number rule, then when a match had been made on the number rule they should revert back to the animal rule and use the rules in this order until all but three cards had been matched. They were then given time to practice this condition. Again measures were taken, and the participants were congratulated on a good performance.

6.2.6 Task 2 - Dual Task Experiment to assess the central executive function of integration and coordination processes

6.2.6.1 Materials

Together with a 49 piece jigsaw puzzle of a cartoon character, Nemo, (Disney/Pixar, 2003, Finding Nemo™) the pairs cards were also used for task 2.

For this task, however, the array was increased to include a further colour (yellow), therefore the total number of cards was 36. The materials are shown in figure 6.2.

<u>Figure 6.2: An example of the pairs cards and jigsaw used in the dual-task</u>

The dual task experiment required the performance of two single task conditions and a dual-task condition where both single tasks were performed simultaneously. The performance on the two single task conditions was used as control conditions for comparison to the dual task condition. Participants were required to undertake the pairs game and the jigsaw puzzle separately under a time constraint of two minutes, and further, undertake the task simultaneously again under the two minute time constraint. The rules for the jigsaw puzzle were to turn over the pieces and place them in an appropriate place for the quickest completion of the jigsaw. The rules for the pairs condition were to match the cards using both type of animal and number of animal, but that the colour of the card was not relevant. The objective was to match as many pairs as possible. On the dual-task condition an overall rule stated that the participant must attempt *both* tasks in the 2 minute period allowed. The minimum possible score on each of the measures was zero, and the maximum scores varied (Appendix 18 for the operationalisation of the measures).

6.2.6.2 Procedure

Pairs Only Condition

Participants were presented with the pairs cards used during the switching task. Each child was shown the cards were explained the rules and shown examples of what constituted a match (e.g. three elephants on a yellow card and three elephants on a green card) and what did not constitute a match (e.g. three elephants on a yellow card and two elephants on a yellow card). The participants were also explained the general rules of pairs, only two cards should be turned over at any one time and replaced if a match is not made and removed from the array if a match is made. The participants were then given the opportunity to practice the pairs game. Once the researcher was satisfied that the child had an understanding of the rules they were informed that they had a total of two minutes to see how many pairs they could match, and that they would not be able to complete the game in this time but to just match as many as they could. They were shown both a stopwatch and a stop clock and informed that they could monitor the remaining time using these (these were placed in a position slightly to the side of the participant in order that both timing devices were easily visible but that it was clear to the researcher if the participant looked at the timers). Measures were taken throughout, as detailed in table 6.1. When 2 minutes had passed the number of correctly matched pairs were recorded.

Jigsaw Only Condition

Participants were presented with the jigsaw. The pieces were separated and placed face up on the table in front of the participant and a picture of the completed jigsaw was placed above this. The participants were informed that their task was to complete as much of the jigsaw as possible in a two-minute period. They were informed that it would be impossible to complete the entire jigsaw in this amount of time but to do as much as they could. Again, the stopwatch and stop clock were displayed to the participant and they were told when to begin the task. Measures were taken during this period. When 2 minutes had passed the number of correct pieces of the jigsaw fitted together were recorded, along with the number of edge pieces placed correctly, and the total number of correct pieces selected.

Dual-task Condition

Participants were presented with the pairs cards to the left and the jigsaw to the right on the table in front of them and informed that they were expected to undertake both of the tasks in a two minute period. Again, they were informed that it would be impossible to complete either or both of the tasks in this time period but they should try to do as much of each as possible. They were also informed that they must undertake at least some of both tasks in the two-minute period, and that this was a rule of the game. When it was clear that the participant understood the rules testing began and measures were taken. The number of correctly matched pairs and correctly selected jigsaw pieces were recorded.

6.2.7 Task 3 - Problem-solving task experiment to measure the central executive function of generating novel responses

Two problem-solving tasks, the farmer task and the eggs and baskets task, were used to assess the central executive function of generating novel responses (Appendix 19 for the operationalisation of the measures). The Farmer task was based on the Missionaries and Cannibals task (see Reed et al., 1974).

6.2.7.1 Materials - Problem-solving tasks

Farmer Task

Participants were asked to undertake two types of problem-solving task. The first task required participants to move a number of characters from one side of a hypothetical river to the other, whilst keeping in mind and applying a set of rules. The following characters were arranged in front of them; a farmer, a fox, a chicken, some grain, together with a boat. They were asked to transport the characters across a river (piece of blue card or paper), bearing in mind the following rules; firstly, only the farmer plus one item can fit into the boat on each trip, secondly, the chicken can not be left alone with the grain, as the chicken will eat the grain, and finally the fox can not be left alone with the chicken, as

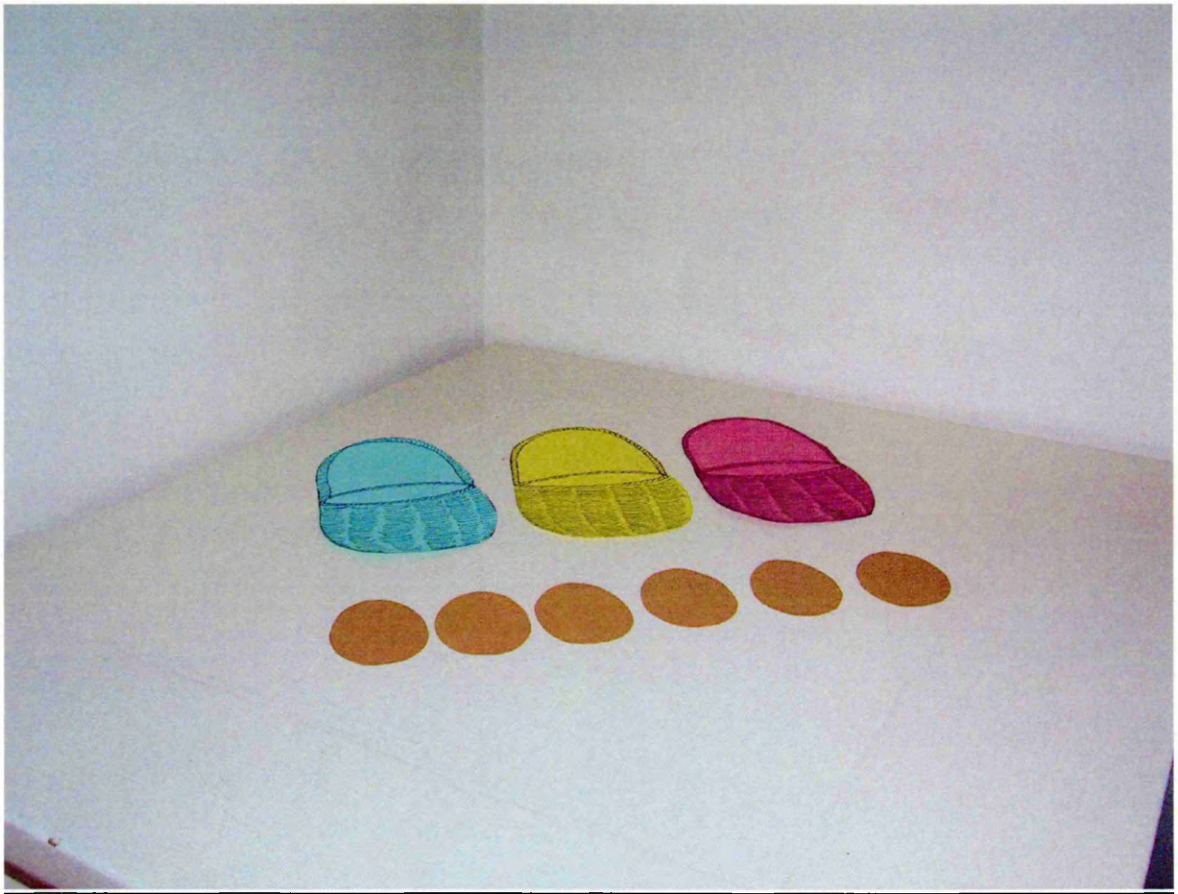


Figure 6.4: An example of the Eggs and baskets used in the task

6.2.7.2 Procedure

Farmer Task

Each participant was presented with a number of three-dimensional objects. These objects represented a boat, a farmer, a chicken, a fox, and a bag of grain. A blue piece of paper was also used to represent a river. Each of the items was explained to each participant, and it was explained that they would be used in a problem-solving task.

The child was then shown a piece of paper on which some information about the task was typed (Appendix 20). This was also read out to the child. When the child indicated that they had understood the instructions of the task they were told that they would be timed to see how long it would take them to solve the problem. When the first character was moved timing began, and measures were taken. When the task had been completed each participant was told how quickly they had completed it and congratulated on their performance.

the fox will eat the chicken. The items used in the farmer task are shown in figure 6.3 below.

Figure 6.3: An example of the items used in the farmer task

Eggs and Baskets Task

The second problem-solving task required the participants to be presented with three one dimensional baskets of differing colours made out of card, and six eggs made out of card. They were also presented with the following information written on a piece of card; the blue basket has one more egg than the yellow basket, the pink basket has one less egg than the yellow basket. They were then asked to place the correct number of eggs in each basket. The items used in the eggs and baskets task are shown in figure 6.4 below. One of the questions children were asked after taking part in the study was concerned with their familiarity with the problem-solving tasks. This revealed that both problem-solving tasks were completely novel to each of the participants.

Eggs in Baskets

Each participant was presented with three one-dimensional baskets made out of blue, pink and yellow card, and 6 one-dimensional eggs. The items were set out in front of the child along with an instruction sheet (Appendix 21) that was also read out to each participant. Each item was explained to the child and they were informed that they would be used in a problem-solving task, and they would be timed to see how long it took them to complete the task. Once the child had indicated they understood the instructions and task objectives they began. Timing started as soon as the first item was moved by the child and measures were taken throughout the task. When the task had been completed each participant was told how quickly they had completed it and congratulated on their performance.

6.3 Results

6.3.1 Task 1 – Switching Task

6.3.1.1 Treatment of the data

A measure of the total number of pairs turned on each condition for each group was taken. The purpose of this was to assess whether there were any differences between the groups or between conditions in terms of the total number of pairs of cards they were able to turn over during the task. If it was ascertained that there was a difference either between the groups or between conditions this would have implications for the findings generated on the other measures taken. A 2x4 mixed Anova revealed no significant effects of group or condition, and there was no significant interaction between group and condition showing that the groups did not differ in the number of cards they turned over during the task on any of the conditions. Any differences between the groups on other measures cannot, therefore, be explained by a difference in the number of cards turned over (Appendix 22).

Histograms and boxplots were produced to assess the distribution of the scores for each condition of each measure of the switching task. In general these figures demonstrated positively skewed distributions of scores on both the switching conditions and the non-switch conditions of the tasks, this positive skew was apparent for both groups. The positive skew on the non-switch conditions supported the hypotheses as the majority of participants would be expected to make very few errors on these conditions as they served as control conditions to represent each dimension of the switching task. These considerations meant it was necessary to analyse the data using non-parametric statistics.

On inspection of the control condition data, it was decided that the range of scores was very small and represented a categorical variable. A number of the participants, particularly those in the NC group, were able to complete the tasks without making errors. Ordinarily this type of data would indicate that there was a problem with the design of the task which had produced a ceiling effect, however, this error free performance had been observed during the pilot study and was anticipated on this task. The modal scores were zero on a number of the conditions of the measures of incorrect rule use, matching errors, requests for reiteration of instructions and turning over too many cards due to both motor error and rule break. It was, therefore, considered more appropriate to use these scores as a categorical variable with the categories error or no errors, and run a chi-square test on these data. Categories were collapsed in order that Fisher's Probability Test could be used.

The measure of completion time was normally distributed for both the switching condition and the non-switch control conditions, and this was also the case for the groups separately. One outlier did emerge on each of the four conditions, the same participant was responsible for this outlier, and it was amended.

6.3.1.2 Results

Table 6.2: Table demonstrating the Means and (Standard Deviations) of Scores on the Switching Task on Each Condition for Each Group and Overall

Measure	Condition	Descriptive Statistics								
		AD Group (N=22)			NC Group (N=22)			Overall (N=44)		
		Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Incorrect Rule Use – Monitoring	S	3.91	4.50	3.26	1.32	1.00	1.43	2.61	2.00	2.81*
	NSA	0.05	0.00	0.21	0.05	0.00	0.21	0.05	0.00	0.21
	NSC	0.09	0.00	0.29	0.05	0.00	0.21	0.07	0.00	0.25
	NSN	0.14	0.00	0.47	0.00	0.00	0.00	0.07	0.00	0.33
Reiteration of Instructions – Monitoring	S	7.00	7.00	4.69	1.50	1.00	1.47	4.25	3.00	4.42*
	NSA	0.73	0.00	1.24	0.23	0.00	0.87	0.48	0.00	1.09*
	NSC	0.36	0.00	1.00	0.05	0.00	0.21	0.20	0.00	0.73
	NSN	0.73	0.00	1.55	0.00	0.00	0.00	0.36	0.00	1.14*
Completion Time (Seconds) – Strategy Application	S	157.91	164.50	59.22	141.09	148.00	51.79	149.50	150.50	55.63
	NSA	120.18	118.00	39.52	128.95	125.50	48.46	124.57	121.50	43.93
	NSC	115.59	104.50	41.01	121.86	115.00	41.28	118.78	110.50	40.79
	NSN	120.09	108.00	42.35	121.14	115.00	45.73	120.61	112.50	43.56
Turning over too many cards – Rule Break – Inhibition	S	1.27	0.00	1.80	0.32	0.00	0.95	0.79	0.00	1.50*
	NSA	0.55	0.00	1.14	0.27	0.00	0.94	0.41	0.00	1.04
	NSC	0.86	0.00	1.28	0.14	0.00	0.64	0.50	0.00	1.07*
	NSN	0.50	0.00	1.01	0.55	0.00	1.71	0.52	0.00	1.39
Matching Errors – Inhibition	S	4.55	3.50	3.89	0.55	0.00	0.91	2.55	2.00	3.45*
	NSA	0.36	0.00	0.58	0.14	0.00	0.35	0.25	0.00	0.49
	NSC	0.36	0.00	0.73	0.45	0.00	1.41	0.20	0.00	2.79
	NSN	0.55	0.00	1.10	0.14	0.00	0.64	0.34	0.00	0.91
Turning over too many cards – Motor	S	0.32	0.00	0.84	0.05	0.00	0.21	0.18	0.00	0.62
	NSA	0.14	0.00	0.35	0.00	0.00	0.00	0.07	0.00	0.25
	NSC	0.32	0.00	0.78	0.05	0.00	0.78	0.05	0.00	0.21
	NSN	0.36	0.00	0.90	0.09	0.00	0.29	0.23	0.00	0.68

Key: S = Switching Condition NSA = Non-switch Animal Condition

NSC = Non-switch colour condition NSN = Non-switch number condition

*indicates significant differences between the groups.

As table 6.2 shows the descriptive statistics demonstrated quite large deviation around the mean scores, particularly for the AD group in comparison to the NC group on the switching conditions. This suggests that the switching condition disrupted some of the participants in the AD group to quite a large extent, whereas the NC group scores were almost error free. This pattern was particularly evident for the measures of incorrect rule use, requests for reiteration of instructions, and matching errors.

As the data are positively skewed on a number of the measures the median scores are more useful in describing the data in comparison to the mean scores. As per the hypotheses, the median scores, in the main, demonstrated that on the non-switch conditions most of the participants in both groups were not making any errors, and on the switching conditions participants in the NC group were making fewer errors than participants in the AD group.

Overview of the analyses

The non-switch conditions of the tasks, with the exception of the completion time measure, were analysed using the chi-square test. The switching conditions of the task were analysed using a non-parametric equivalent to an independent t-test, the Mann-Whitney test. The completion time measure, as it conformed to parametric assumptions, was analysed using a 2x4 mixed Anova.

Chi-square Analyses

The chi-square tests revealed that there was no significant association between group and incorrect rule use, group and matching errors, and group and turning over too many cards on any of the non-switch conditions of the pairs game. On the measure of turning over too many cards (impulsivity) on the non-switch animal condition and the non-switch number condition the relationship between group membership and turning over too many cards was not significant. On the non-switch colour condition, however, there was a significant association. The X^2 value of 8.282 had an associated probability of <0.01, df=1. Cramer's V was found to be 0.434, thus 19% of the variation in frequencies of turning over too many cards could be explained by group. The mean number of occasions too many cards were turned over by the AD group was 0.86 yet this figure was only 0.14 for the NC group. This indicates that the AD group were more likely to turn over too many cards. Further testing was, therefore, required on this condition. The chi-square analysis of the measure of participants' requests for reiteration of instructions revealed a non-significant association between group and requests for reiteration of instructions on the non-switch colour condition. On the non-switch animal condition, however, the X^2 value of 4.659 had an associated probability value of <0.05, df=1, showing that there was a significant association. Cramer's V was found to be 0.325, thus 11% of the variation in frequencies of requests for reiteration of instructions can be explained by group. The mean number of requests for reiteration of instructions by the AD group was 0.73 and for the NC group this figure was 0.23. This showed that the AD group were more likely to make more requests for reiteration of instructions. Further, the non-switch number condition revealed a Fisher's Exact Probability of p=0.048 and Cramer's V was found to be .358, thus 13% of the variation in frequencies of requests for reiteration of instructions can be explained by group. Again, the AD group were more likely to make requests for reiteration of instructions with a mean of 0.73 compared to a mean value of 0.00 by the NC group. Further testing was, therefore, required on the non-switch animal and non-switch number conditions of this measure (Appendix 23).

Mann-Whitney Analysis

Further analysis of the switching conditions, the non-switch colour condition of the measure of turning over too many cards (impulsivity), and the non-switch animal and number conditions of the requests for reiteration of instructions was undertaken using the Mann-Whitney U test.

Table 6.3: Table Demonstrating the Mann-Whitney U Test on the measures which did not meet parametric assumptions

Measure	Condition	Test of independence Mann-Whitney U Test	Significance Level
Incorrect Rule Use – Monitoring	*Switching Condition*	*U* = 129.00, z = -2.730	0.006**
Matching Errors – Inhibition	*Switching Condition*	*U* = 46.50, z = -4.744	0.001***
Turning Over too many cards – Motor	*Switching Condition*	*U* = 218.50, z = -1.106	0.296
Requests for reiteration of instructions – Monitoring	*Switching Condition*	*U* = 42.50, z = -4.723	0.001***
	Non-Switch Animal Condition	*U* = 176.00, z = -2.097	0.036*
	Non-Switch Number Condition	*U* = 187.00, z = -2.343	0.019*
Rule breaks- Turning over too many cards – Inhibition	*Switching Condition*	*U* = 162.50, z = -2319	0.020*
	Non-Switch Colour	*U* = 156.00, z = -2.754	0.006**

Levels of significance = *p<0.05, **p<0.01, ***p<0.001

As table 6.3 shows, the AD group used an incorrect rule significantly more than children in the NC group on the switching condition. Children in the AD group also made significantly more matching errors. The AD group were also significantly more likely to request reiteration of instructions on three of the conditions, the switching condition, the non-switch animal condition, and the non-switch number condition. There were no significant differences between the groups on the switching condition for motor errors (Appendix 24).

Friedman and Wilcoxon Analyses

Requests for reiteration of instructions

As three of the conditions of the requests for reiteration of instructions measure revealed significant differences between the groups, the non-parametric equivalent to a repeated measures Anova was applied to the data to assess whether within the groups there were any differences between the conditions. The Friedman Test applied to the AD group data revealed a chi-square value of 35.52 with an associated probability of p<0.001, and for the NC group alone the chi-square value was 23.46 with an associated probability value of p<0.001.

In order to clarify exactly where these differences lay the non-parametric equivalent of a paired-samples t-test was applied to pairings of conditions. The Wilcoxon signed ranks test assessed two possible pairings of the three conditions for the NC group and AD group separately. A Bonferroni correction was applied to the acceptable levels of significance.

<u>Table 6.4: Table Demonstrating the Wilcoxon Signed Ranks Test on the requests for reiteration of instructions measure</u>

Measure	Group	Pairing	Test of independence Wilcoxon Test	Significance Level
Requests for reiteration of instructions – Monitoring	*AD*	*Switching Condition v Non-Switch Animal Condition*	T = 0, z = -4.022	0.0001*
	NC		T = 10, z = -2.691	0.007*
	AD	*Switching Condition v Non-Switch Number Condition*	T = 0, z = -3.931	0.0001*
	NC		T = 0, z = -3.319	0.001*

Levels of significance = *p<0.017

For the AD group the descriptive statistics (table 6.2) showed that the median value of the switching condition (7) was higher than in each of the non-switch conditions (0), this was also true for the NC group with the switching condition having a higher median value (1) than each of the non-switch conditions (0). Pairings of the switching condition with each of the non-switch conditions were analysed.

The Wilcoxon analysis (see table 6.4) revealed that within both the NC group and the AD group significantly more requests for reiteration of instructions were made on the switching condition compared to both the non-switch animal condition and the non-switch number condition.

Turning over too many cards - inhibition

As it had been shown that children in the AD group were significantly more likely to turn over too many cards, on the switching condition and the non-switch colour condition, the non-parametric equivalent to a related t-test was applied to the data to assess whether there were any differences between conditions within each of the groups separately.

Table 6.5: Table Demonstrating the Wilcoxon Signed Ranks Test on the turning over too many cards measure

Measure	Group	Pairing	Wilcoxon Signed Ranks Test	Significance Level
Turning over too many cards – Inhibition	*AD*	*Switching Condition v Non-Switch Colour Condition*	T = 20, z = 0.770	0.441
	NC		T=1.50, z = -0.816	0.414

Levels of significance = *p<0.05, **p<0.01, ***p<0.001

The previous analyses showed an effect of group. The AD group turn over too many cards more often than the NC group. Table 6.5, however, shows that there are no differences between conditions, with the AD group making more of these errors in both conditions (Appendix 25).

Analysis of variance for completion time

The completion time measure of strategy was analysed using a 2x4 mixed Anova to assess the effects between groups and within conditions and any interactions between these factors. Completion time of the task did not yield a main effect of group, however, a significant main effect of condition did emerge

$F(2.277, 95.624) = 14.110, p<0.001$. There was no significant interaction between group and condition. Follow up analyses of the main effect of condition revealed that there was a significant difference between completion time on the switching condition when compared to each of the non-switch conditions, non-switch animal $t(43) = 3.960, p< 0.017$, non-switch colour $t(43) = 4.291, p<0.017$, and non-switch animal $t(43) = 5.546, p< 0.017$ (Appendix 26).

6.3.1.3 Summary of findings: Task 1

There were no significant associations between group membership and inhibition or monitoring on the control conditions of the task, with the exception of the non-switch colour condition on the inhibition measure (turning over too many cards) and on the non-switch animal and number conditions of the monitoring measure (requests for reiteration of instructions). These findings confirm as hypothesised, there was no difference between groups on the majority of the control conditions. The fact that monitoring (requests for reiterations of instructions) differentiated the groups on two of the control conditions, although not predicted, is unsurprising given the characteristics of children with attentional difficulties and the overall predictions of the thesis. The fact that the non-switch colour control condition differentiated the groups on the inhibition measure (turning over too many cards) was surprising as impulsivity was hypothesised to occur as a result of the central executive load placed on the participants.

The analyses of the switching conditions and the non-switch conditions on which associations were observed, revealed significant differences between the groups on all, with the exception of motor errors, measures. These findings suggest, in line with the hypotheses that although few differences between the groups were observed in terms of making mistakes on the control conditions, the switching condition did significantly differentiate the groups in this respect. The anomalous findings associated with monitoring and inhibition on the control conditions might indicate, regardless of central executive load, children with attentional difficulties have more difficulties compared to controls with these particular attentional mechanisms.

6.3.2 Task 2 – Dual Task

6.3.2.1 Treatment of the data

As in the switching task a measure of the total number of pairs turned on each condition for each group was taken, to assess whether there were any differences between the groups or between conditions in terms of the total number of pairs of cards they were able to turn over during the task. One-way Anovas were performed on each condition to assess whether there were any differences between the groups and these showed no significant differences (Appendix 27).

Histograms and boxplots were produced to assess the distribution of scores on each condition for each measure. A normal distribution of scores was observed for the measure of number of looks towards the timer. A normal distribution of scores was evidenced on the measure of correct matches, however outliers did appear and were amended to one above the next highest score. Normal distribution on total pieces of jigsaw correctly selected measure was also evident, however again an outlier was present.

The measures which were not normally distributed were the number of incorrect matches, the number of reiteration of instructions, the number of total motor errors, and the number of rule breaks committed which were defined as turning over too many cards. A positively skewed distribution of scores for both groups of participants was observed on these measures.

6.3.2.2 Results

Table 6.6: Table demonstrating the Mean, Median and Standard Deviation Scores on each condition of the Dual-Task for Each Group and Overall

Measure	Condition	Descriptive Statistics								
		AD Group (N=22)			NC Group (N=22)			Overall (N=22)		
		Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Looks Toward Timer – Monitoring	Dual	1.32	1.00	1.21	1.23	1.00	0.92	1.27	1.00	1.06
	Pairs	0.91	1.00	1.06	1.41	1.00	1.26	1.16	1.00	1.18
	Jigsaw	0.77	1.00	0.92	1.36	1.00	1.18	1.07	1.00	1.09
Reiteration of Instructions – Monitoring	Dual	2.64	0.00	4.04	0.23	0.00	0.53	1.43	0.00	3.10
	Pairs	1.55	0.00	2.94	0.41	0.00	0.53	0.98	0.00	2.30
	Jigsaw	0.00	0.00	0.00	0.05	0.00	0.21	0.02	0.00	0.15
Correct Matches – Strategy	Dual	1.36	1.00	1.26	4.09	4.00	2.33	2.73	2.00	2.31
	Pairs	5.91	6.00	2.45	7.91	8.00	2.45	6.91	7.00	2.62
Incorrect Matches – Inhibition	Dual	0.64	0.00	1.09	0.00	0.00	0.00	0.32	0.00	0.83
	Pairs	1.64	0.00	2.79	0.05	0.00	0.21	0.84	0.00	2.11
Jigsaw Pieces correctly used – Strategy	Dual	7.68	7.00	3.81	12.00	11.50	3.93	9.84	9.50	4.40
	Jigsaw	13.09	13.00	3.82	16.50	15.50	4.19	14.80	15.00	4.32
Total Motor Errors – Motor	Dual	0.82	0.00	1.94	0.00	0.00	0.00	0.41	0.00	1.42
	Pairs	0.23	0.00	0.87	0.09	0.00	0.29	0.16	0.00	0.64
	Jigsaw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Too Many Pieces turned – Inhibition	Dual	0.86	0.00	1.75	0.14	0.00	0.64	0.50	0.00	1.36
	Pairs	1.55	0.00	3.02	0.18	0.00	0.66	0.86	0.00	2.27

Table 6.6 shows that the AD group gained higher scores on the measures of reiteration of instructions, and incorrect matches. The AD group also scored lower than the NC group on correct matches. The differences between the groups appear to be reserved for the dual and pairs only conditions, the jigsaw condition appears, as expected, to produce error free performance in both groups.

Anova Analysis

Looks toward timer

In terms of the number of occasions that the participants looked towards the timer, there was no main effect of group and no main effect of condition, however, there was a significant interaction between group and condition $F(1.383,58.092) = 4.408, p<0.05$.

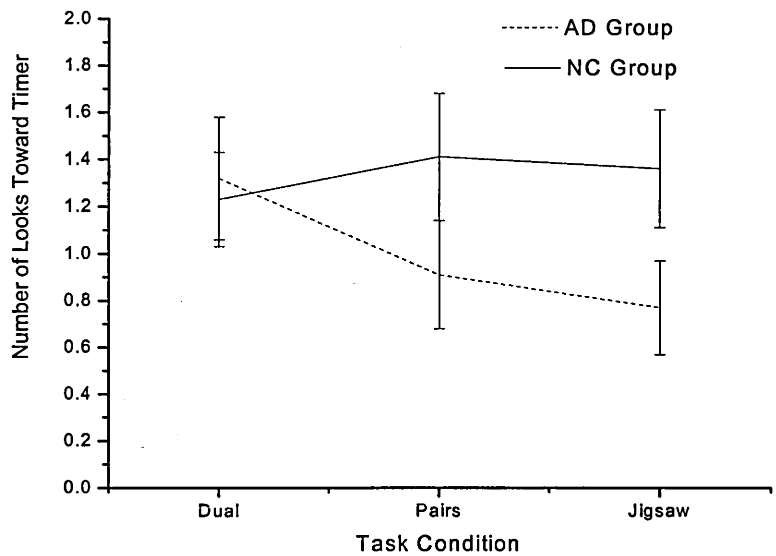


Figure 6.5: Graph to demonstrate the interaction between group membership and condition on the measure of looks towards the timer, mean scores and standard error of the mean are plotted

Although there was a significant interaction between group and condition on the measure of looks toward the timer, when analysed separately differences between the dual condition and control conditions did not reach significance in either group. This showed that although children in the AD group looked at the timer more often on the dual-task condition in comparison to the control conditions this difference was not significant. Within the NC group the opposite pattern occurred with more looks toward the timer on the control conditions in comparison to the dual-task condition, although again these differences did not reach significance (Appendix 28).

Correct Matches

There was a significant main effect of group on the correct matches measures *F(1,42) = 16.589, p<0.001*, indicating that the NC group made significantly more correct matches in comparison to the AD group. There was also a main effect of condition *F(1,42) = 184.957, p<0.001* in that the pairs only control condition yielded significantly more matches. This is unsurprising as in the pairs only condition the participants did not have the distraction of completing another task during the same time period. The main effect of condition would also go towards explaining why there was no significant interaction between the factors of group and condition *F(1,42) = 1.399, p>0.05*. Follow up independent t-tests revealed that the AD group made fewer correct matches in comparison to the NC group on both the dual-task condition *t(42)-4.836, p<0.0125*, and the pairs only condition *t(42)-2.710, p<0.0125*. Further, paired samples t-tests on the groups separately revealed that within the AD group there was a significant difference between the dual and pairs only condition *t(21)-9.700, p<0.0125*. This also occurred within the NC group *t(21)-9.588, p<0.0125*. These analyses suggest the both groups demonstrated the same pattern of performance in terms of correct matches, while the NC group performed at a higher level (Appendix 29).

Total Jigsaw Pieces Used

The total pieces of jigsaw correctly used measure yielded a significant main effect of group *F(1,42) = 12.646, p<0.01* in that the NC group selected significantly more correct pieces in comparison to the AD group. As expected, there was also a significant main effect of condition *F(1,42) = 106.284, p<0.001* indicating that the jigsaw only condition yielded significantly more correct pieces selected in comparison to the dual task condition. There was no significant interaction between group and condition. Follow up independent t-tests confirmed that in both conditions the AD group selected significantly fewer correct pieces, dual-task *t(42)-3.701, p<0.0125*, Jigsaw *t(42)-2.820, p<0.0125*. There was also a significant difference between conditions for both groups, AD group *t(21)-6.257, p<0.0125*, NC group *t(21)-10.714, p<0.0125*. This pattern of results suggests that both groups are detrimentally affected by the dual-task condition, with the AD group performing at a significantly lower level than the NC group on both conditions (Appendix 30).

Non-parametric analyses

The measures of incorrect matches, total motor errors, too many pieces turned over (impulsive), and reiteration of instructions did not meet the assumptions for parametric testing as the data were skewed. The Mann-Whitney U values are displayed below in table 6.7., and Wilcoxon values in table 6.8.

Table 6.7: Table to demonstrate differences between the groups using the Mann-Whitney U Test

Measure	Condition	Test of independence Mann-Whitney U Test	Significance Levels
Incorrect Matches – Inhibition	*Dual Task Condition*	*U* = 165, z=-2.841	0.004**
	Pairs Only Condition	*U* =150, z=-2.927	0.003**
Total Motor Errors – Motor	*Dual Task Condition*	*U* = 187, z=-2.342	0.019*
	Pairs Only Condition	*U* = 241, z=-0.047	0.92
	Jigsaw Only Condition	*U* = 242, z=0	1.000
Too many pieces turned – Inhibition	*Dual-Task Condition*	*U* = 187, z=-2.028	0.043*
	Pairs Only Condition	*U* = 183, z=-1.966	0.049*
Reiteration of Instructions – Monitoring	*Dual-Task Condition*	*U* = 159, z=-2.359	0.018*
	Pairs Only Condition	*U* = 176, z=-1.962	0.05
	Jigsaw Only Condition	*U* = 231, z=-1.000	0.317

Levels of significance = *p<0.05, **p<0.01, ***p<0.001

Table 6.8: Table to demonstrate differences between the conditions using the Wilcoxon Signed Ranks Test

Measure	Group	Paired Conditions	Wilcoxon Signed Ranks Test	Significance Levels
Incorrect Matches – Inhibition	*Overall*	*Dual Task Condition v Pairs Only Condition*	t=36, z = -1.044	0.297
Too many pieces turned – Inhibition	*Overall*	*Dual-Task Condition v Pairs Only Condition*	t=19, z = -0.872	0.383
Reiteration of Instructions – Monitoring	*AD*	*Dual-Task Condition v Pairs Only Condition*	t=0, z = -2.392	0.017*
		Dual-Task Condition v Jigsaw Only Condition	t=0, z = -2.809	0.005**

Levels of significance = *p<0.05, **p<0.01, ***p<0.001

Incorrect Matches

On both the dual and pairs only conditions the median scores showed no difference between the groups on the incorrect matches measure. The Mann-

Whitney test, however, did demonstrate that the groups differed significantly and the mean scores explained this, showing that the AD group were more likely to make incorrect matches on both conditions. The skewed distribution of scores can explain this pattern of findings. The Wilcoxon test was then applied to the data to assess the effects of condition. This showed that there were no significant differences in incorrect matches between the conditions. These analyses overall have suggested that children in the AD group are more likely in comparison to children in the NC group to make incorrect matches and there are no differences on the measure of incorrect matches between conditions overall. Although children in the AD group are more likely to make more incorrect matches overall, the dual-task condition does not induce more incorrect matches in comparison to the pairs only condition.

Motor Errors

On the measure of total motor errors, again descriptive statistics revealed no difference between the groups in terms of the median scores on any of the three conditions, all being zero. On the dual-task condition there was a statistically significant difference between the groups, the mean values showing that the AD group make more motor errors on this condition. On the pairs only and jigsaw only condition there were no significant differences between the groups in motor errors (see table 6.8). These analyses demonstrate that children in the AD group make more motor errors in comparison to the NC group but only on the dual-task condition. In order to assess whether there were any effects of condition the Friedman test was applied to the data. The X^2 value was 4.667 with an associated probability of 0.97, indicating that there were no significant differences in terms of motor error between the conditions of the task.

Too Many Pieces Turned Over

On the measure of too many pieces turned over (impulsive) the median scores for each group on both the dual-task and pairs only condition were zero. The Mann-Whitney test, however, revealed that there were significant differences between the groups on both the dual-task and pairs only conditions (see table 6.8). The mean values indicate that the AD group were more likely to turn over too many pieces in comparison to the NC group. The Wilcoxon test showed no significant differences between the conditions (see table 6.8). Overall these results suggest that children in the AD group may be slightly more impulsive than the NC group but this is not affected by condition.

Requests for reiteration of instructions

On the measure of reiteration of instructions, again median scores on all three conditions and for both groups were zero. The Mann-Whitney tests indicated that the groups differed in the number of requests for reiteration of instructions only on the dual-task condition (see table 6.7). The mean scores demonstrated that the AD group made more of these requests. The Friedman test was then applied to the data to assess whether there were any differences in scores dependent on condition. The X^2 value of 19.276 had an associated probability value of 0.0001 indicating that there were significant differences between scores on the three conditions. In order to assess whether this was true for the groups separately the analysis was performed on each of the groups, this revealed a X^2 value of 18.167 with an associated probability of <0.001 within the AD group, however within the NC group, the X^2 value of 2.818 was not significant >0.05. These findings necessitated further analysis of the AD group data. A Wilcoxon Signed ranks test was performed on selected pairings of the conditions, showing significant differences between the dual-task condition and the pairs only condition, and the dual-task condition and the jigsaw only condition (see table 6.8). These findings show that the AD group are detrimentally affected by the dual-task condition in terms of requests for reiteration of instructions, whereas the NC group appear to perform at the same level on all of the conditions (Appendix 31).

6.3.2.3 Summary of findings: Task 2

Although both groups were able to undertake each of the tasks presented to them these findings have revealed, as would be expected, that the dual condition induced significantly fewer correct matches and fewer total jigsaw pieces selected compared to the control conditions. More interestingly, the AD group demonstrated a significantly lowered performance on these measures relative to the NC group on both the dual and control conditions. There were no significant differences between the conditions in terms of inhibition (incorrect matches and too many pieces turned), or motor errors, but the AD group made significantly more inhibitory errors on both conditions, and made more motor errors on the dual condition only. There were significantly more requests for reiteration of instructions on the dual condition compared to the control conditions, but for the AD group only, and the AD group made significantly more requests for reiteration of instructions compared to the NC group, only on the dual condition, indicating a difference in monitoring. Overall there seems to be an effect of group as the AD group are more likely to make errors. Although there seems to be some effect of condition in that some of these errors appear to be increased in the dual-task condition the effects observed on the dual task are actually apparent in both dual and dual task conditions. This pattern is particularly apparent for the monitoring measure (requests for reiteration of instructions).

6.3.3 Task 3 – Problem-solving tasks

Treatment of the data

Histograms and boxplots were run on the problem-solving task data to assess whether the assumptions for running parametric testing had been met. On initial inspection of the descriptive statistics, histograms, and boxplots it appeared that most of the measures of both tasks were normally distributed. On the farmer task, the measure of requests for reiteration of instructions was normally distributed, as was the measure of incorrect moves. Outliers were evident and amended on the measure of solution time, and on the measure of total moves. The eggs and baskets task measure of correct moves was normally distributed and did not have any outliers. The measure of total moves was also normally distributed, however three outliers were evident and amended. The measure of solution time, although normally distributed also had outliers which were amended. As these data met parametric assumptions they could be analysed using separate Manova to assess the differences between the groups on each of the tasks.

Two measures of the eggs and baskets task, requests for reiteration of instructions and incorrect moves, had positively skewed distributions of scores, having more than 50% zero values. These variables seemed characteristic of a discrete rather a continuous variable. Further boxplots were produced to assess the distribution of scores within each group on these measures and a decision was taken to treat the data as categorical, and thus assess any associations between group and each of the measures using chi-square tests.

The farmer task measure, correct moves, did not meet the assumptions for parametric testing, as the majority of the participants had achieved similar scores. Therefore this measure was analysed using the Mann-Whitney U test.

6.3.3.1 Results – Farmer Task

Table 6.9: Table demonstrating the descriptive statistics for scores on the farmer problem-solving task for each group and overall

Measure	Descriptive Statistics								
	AD Group (N=22)			NC Group (N=22)			Overall (N=22)		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Solution Time (seconds) – Strategy	93.50	89.50	40.85	92.82	92.50	30.23	93.16	89.50	35.52
Requests for reiteration of instructions – Monitoring	4.05	3.50	2.55	1.91	2.00	1.66	2.98	3.00	2.39
Correct moves – Strategy	5.00	5.00	0.31	5.09	5.00	0.43	5.05	5.00	0.37
Incorrect Moves – Inhibition	1.91	2.00	1.63	1.59	2.00	1.26	1.75	2.00	1.45
Total Moves – Strategy	6.86	7.00	1.49	6.64	7.00	1.09	6.75	7.00	1.30

The mean, median and standard deviation scores are presented in table 6.9 above. There was very little difference between the groups on completion time, although the AD group made slightly more incorrect moves. The standard deviation scores demonstrate that the scores were more variable in the AD group. There is little difference between the groups on measures of correct moves and total moves.

The data gained to assess performance of each group on the farmer task was analysed using a Manova. The between participants variable was group and the dependent variables were solution time, requests for reiteration of instructions, incorrect moves and total moves. The analysis revealed a multivariate difference between the groups $F(4,39) = 4.056, p<0.01, Wilks' \lambda =$

0.706. Follow up univariate anovas revealed significant differences between the groups on only one of the four dependent variables which were analysed. The only significant difference between the groups emerged on the measure of reiteration of instructions $F(1,42) = 10.826, p < 0.01$, in that children in the AD group made more of these requests. There were no significant differences between the groups for completion time, incorrect moves, or total moves (Appendix 32)

The Mann-Whitney U test was implemented to assess the measure of correct moves and was non significant (Appendix 33). It is evident, therefore, that there is no significant difference between the groups in terms of correct moves on the farmer task.

6.3.3.1.1 Summary of findings

Both groups of participants were able to complete the problem-solving task. The only difference between the groups was in the number of requests for reiteration of instructions. The AD group made significantly more of these requests in comparison to the NC group.

6.3.3.2 Results - Eggs and Baskets Task

<u>Table 6.10: Table demonstrating the descriptive statistics for scores on the eggs and baskets problem-solving task for each group and overall</u>

Measure	Descriptive Statistics								
	AD Group (N=22)			NC Group (N=22)			Overall (N=22)		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Solution Time (seconds) – Strategy	25.50	25.00	11.33	23.55	20.50	11.96	24.52	24.50	11.56
Requests for reiteration of instructions – Monitoring	1.55	0.00	2.10	0.32	0.00	0.72	0.93	0.00	1.72
Correct moves – Strategy	5.32	6.00	1.29	4.82	5.00	1.40	5.07	6.00	1.35
Incorrect Moves – Inhibition	0.50	0.00	1.34	0.50	0.00	1.19	0.50	0.00	1.25
Total Moves – Strategy	5.50	6.00	2.02	5.14	5.50	1.81	5.32	6.00	1.90

Table 6.10 above demonstrates that the AD group took longer than the NC group to complete the eggs and baskets tasks, there were very few differences between the groups on each of the other measures.

The data obtained on the eggs and baskets task was also analysed using Manova. Again, the between participants variable was group and the dependent variables were solution time, correct moves and total moves. The analysis revealed that there was no significant multivariate difference between the groups (Appendix 34).

A chi-square analysis was implemented to assess the measures of requests for reiteration of instructions and incorrect moves. This showed that there was no significant association between group membership and whether requests for reiteration of instructions were made or not (Appendix 35).

6.3.3.2.1 Summary of findings

Again both groups of participants were able to complete the task and there were no significant differences on any of the task measures. These findings suggest that on this particular task both groups were equally capable. The instructions for the task were explicit and the task could be completed easily in a short space of time.

6.3.4 Qualitative Analysis

In addition to the quantitative measures of task performance, the participants were asked some questions to give an indication of their thought processes whilst undertaking the tasks. The questions were of both open and closed type. All of the children were able to answer the closed questions, whereas only ten children from the AD group, and twelve children from the NC group were able to give full answers to the open questions. The closed questions were analysed using chi-square tests. In the main these revealed no association between group membership and the participants' opinions on the tasks (Appendix 36).

Six questions were in open format and therefore demanded elaboration by the participants. For each question and for each group the themes which emerged are set out below;

1) How did you match all the pairs so quickly?

A number of the children said they didn't know how they did it or that they just did it quickly, or turned over as many cards as possible. Some children (8), however, said that they remembered the position of the cards indicating that they did have a strategy. The responses to this question did not appear to differ by group.

2) i) How did you go about doing the jigsaw?

Most (10) of the children in the AD group referred to the picture on the jigsaw and said they tried to do that part first. A small number (3) said they had looked for a common colour or edge pieces. The NC group children seemed to be more specific in terms of describing exactly which edge pieces they used. For example one participant commented; 'I found all the coral edge pieces first.'

ii) What is the best way to do a jigsaw?

The responses to this questioned mirrored the responses to the previous question. The responses gained here, therefore, may have been confounded by the fact that the children wanted to save face by saying that the best way to do a jigsaw was the way that *they* had done it.

3) i) On the dual-task, how did you decide when to change?

Most participants in the AD group said they didn't know, a few said when they were running out of time or when they remembered to. The NC group seemed to have more insight and some had a strategy. For example, spending one minute on each or to change when they had made a match, or a section (e.g. one corner) of the jigsaw. They were also more concerned that equal amounts of each task had been completed.

ii) Did the clock help you to decide when to change?

The majority of the AD group said they didn't look at it or forgot to look at it. The majority of the NC group said they did use the clock, and most of the remaining participants in the NC group said they didn't look at it because it would have wasted time. This seems to indicate insight into their own strategy, and also that the strategy had been pre-planned.

4) i) On the farmer task, how did you get all the characters across the river?
Within the AD group the majority of the participants said they didn't know. A small number said they just tried it or thought about where the chicken should be, the key element to the task. Within the NC group the majority of the group mentioned the chicken and how it could be kept safe, a number thought the task was easy once they had worked out where the chicken needed to be. A small number said they had used a process of trial and error e.g. 'just kept trying different ways..', and one said they had '...thought about it first and then moved the characters..'. These comments seem to indicate that more strategic thought was evident in the NC group, or that the NC group were more able to express this.

ii) Which part was the hardest?
Approximately half of the children in the AD group thought 'bringing the chicken back' or keeping the chicken away from the fox was the hardest part. The other half said they didn't know. All of the NC children referred to keeping the various characters apart.

5) How did you work out the eggs and baskets problem?
Most of the children in the AD group said they didn't know or had guessed. One gave the formula and one said it was like maths. Most of the children in the NC group referred to maths, a number said they had thought about numbers. Although the AD group said they didn't know how they had worked the problem out, all of them completed the problem correctly, indicating that they either do not have an insight into how they have worked problems out, or cannot express this.

6.3.5.1 Summary of findings: Qualitative Analysis

The AD group were more likely to say they didn't know how they had completed a task, although the quantitative results suggest they could complete the tasks successfully. The NC group were more likely to provide an explanation for the actions they had taken in completing the tasks.

6.4 Discussion

6.4.1 Summary of the findings

The aim of this series of experiments was to extend the findings of experiment 1 and substantiate the interpretations of experiment 2 which suggested that the attentional difficulty group had more difficulties than the control group with tasks requiring the use of the central executive. A second aim was to build upon Barkley's (1997) inhibition model and address the propositions of Sergeant et al. (2003) regarding the association between working memory and executive function by assessing on which if any measures of executive function the groups differed.

The findings have suggested that some of the tasks hypothesised by Baddeley (1996) as tapping the functions of the central executive can distinguish between children with attentional difficulties and those without, whereas others cannot. In short, the measure of errors on the switching task and correct matches on the dual-task revealed that performance was lower in the AD group in comparison to the NC group. The problem-solving tasks differentiated groups to a lesser extent. The findings suggest that the switching and dual-task conditions of the tasks had a heavier demand for the attentional mechanisms, such as inhibitory control, which had been demonstrated as reduced in children with attentional difficulties in experiments 1 and 2. Like the single task conditions on the dual-task and the non-switch conditions of the switching task, the problem-solving tasks appeared to require fewer of these executive resources, and this may have been associated with the memory load for these tasks being lower.

The measures of executive function which were most successful in differentiating the groups were monitoring and inhibition. Monitoring was measured primarily by number of requests for reiteration of instructions, but also by incorrect rule use, and looks toward the timer. Inhibition was measured by errors and turning over too many cards. Strategy application, measured by completion time and correct matches or moves, and motor error, measured by dropping cards or objects, appeared to differentiate the groups to a lesser extent. The AD group performed worse in comparison to the control group on some measures of monitoring and inhibition on each of the tasks and this was more often the case on central executive loaded conditions, but also occurred on some control conditions. This was particularly the case for the monitoring measure, requests for reiteration of instructions, suggesting that external reinforcement may improve task performance by way of monitoring and inhibition processes in children with attentional difficulties.

The results offer no real support for a difficulty in the recruitment of resources for motor control in the attentional difficulty group. The findings appear to confirm that cognitive rather than motor control is the primary area of concern in this group of children. If the central executive is responsible for the recruitment of motor control resources, then either it is having no difficulties in the recruitment of these resources or the demands for motor resources on the tasks presented here are not heavy and can be coped with.

The qualitative findings showed that the AD group either didn't have much insight or were inhibiting their own viewpoints, perhaps due to embarrassment or thinking that they may be wrong. The NC group appeared to be more aware of the strategies they had implemented on the tasks and were less afraid to express these viewpoints. Although, overall the qualitative data appears to indicate a difference between the groups dependent on an insight into their problem-solving strategies, it may be the case that the answers to the questions did not reflect the processes they were aimed at. The responses, particularly by the AD group, may have been shaped by social learning. This group may be more accustomed than the NC group to making mistakes, and are more likely to assume they have made a mistake if they are being asked why an action was chosen.

Alternative explanations for the difference between the groups in the number of requests for reiteration of instructions were supported by the interpretations made from the qualitative data. This difference could be associated with learned behaviour or low self-esteem. A history of failure may lead to the development of a 'failure set'. The children in the AD group may be used to failing on tasks and are keen to be reassured that they are undertaking the task correctly. It may, therefore, be the case that requests for reiteration of instructions is a strategy rather than a deficit in monitoring. This possibility will be addressed in more detail in section 6.4.4.

6.4.2 Implications of the findings for the central executive and executive demands associated with it

With reference to Baddeley (1996) the AD group seem to have problems associated with their capacity for selective attention/inhibition, as measured by the switching task, and integration and coordination, as measured by the dual-task. They appear to be unaffected, however, in generating novel responses, as measured by the problem-solving tasks used in this experiment, and by the fluency tasks used in experiment 1. The findings, however, seem to indicate that task performance was based on overall demands for executive attentional control based on a number of different processes rather than for the specific functions Baddeley (1996) proposed. This is unsurprising given that the tasks were aimed to reflect 'real life' tasks which have multiple and varied executive attentional demands. The findings provided support for separable executive attentional processes on central executive tasks, but not necessarily in the same way as Baddeley proposed, therefore the implications are that more specific models of attentional control such as Barkley's (1997) inhibition model and Norman and Shallice's (1980) Supervisory Attentional System (SAS) can more fully explain the findings.

6.4.3 Implications of the findings for Barkley's (1997) inhibition model

The findings that inhibition and monitoring measures differentiated the groups lend support to Barkley's model which suggested that response inhibition is required for the adequate performance of working memory. The construct of response inhibition, however, needs further analysis to describe executive attentional processes. Inhibition and monitoring together appear to reflect the response inhibition construct proposed by Barkley (1997). In Barkley's model a deficit in response inhibition results in lowered performance on a range of tasks including working memory tasks. It is possible that the response inhibition construct reflects the monitoring and modulation processes of the SAS (Norman and Shallice, 1980) and that the lowered performance on working memory tasks is due to inadequate strategy generation functions which are dependent on the monitoring and modulation processes of the SAS. The results presented here are consistent with this interpretation. The findings can also be taken as supporting other models of executive function in children with ADHD (Sergeant et al., 2003; Pennington and Ozonoff; 1996). They also provide more specific predictions to be made, such as a lowered performance by the AD group on the tasks used here which demand executive attentional mechanisms such as monitoring and modulation processes of the SAS.

6.4.4 Implications of the findings for the SAS

The construct of response inhibition has been interpreted here as reflecting the monitoring and modulation processes described in the SAS (Norman and Shallice, 1980). Roodendrys et al. (2001) found children with ADHD had difficulties on tasks which involved controlled information processing, modifying and accommodating new input, switching rehearsal strategies, and it was observed that children with ADHD also had a limited supervisory capacity within the central executive. Roodendrys et al.'s findings together with the results presented here could be consistent with a theory of failure or dysfunction of the Supervisory Attentional System (SAS) (Norman and Shallice, 1980). The SAS is required on tasks which require deliberate conscious control of attention. Such tasks are those which involve planning or decision making and which are novel or ill-learned and these skills are required for all three types of task administered here. The SAS is also said (Norman and Shallice, 1980) to be required to overcome a strong habitual response, which would apply to the switching task used here. The difference between the groups primarily on the experimental conditions could be explained by a SAS problem. The control conditions of the tasks, particularly the non-switch conditions, and the single in comparison to the dual tasks, may rely only on contention scheduling, which is intact in both groups, whereas the switching and dual tasks rely on the SAS, which functions better in the NC group.

Further evidence for the SAS explanation can be derived from parallels between attentional difficulty group children and patients with Strategy Application Disorder (Burgess, 2000). Indecisiveness has been reported as a difficulty in real-life situations for patients with strategy application disorder. These patients have an inability to complete tasks and follow time constraints and this difficulty is attributed to a problem associated with the SAS.

Indecisiveness due to a monitoring problem could explain the increase in requests for instructions in the attentional difficulty group and particularly on tasks where monitoring demands are heavier, such as in the dual-task or switching situation.

An explanation for the finding that measures of strategy application did not seem to differentiate the groups, may be associated with the fact that both groups were allowed to request reiteration of instructions at any point. This external assistance may have served to improve performance on measures of strategy without reliance on the inhibition mechanisms to allow for strategy generation provided by the SAS. The qualitative analysis provides support for this explanation as it was revealed that the AD group were less likely to be able to report the use of a strategy in comparison to the NC group.

An alternative explanation for differences between the groups on the number of requests for reiteration of instructions being due to a difference between the groups in strategy use will have different implications for the SAS explanation. If this measure does reflect a lower level strategy that the AD group have learned, then the interpretation of a problem associated with monitoring functions of the SAS to account for this is not supported. In this case the children in the AD group may have become reliant on external cues due, initially, to an inhibitory control problem and subsequently as a learned behaviour. The fact that more requests for reiteration of instructions were made by the AD group on most task conditions, including control conditions, provides support for this latter interpretation, as it does not appear to be dependent on task demand. This would imply that the monitoring functions of the SAS may be intact yet modulation processes are disrupted in the AD group. Further research would be required to differentiate between the theories to explain the differences between groups on the number of requests for reiteration of instructions.

It should be noted, however, that the monitoring explanation is still supported by other monitoring measures employed on the switching task. Differences between the groups were observed for the monitoring measure of incorrect rule use. These two explanations, a monitoring explanation and a lower level strategy explanation, could be consistent with each other and it appears that the switching task is more sensitive in assessing monitoring processes in comparison to the dual and problem-solving tasks.

6.4.5 Implications of the findings for a new model encompassing the original models

Barkley's (1997) inhibition model described three separate processes associated with response inhibition. These were inhibition of a prepotent response, interruption of an ongoing response and interference control. The present findings demonstrate that the attentional difficulty group are unable to complete a task adequately when they are asked to modify an action, such as switching rules, which is hypothesised as dependent on the SAS. Barkley's inhibition model becomes important at this point as this modification can only take place if the previously performed action is successfully inhibited (Norman and Shallice, 1980). It would be assumed, therefore, that the inhibition of a prepotent response and the interruption of an ongoing response functions described in Barkley's model reflect the modulation of actions function of the SAS. These interpretations appear to be consistent with previous empirical findings, such as those by Cepeda et al. (2000). They found that ADHD children had impaired performance on switching trials of a task, whereas medicated ADHD children and control children did not demonstrate this deficient performance. There were no differences in performance between the groups on the individual tasks which did not require switching. Cepeda et al. interpreted these findings as reflecting a deficit in executive control and more specifically inhibitory processes.

6.4.6 Implications for task performance in children with attentional difficulties

An encouraging finding was that children in the attentional difficulty group, although often making more errors, were able to undertake and complete all of the tasks they were presented with. Further, the fact that problem-solving tasks did not differentiate the groups suggests that with conscious effort children with attentional difficulties can achieve higher order tasks. These findings were consistent with the findings of Lawrence et al. (2002) who showed that children with ADHD exhibited varying levels of impaired performance on measures of executive function on two different real life tasks, a computer task and a trip to the zoo. The ADHD group appeared to make relatively few errors associated with impaired executive function, particularly on the zoo task which was intended to be the more reflective of a real life situation. The most important factors which contribute toward task success within the attentional difficulty group appear to be external assistance towards monitoring by the reiteration of instructions. This extra instruction and reinforcement together with a motivational structure that provided a clear goal for the problem solving tasks, appeared to improve the performance of the children in the AD group. This finding may have implications for educational strategy, suggesting that by using tasks with clear goals and providing extra instruction performance on educational tasks may be improved in children with attentional difficulties. This interpretation would be consistent with the SAS model as it is assumed that motivational factors supplement the activational influences of the SAS (Norman and Shallice, 1980). Further research should focus on which tasks may increase motivation in children with attentional difficulties and thus may develop their attentional skills.

6.6.7 Conclusion

Consistent with Barkley's model, the results presented here suggest an inhibitory control hypothesis rather than an attention deficit hypothesis in children with attentional difficulties. The findings appear to go further to suggest that the tasks with heavier demands for executive attentional mechanisms, both monitoring and inhibition were the tasks on which the children in the attentional difficulty group were more likely to experience difficulties. The apparent difficulty experienced by children with attentional difficulties on certain central executive functions could be feasibly explained by a difficulty associated with executive attentional mechanisms. The Supervisory Attentional System (SAS) (Norman and Shallice, 1980) has emerged as the most comprehensive framework to explain the differences between the AD and NC groups.

Further research is required to assess the explanations for the differences between the groups on the measure of requests for reiteration of instructions. Tasks which specifically demand monitoring processes, such as those with heavy interference demands, could be employed, together with the development of additional measures of monitoring. Additional measures of monitoring could include asking the participants to tell the examiner the rules of the task prior to the task, during the task and after completion of the task, and in another condition asking the participants to vocalise the steps they are taking during the undertaking the task. A study assessing the typical developmental trajectory of executive attentional control mechanisms would be particularly useful to further explain these functions. It would further confirm or reject the possibility of developmental delay as an explanation for the differences between the AD and NC groups reported here.

By using tasks which specifically demand monitoring processes and by using the additional measures of monitoring suggested above it may be possible to address the problem concerning the different definitions of strategy used in the literature. Here the measures of strategy application were aimed to reflect the strategy generation function of the SAS, however, if the alternative explanation for the findings are accepted, the measure of requests for reiteration of instructions which was intended to be a measure of monitoring may have reflected strategy generation processes of the SAS. The use of additional monitoring tasks and measures may allow us to distinguish between the interpretations of a problem associated with strategy generation or a problem associated with monitoring.

7.1 Overview

The purpose of this chapter is to draw together the findings of the observational study and three experiments reported in the thesis (section 7.2), and to integrate the findings into a new model of executive function in children with attentional difficulties (section 7.4). The aim of the research programme was to investigate cognitive function, in particular working memory and executive function, in children with observed and rated attentional difficulties. There has been a large amount of research focussing on attention deficit / hyperactivity disorder (ADHD) and although this empirical and theoretical evidence has helped to shape both the theory and the methodology of this research it should be reiterated that the findings presented here do not apply to ADHD. A number of the cognitive models of executive function, which have been reviewed in this thesis have been developed to account for ADHD, and therefore, references to ADHD are inevitable.

The hypotheses were, firstly, that there would be children in mainstream schools with identifiable attentional difficulties relative to their peers, this hypothesis was tested by study 1. Experiment 1 tested a second hypothesis, that the group with attentional difficulties would perform significantly worse than the control group on measures of executive function hypothesised by Barkley (1997) as impaired in ADHD. A third hypothesis was that the group with attentional difficulties would perform significantly worse than the control group on spatial in comparison to visual working memory tasks and on dynamic in comparison to static working memory tasks, which was tested by experiment 2. The final hypothesis was that the attentional difficulty group would perform significantly worse than the control group on tasks designed to load on the central executive and on measures of executive attentional control on these tasks, this was tested by experiment 3. The outcomes of the experiments are summarised in table 7.1 in the next section.

This chapter will demonstrate how each of the four studies has contributed to addressing the broad aims of the thesis, and highlight how the individual hypotheses have been tested by each of the four studies (Sections 7.3, 7.4, 7.5). The implications of the findings will be addressed, particularly for an understanding of cognitive function in children with attentional difficulties (section 7.3), for theoretical developments of cognitive models (section 7.4), and for improvement in functioning in children with attentional difficulties (section 7.5). Section 7.6 will outline the new interpretations of the findings, further research to address unanswered questions will be detailed in section 7.7, and the chapter will close with a conclusion and summary of the theoretical position reached as a result of the findings of the four studies undertaken (section 7.8).

7.2 Summary of findings

The following sections will describe the aims, hypotheses, and findings of each of the four studies conducted during the period of the research and will indicate whether aims have been met and questions answered.

Table 7.1: Summary of findings from Study 1 and Experiments 1 to 3

Study or Experiment	Hypothesis	Performance of AD Group compared with the NC Group
Study 1 – Observations and Teacher Ratings of Attentional Difficulties	There would be children in mainstream schools with attentional difficulties relative to their peers.	Observed and rated as displaying significantly more behaviours associated with inattention, hyperactivity and impulsivity. Reliability of observation checklist confirmed.
Experiment 1 – Executive Function Tasks	AD group would perform significantly worse than NC group on measures of executive function hypothesised by Barkley (1997) as impaired in ADHD.	Significantly worse on EF measures of response inhibition relating to inhibition but not to inattention, significantly worse on verbal and non-verbal working memory, and self-regulation, although scores were in the normal range on standardised tasks. No significant differences between the groups on measures of reconstitution.
Experiment 2 – Visuo-spatial Working Memory Tasks	AD group would perform significantly worse than the NC group on spatial in comparison to visual working memory tasks and on dynamic in comparison to static working memory tasks.	Significantly worse on spatial tasks. No significant difference on visual tasks. Significantly worse on dynamic conditions and memory formats.
Experiment 3 – Central Executive Tasks	AD group would perform significantly worse than NC group on tasks designed to load on the central executive and on measures of executive attentional control on these tasks.	Undifferentiated on ability to complete tasks and on majority of control conditions. Significantly more errors made on switching and dual tasks, and significantly worse on executive function measures of inhibition and monitoring.

7.2.1 Study 1 - Selection of Children with Attentional Difficulties

The primary aim of the initial study was to select a sample of children with attentional difficulties (AD group), together with a comparison group of children without attentional difficulties (NC group). A secondary aim was to develop an observational tool (the Scope Observation Checklist) for the measurement of behaviour associated with attentional difficulties.

The reliability of the observation checklist was thought adequate, with 98.9% agreement using a method of inter-observer reliability and 77% agreement comparing the observation score and teacher ratings. Future studies may benefit from the use of additional methods of assessing the orienting of attention, such as eye-tracking. The observation checklist scores were then used to select the two groups and teacher ratings were used to confirm group membership. The results of study 1 revealed a normal distribution of scores on the observation checklist and therefore, as expected, a significant difference in the number of displayed behaviours associated with inattention, hyperactivity and impulsivity between total scores in the top 25% and the bottom 25% of the data gained using the observation checklist.

The findings were interpreted as supporting the hypothesis that there are children in mainstream classrooms with attentional difficulties relative to their peers, without a clinical diagnosis of ADHD or other identified special needs.

7.2.2 Experiment 1 - Executive Function in children with Attentional Difficulties

The current dominant cognitive models of ADHD concern impairments in executive function (EF) (Barkley, 1997; Pennington and Ozonoff, 1996; Sergeant et al., 1999; Sonuga-Barke, 1994; Quay, 1997, see section 1.3.2). The main aim of the first experiment was, therefore, to address the question of whether children in the AD group would have difficulties on tasks measuring EF in comparison with controls. A second aim was to ascertain whether the pattern of difficulties associated with EF paralleled those experienced by children with a diagnosis of ADHD according to the inhibition model proposed by Barkley (1997). The intention was to compare these findings to findings of previous investigations of EF in children with attentional difficulties, based on both Barkley's and other models of EF in ADHD (see section 1.3.2, for a review). A battery of tasks designed to assess executive function in children were administered.

The differences between the groups emerged on the measures of response inhibition, central executive, non-verbal working memory, verbal working memory, and emotional self-regulation, with the AD group scoring significantly worse than the NC group. The differences between the groups on measures to assess Barkley's (1997) concept of 'response inhibition', however, emerged on measures relating to inhibition, and differences did not emerge on measures of inattention. This was an important finding and was interpreted as suggesting that there were no differences between the groups in attentional capacity, rather differences between the groups could be explained by differences in executive attentional control. There were no significant quantitative differences between the groups on the measures of reconstitution, however further analysis of this data revealed some qualitative differences. The AD group was more likely to provide answers that could be considered socially inappropriate. This finding may be related to difficulties in inhibition, as children in the AD group may be less able to inhibit these inappropriate responses in comparison to the control group. The largest effect sizes were observed on working memory measures of the visuo-spatial sketchpad ($\mu^2 = 0.44$) and the central executive ($\mu^2 = 0.58$).

Overall the findings did indicate that AD children had difficulties with a number of the EF tasks in comparison to controls, and the pattern of findings did approximate to the inhibition model of ADHD proposed by Barkley. Although the design of this experiment could not confirm the hierarchical nature of the model suggested by Barkley, the findings did support its utility in differentiating between children with and without attentional difficulties. It was further concluded that the findings supported the theory of an attentional skills continuum. Although there were significant differences between the groups on the cognitive tasks, the scores were not outside the typical range and therefore it was concluded that the variation in attentional skills represented differences across the *typical* population. The AD group did not represent a clinical group such as those with ADHD.

7.2.3 Experiment 2 - Visuo-spatial Working Memory in children with Attentional Difficulties

Developmental differences have been found in typical groups (Pickering et al., 2001). Pickering et al. demonstrated that the developmental trajectory for visuo-spatial tasks that were dynamic in nature was steeper in comparison to visuo-spatial tasks that were static in nature. It was assessed on which, if any, of the two task types (spatial or visual) the groups differed, and on which, if any, of the two conditions (static or dynamic) the groups differed. The hypotheses were that the attentional difficulty group would perform significantly worse on spatial tasks and on dynamic tasks in comparison to the control group, this was based on the idea that these task conditions would load more heavily on the central executive and this is why these tasks have a steeper developmental trajectory.

The results indicated that the AD group performed significantly worse than the NC group on the spatial tasks in both formats and under both conditions, with the exception of the dynamic condition of the spatial working memory task, where both groups performed poorly compared to the other versions of the task. The differences between the groups on the visual tasks were only close to significance. There were main effects of format (memory or non-memory) and condition (dynamic or static) for both task types (visual and spatial), indicating that the format of the task with a memory load had an effect of lowering performance, as did the dynamic conditions of the tasks. Both task types yielded an interaction between condition and format. This suggested that the dynamic condition and memory format together had a disproportionate effect compared to the dynamic condition and non-memory format separately. Further analysis of the main effect of group on the spatial tasks revealed that this interaction occurred only for the AD group. (see section 2.4.3 for details of the design of the experiment).

Analysis of the data disregarding order recall errors on the dynamic conditions revealed a similar pattern of results. A notable exception was a significant difference on all four of the spatial tasks, the AD group performing worse than the NC group, caused by improved scores on the spatial working memory task in the dynamic condition by the NC group when order errors were disregarded.

The findings of the Articulatory Suppression (AS) condition did not support a verbal encoding explanation for the results. Significant differences were found on all eight tasks with the AD group obtaining lower scores in comparison to the NC group. If verbal encoding was responsible for the results, no differences in task scores between the groups would be expected on the AS conditions.

Inhibitory control was implicated in the performance of the spatial tasks, and it was suggested that the lowered performance in the attentional difficulty group was associated with inhibitory control. The hypotheses of the experiment were supported, as there were significant differences between the groups on the spatial tasks and on the dynamic tasks. Specific hypotheses relating to working memory literature were not fully supported. In particular, with regard to the developmental fractionation of the visuo-spatial sketchpad based on dynamic properties of tasks (Pickering et al., 2001), the spatial task type was more likely to differentiate the groups than the dynamic condition.

7.2.4 Experiment 3 – An investigation of the central executive construct in children with Attentional Difficulties using familiar tasks.

The broad aim of the experiment was to investigate higher order cognitive task performance in children with attentional difficulties. This aim was to be met by using both tasks based on the functions of the CE, and measures of EF. Further aims were to examine the findings in the context of the fractionation of the central executive into separate functions dependent on 'executive attentional control' mechanisms, thus integrating the WM and EF literature, and to answer questions relating to the importance of the activities attributed to response inhibition for CE function. The first hypothesis was that the attentional difficulty group would perform significantly worse (making more errors) than the control group on the central executive conditions of the three tasks, and they would not differ on the control conditions. The second hypothesis was that the attentional difficulty group would perform significantly worse than the control group on each of the measures of executive attentional control on the central executive tasks, and not differ on the control conditions.

Both groups of children were able to undertake and complete the tasks administered. As predicted, overall few differences between groups emerged on control conditions of the tasks, which were proposed to be free of the higher order cognitive demands of simultaneous storage and manipulation. The CE loaded conditions of the tasks did, however, differentiate the groups, as did a number of the EF measures, in particular inhibition and monitoring, with the AD group performing significantly worse. This confirmed the findings of experiments 1 and 2 with regard to a distinction between attentional capacity and executive attentional control, the latter differentiating the groups. Inhibition and monitoring appeared to be the most important concepts to emerge and it was proposed that inhibitory control could explain the differences between the groups. It is possible that the concept of inhibition underpins impulsivity and could go towards explaining the high prevalence of problems associated with conduct in individuals with attentional difficulties.

Consistent with previous empirical investigations that suggested that children with ADHD have an impairment associated with the central executive (section 1.3.2.2), the AD group performed significantly worse than the NC group on the switching and dual tasks. These differences did not seem to emerge on real-world problem-solving tasks, however. These findings appeared to implicate the selective attention/inhibition, and integration and co-ordination functions of the CE. The CE function of generating novel responses appeared to be relatively unaffected. This was consistent with the findings of experiment 1 which indicated that the groups did not differ on measures of fluency. Measures of inhibition and monitoring significantly differentiated the groups on all of the tasks with the AD group performing worse. Strategy and motor control measures differentiated the groups to a lesser extent. The main findings indicated that both the tasks and the measures associated with monitoring and inhibition were difficult for the AD group relative to the NC group, confirming the importance of some activities of response inhibition for the performance of CE tasks. The findings partially supported the hypotheses.

7.3 Implications of the findings for an understanding of cognitive function in children with attentional difficulties

This thesis began with two broad themes that have remained central to the investigation as it has progressed, the ways in which these themes, together with their corresponding research questions, have been addressed will be outlined in this section. The first theme referred to the investigation of attentional difficulties in children in the context of an attentional skills continuum (Conner, 1997) (section 7.3.1). The second focussed on the investigation of EF and working memory in children with attentional difficulties compared to their peers (section 7.3.2).

7.3.1 Implications for the investigation of attentional difficulties in children: An 'attentional skills continuum'?

This theme was addressed by answering two key questions; firstly, are there children in mainstream school classrooms with attentional difficulties who are not, and would not be, clinically diagnosed with ADHD or any other disorder, and secondly, do these children have cognitive function difficulties in comparison with their peers.

It was claimed in chapter 3, section 3.4 that the findings have indicated that observable behaviours, similar to those displayed by children with DSM-IV diagnosed ADHD, are evident in the population of typically developing children to varying degrees. Further, it was concluded that the finding of a significant difference in the number of behaviours associated with inattention, hyperactivity and impulsivity displayed by two groups of mainstream school children supports the position of an attentional skills continuum. It was further claimed (chapter 4, section 4.4) that significant differences on cognitive task scores between the groups supported the attentional skills continuum hypothesis. The fact that the scores for both groups on the standardised cognitive tasks remained in the normal range was also thought to support the hypothesis. The explanation given for this was that performance on cognitive tasks proposed to be reliant on attentional skills did vary significantly between these groups but did not indicate that the groups represented a typical and an atypical group, whereas scores on

EF tasks obtained by ADHD groups are reportedly outside the typical range (Barkley et al., 2001).

Potential problems with these interpretations are as follows;

i) Only behavioural measures of attentional difficulties were administered when selecting the groups.

ii) There were no differences between the groups on measures of reconstitution.

iii) Scores in the typical range on standardised cognitive tasks may be interpreted as indicating that children in the AD group do not have cognitive difficulties associated with attentional difficulties.

The first criticism was addressed during experiment 1 where tasks requiring cognitive functioning were also shown to differentiate the groups. This criticism can be countered further by highlighting that ADHD is routinely diagnosed using only behavioural measures such as teacher and parent ratings (see section 2.3.1).

It was claimed in section 4.4 that the pattern of findings of experiment 1 supported the hypothesis that the pattern of cognitive difficulties in the AD group are similar, although less severe, to those experienced by children with ADHD. One potential problem with this interpretation was that differences between the groups were not significant for all EF tasks. There were no significant differences between the groups on the three fluency tasks that were measuring reconstitution and no significant differences between the groups on the measures of inattention on the continuous performance task.

This implies that the hypothesis that the AD group would perform significantly worse than the NC group on measures of EF should be rejected, as differences between the groups were not evident on all of the EF measures found by Barkley (1997) to be deficient in children with ADHD. This argument can be countered with reference to Barkley's model. As inhibitory control is the dominant EF in the model, performance on tasks proposed to be reliant on inhibitory control will vary as a function of the inhibitory load on that particular task, and also as a function of the level of inhibitory difficulty an individual has. Further explanation of this position will be dealt with in more detail in section 7.3.2 and concerns the idea that fluency is not dependent on inhibitory control to the same extent as other EF measures. For the moment it will be concluded that there is support for the AD group having difficulties on some EF tasks compared to controls.

It is important to address the third criticism, as this point is highly relevant for the interpretation of the findings of experiments 2 and 3. It could be argued that the finding that the AD group were in the normal range on EF measures demonstrates that children in the AD group do not have attentional difficulties, and therefore will invalidate any interpretations of the findings of experiments 2 and 3. This claim, however, can be easily countered by referring to the findings of study 1 which showed that every child in the AD group was reported by teachers as being in the atypical range on subscales of inattention, hyperactivity and impulsivity on the teacher rating scale for attentional difficulties. Further, the findings undoubtedly demonstrate that children in the AD group do have cognitive difficulties compared to the NC group. In this context the findings of experiment 1 are interpreted as strengthening the hypothesis of an attentional skills continuum as outlined above.

These interpretations are supported by theoretical and empirical work (see chapter 3, section 3.4). It has been argued that these findings support the idea that minor attentional lapses are common in the typical population (Manly et al., 1999). The theory that attentional skills lie on a continuum (Conner, 1997) implies that these minor attentional lapses can vary in severity in the typical population. Such an implication has been supported by experimental work by Levy et al. (1997). On findings from a twin study the authors argued that ADHD, rather than being viewed as having discrete determinants, should be thought of as varying genetically throughout the entire population. Secondary evidence, such as differences in prevalence rates of ADHD between different countries, and the prevalence of attentional difficulties amongst children classed as having special educational needs, serves to support this position. It has been shown that far more school-age children are diagnosed with ADHD in the United States as compared to Britain (Kewley, 1998). This variation has been explained by differences in the criteria used to diagnose attentional disorders (Swanson et al., 1998) demonstrating the variation in attentional skills across the population. Further, the literature relating to attentional difficulties in school-aged children has made clear the links between the categories of difficulties defined in the Special Educational Needs (SEN) code of practice and attentional difficulties, and has shown that attentional difficulties are relatively common in school children (Day and Peters, 1989).

Developmental differences could provide an explanation for the variation in attentional skills. Cognitive abilities, particularly executive abilities which demand high levels of attentional control improve during childhood and are reportedly fully developed by the age of seven (Zelazo and Frye, 1998). The findings reported in this thesis could be consistent with differences between the groups in the development of these skills. Further support for this interpretation comes from Vuontela et al. (2003) who found that improvement on working memory tasks was related to both development and to sex. Boys overall had shorter reaction times and were less accurate than girls. The findings were interpreted as reflecting slower maturation of higher order cognitive systems in boys and suggested that some ADHD-like symptoms in boys may be due to slower maturation compared to girls and not to ADHD. These findings are also consistent with the results of study 1 which identified more boys as eligible for the AD group.

7.3.2 Implications for children with attentional difficulties; the role of working memory in EF models of ADHD as applied to lesser levels of attentional difficulties.

The overall conclusions drawn from the series of experiments were that children in the AD group performed significantly worse than the children in the NC group on tasks with heavy demands for executive attentional control demands, such as monitoring and inhibition functions. It was concluded that CE tasks have high executive attentional demands, and should be placed within an EF model of attentional difficulties accordingly (see figure 7.1, below). The Supervisory Attentional System (SAS) (Norman and Shallice, 1980) was also proposed to more clearly explain the links between working memory and executive function.

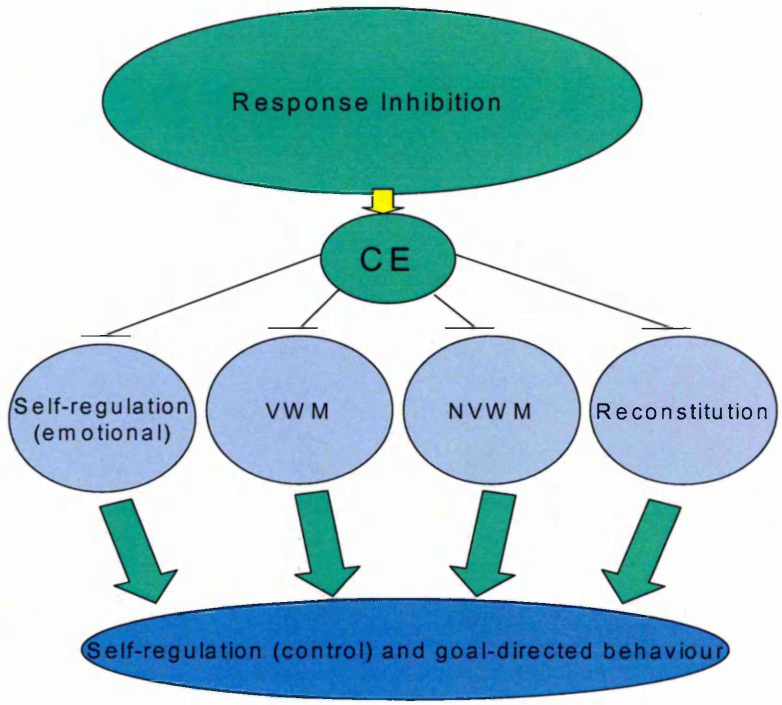


Figure 7.1: Figure demonstrating the place of the central executive within Barkley's (1997) inhibition model

Differences between the groups on measures of executive function provided support for Barkley's (1997) inhibitory control explanation, rather than reduced attentional capacity, for the cognitive difficulties experienced by children with attentional difficulties compared to the control group. It was further revealed that the AD group had difficulties compared to the NC group on working memory tasks based on the Baddeley and Hitch (1974) model. Performance on visual and spatial working memory tasks did not support the hypothesis of a developmental fractionation of the VSSP based on dynamic and static properties of visuo-spatial tasks (Pickering et al., 2001). Yet these results did suggest differences dependent on the stimuli presented, the findings were interpreted as indicating differences between the groups at high executive demand levels. This highlighted the relevance of the central executive construct, and also the role of executive attentional mechanisms in central executive tasks (see section 1.3.3). Differences between the groups on central executive tasks and measures of executive attentional control on these tasks, namely inhibition and monitoring were tested and confirmed.

Again, there are potential arguments against these interpretations relating to the following issues;

i) The tasks administered may not be measuring the intended constructs.

ii) Findings may be dependent on factors other than attentional difficulties, for example, children may not be motivated to undertake the tasks.

The measures of reconstitution, although in accordance with the measures Barkley et al. (2001) has used, differ from measures used in other studies. Every effort was made to ensure that measures used are measuring the EFs proposed by Barkley, and the use of a large number of cognitive tasks with various conditions throughout the research programme should minimise any effect of this criticism. (This point was addressed in more detail in chapter 2 section 2.4).

The second point regarding motivation can be countered by the fact that although motivation was not measured directly, the participants were given the option as to whether they took part in the research, and further whether they wanted to continue or not both during testing sessions and between testing sessions, motivation also appeared to be sustained by the one to one attention the participants received and by the perceived achievements made during testing (see section 2.4). The conclusion is, therefore, that these criticisms did not seriously undermine the interpretations made.

7.3.2.1 Can existing models of Executive Function (EF) explain the findings?

The results of all three experiments were interpreted as providing support for the idea that executive attentional control is core to adequate performance on EF tasks and that the theory of an attentional skills continuum was consistent with these findings. The results showed that the AD group performed at a significantly lower level in comparison to the NC group on tasks with high executive attentional control demands. Direct measures of inhibitory control revealed significant differences between the AD and NC groups, as did measures associated with different activities attributed to EF, namely inhibition and monitoring. It was suggested that performance varied between the groups dependent on attentional skills yet as performance was within the typical range for both groups of participants, the theory of an attentional skills continuum (Conner, 1997) was supported.

The findings appeared to be consistent with the claims of Barkley (1997), with the notable exception of the fluency task findings. The findings, however, could not confirm the hierarchical nature of the model, and thus are limited in their applicability to some features of the model. Further the AD group's relative difficulties on the spatial working memory task were not dependent on condition or format of the task. The same effect emerged when sequence errors were disregarded implicating the properties of this particular task as responsible for the differences between the groups.

Barkley's model would suggest that the final stage in the initiation of a task, in which self-regulation (control) and goal-directed behaviour is achieved, has not been fully achieved by the AD group in the performance of the some of the working memory tasks. The model would predict that this is due to the inadequate performance of one or more of the EFs; non-verbal working memory (NVWM), self-regulation (emotional), internalisation of speech (VWM), and reconstitution, due to an inhibitory control problem. This implicates poorer functioning of inhibitory control and one or more of the four EFs reliant on it in the AD group compared to the NC group. On the tasks where the demands for inhibitory control were high differences between the groups were highly significant. At the behavioural level Barkley's model would suggest this could be accounted for by a difference in terms of self-regulation and goal-directed behaviour, resulting from inadequate inhibitory control and one or more of the four EFs under its control on these tasks. Where individual measures relating to executive function were compared between the groups it was indicated that some but not all activities attributed to response inhibition were affected in the AD group. It is beyond the remit of the inhibition model, however, to provide further explanation of these findings.

A strength of Barkley's (1997) model in explaining the findings is the relative importance attributed to inhibitory control. The relative failings of the AD group on the cognitive tasks administered have been interpreted as due to problems in controlling inhibition. Most, although not all, previous empirical findings based on top-down models of EF identify behavioural or response inhibition as impaired in ADHD (West et al., 2002; Berlin et al., 2004; Muir-Broaddus et al., 2002; Mahone et al., 2002) (see section 1.3.2.3). The fact that no differences emerged between groups on fluency tasks and few differences emerged between the groups on problem-solving tasks can also be interpreted as support for an inhibitory control explanation. These tasks did not seem to have heavy demands to inhibit responses, rather, they had opposite demands. Although the inhibition model suggests that success on fluency tasks is dependent on inhibitory control, previous experimental findings have not consistently found that ADHD children fail on such tasks (see Pennington and Ozonoff, 1996).

Support for the inhibition hypothesis comes from Pennington and Ozonoff (1996) who, in their meta-analysis of EF studies of ADHD found that letter fluency tasks were not good indicators of attentional difficulties. Shallice et al. (2002) support this position, finding no differences between ADHD and NC children on letter fluency tasks. They hypothesised that this task did not have heavy demands for sustained attention, which is argued by Barkley to be an activity of response inhibition, as measured by omission errors on continuous performance tasks (CPT). Success on fluency tasks may not necessarily depend on good inhibitory control. In fact poor inhibitory control may even benefit performance on fluency tasks, as it would be assumed that no potential responses are held back. Anecdotal evidence (Dowdy et al., 1998) also suggests that ADHD children are more likely to talk and shout out compared to their peers, attributes that could be seen as contributing to success on fluency tasks.

The weakness of Barkley's model in explaining the present findings is its under-specification. Firstly, there is no clear explanation of the relationship between inhibition and each of the four EFs dependent on it. Of particular concern here is the relationship between inhibition and working memory. Secondly, the construct of response inhibition needs further explanation as the three components or activities that Barkley (1997) refers to are treated as a single construct. Weaknesses of the model relating to further specifying response inhibition are supported by empirical findings by Lawrence et al. (2002). They found that ADHD children were impaired on some but not all aspects of behavioural inhibition. Contrary to Lawrence et al.'s findings a more recent experiment by Scheres et al. (2004) questioned the distinctiveness of the three types of response inhibition described by Barkley (1997) finding that correlations within domains were not higher than correlations between domains of inhibition.

Other EF models (Sergeant et al., 1999) make reference to 'executive attentional control', rather than inhibitory control. This term describes the resources which working memory demands for its adequate performance, and includes both inhibition and monitoring. Executive attentional mechanisms also seem to be synonymous to those described as constituting the Supervisory Attentional System (SAS) (Norman and Shallice, 1980). The findings presented here are important as they make it clear that further constructs are required to explain fully the pattern of performance of the AD group, providing support for the use of the term 'executive attentional control'.

The term 'executive attentional control' implicates lower level processes that are implied in Barkley's response inhibition construct and are proposed here to explain the lowered performance of the AD group. Bottom-up models may provide a more appropriate explanation of the findings. Sonuga-Barke (1994) proposes that the delay aversion model can explain patterns of behaviour that the inhibition model cannot. The delay aversion model is based on a theory of a motivational dysfunction in children with ADHD from a bottom-up perspective. More recently, however, a dual-pathway model (Sonuga-Barke, 2003) was proposed, implicating both delay aversion and inhibition deficits in ADHD. This theory was consistent with the idea that more than one level of activity is involved in response inhibition. Although the majority of neuroscientific investigations into ADHD have implicated prefrontal brain regions (Castellanos et al., 1996; Filipek, 1997) there is some support for the involvement of a number of brain regions in ADHD. This evidence comes from a review by

Castellanos and Tannock (2002) who suggest that recent evidence supports the existence of three endophenotypes in ADHD; an abnormality in reward-related circuitry, deficits in temporal processing and deficits in working memory, thus implicating a number of brain regions. The hypothesis that dysfunctions in response inhibition stem from lower brain regions rather than the prefrontal cortex only is consistent with the interpretations made here, that differences between the groups on measures of inhibition and monitoring were due to reduced executive attentional control in the AD group.

Also consistent with lower level explanations were the findings that external factors such as, task structure and task instruction, appeared to improve task performance, and was interpreted as due to external regulation of executive attentional control. These interpretations, therefore, support the introduction of further models to explain the findings. The working memory model and the Supervisory Attentional System (SAS) may be able to explain functioning at a lower level than the inhibition model can.

7.3.2.2 Can the Working Memory Model (Baddeley and Hitch, 1974) explain the findings?

A question which all EF models raise yet fail to answer is how working memory and inhibition are related. The inhibition model (Barkley, 1997), the EF model (Pennington and Ozonoff, 1996) and the Cognitive-energetic model (Sergeant et al., 2003), all place importance on working memory. The EF and the cognitive-energetic model explicitly use a definition of working memory which refers to only its executive responsibilities, in other words responsibilities attributed to the CE. The Cognitive Energetic Model (Sergeant et al., 2003) further explicitly suggests that inhibition is integral to WM, strengthening the argument for the Baddeley and Hitch (1974) working memory model to be integrated into an EF model. The findings reported here support and expand on Sergeant et al's proposals in terms of the importance of inhibition, and the executive responsibilities of WM.

Significant differences between the groups on all three components of the model have been revealed, and the relative importance of the CE construct in differentiating the groups has been indicated. The results reported here were interpreted as indicating that differences between the groups emerged dependent on demands for both maintenance and manipulation of stimuli, and further in situations where executive attentional control demands were high.

The findings provided support for the argument that WM and inhibitory control are linked. These findings replicated to some extent previous empirical findings on WM function in ADHD (see section 1.3.3.1 for a review), as impairments in CE function (Roodendrys et al., 2001; Karatekin, 2004) have been identified. Impairments of the slave systems, however, have not been consistently reported in children with attentional difficulties.

The literature on the fractionation of the VSSP provided some insight into the findings that the groups differed on spatial but not visual tasks administered in experiment 2. Pickering et al's (2001) hypothesis based on the dynamic and static properties inherent in visuo-spatial tasks could not fully explain the findings. Logie's (1995) model, however, provided more clear-cut explanations for the differences between the groups. The strength of Logie's model was the link to the CE. This model suggests that the demands associated with location tasks as opposed to pattern tasks, load on the CE, via the inner scribe and visual buffer (Logie, 1995). Empirical findings support the view that the demands of the location task load on the CE, and further link to the idea of inhibition being associated with the CE by suggesting that interference control, which is hypothesised as one function of inhibitory control, is demanded for such tasks (Cornoldi et al., 2001). Although the model strengthens support for a difference between the groups based on CE function, the aim of these models is purely associated with the investigation of the VSSP and they cannot go further to explain the functioning of the CE in these tasks. The literature on the fractionation of the CE can provide further insight in this respect.

The literature suggests up to four functions of attentional control may be at work when undertaking CE tasks. In short these are, switching attention, dividing attention, selective attention, and integration of information from long-term memory. The tasks which discriminated between the groups were high on demands for selective attention, focussing attention against potentially distracting irrelevant information (Baddeley, 1996). Significant differences between the groups were observed where more than one piece of information was required to be stored and manipulated to achieve a task. Where only one piece of information was stored and very little manipulation was required the groups did not differ. The selective attention function of the CE is conceptually very similar to the interference control function of inhibition proposed by Barkley (1997), and has been used to explain why fluency tasks do not differentiate the groups, the reason being that they do not demand selective attention (Shallice, et al., 2002). The AD group made more errors than the NC group on the CE tasks they performed, yet there were no differences between groups on the majority of the control conditions of the tasks that did not have CE demands. The WM model, therefore, was used to explain the differences between the groups as due to a CE dysfunction.

Although the WM model, and particularly the recent theoretical developments of the CE component (Baddeley, 1996) were able to explain the findings to some extent, it was still clear that the AD children had difficulties that were common to all three CE tasks. These difficulties were interpreted as being dependent on the 'executive attentional control' mechanisms, monitoring and inhibition. It was concluded that 'executive attentional control' is required for the adequate performance of all of the CE tasks, although to differing degrees, and it was suggested that the Supervisory Attentional System (SAS) (Norman and Shallice, 1980) may further explain the differences between the groups in executive functioning.

The strength of the Working Memory model in explaining the findings is that it is able to explain more clearly those constructs on which problems may be occurring. The model appears to go further than the EF model to examine the parts of the inhibition model associated with Working Memory and the inter-relations between WM and executive attentional control mechanisms. The weakness of the working memory model, however, is that it cannot fully explain the difficulties of AD group in isolation, and therefore needs to be used in conjunction with models of 'executive attentional control'. Baddeley (2003) has also indicated that the emotional and motivational underpinnings of the working memory model have been neglected. A more elaborated model of CE responsibilities could address these weaknesses and may also provide some explanation of the social aspects associated with attentional difficulties.

7.3.2.3 Can the Supervisory Attentional System (SAS) (Norman and Shallice, 1980) explain the findings?

The Supervisory Attentional System (SAS) may serve to more clearly explain the links between CE control and inhibitory control. The SAS has been adopted by Baddeley (1996) to provide further explanation of Central Executive activities. As described in section 1.3.1, the CE and the SAS are characterised as attentional systems rather than storage systems, immediately implicating executive attentional mechanisms in their adequate performance. Strategy generation is hypothesised as the main function of the SAS (Norman and Shallice, 1980). The SAS achieves this by the monitoring of current and intended behaviour that can induce activation of attentional mechanisms, and the modulation of action selection.

An important interpretation of the findings concerns the idea that the construct of response inhibition (Barkley, 1997) may reflect the monitoring and modulation processes described as constituting the SAS. This would be consistent with the idea that the AD group have difficulties with attentional control rather than attentional capacity. The inadequate functioning of the SAS due to poor inhibitory control could explain both cognitive and behavioural impulsivity in children with attentional difficulties, and therefore, conduct problems. If this interpretation is accepted the difference between the groups primarily on CE loaded tasks could be explained by an SAS problem. The control conditions of the tasks may rely only on contention scheduling, which is intact in both groups, whereas the tasks on which the groups differ rely on the SAS. This interpretation is consistent with Shallice et al. (2002) who explained findings of impaired performance on EF tasks in children with ADHD using the SAS. Shallice et al. interpreted the findings as a failure by the ADHD group to generate strategies and therefore a failure of the SAS. Although they found no specific impairment on the measures of inhibition they employed, measures they defined as attentional measures and which Barkley defined as measures of response inhibition (commission errors), were impaired in ADHD children.

Inadequate performance of the SAS is implied in the AD group in comparison with the NC group as the AD group had a significantly lower performance on the EF tasks, particularly on measures of inhibition and monitoring. The SAS explanation would suggest that the children in the AD group had problems in modulation and monitoring resulting in impaired strategy generation. Although measures of strategy application as they are termed here did not appear to differentiate the groups it was suggested in chapter 6, section 6.4, that the differences between the groups on the number of requests for reiteration of instructions could be accounted for by a difference between the groups in the type of strategy they were using. It was further suggested that children in the AD group may have become reliant on external cues due, initially, to an inhibitory control problem and subsequently as a learned behaviour. This interpretation implicates a problem with modulation functions of the SAS rather than monitoring functions in the AD group. Problems with monitoring functions, however, were indicated by other measures. Further support for the SAS explanation was the finding that children in the AD group were less likely to be able to report the use of a strategy, when, retrospectively they were asked to explain the strategies they had used.

The two inhibitory processes in Barkley's (1997) model may reflect the modulation processes in the SAS model, whereas the interference control processes in Barkley's model and the central executive functions could be compared to the monitoring functions of the SAS. Barkley's hypothesis suggests that an impairment in response inhibition results in inadequate working memory processing, the SAS goes further to explain how this may occur, via modulation, monitoring and strategy generation functions. These processes could underlie the central executive functions proposed by Baddeley (1996). Thus, the findings appear to demonstrate that the SAS can explain some of the executive attentional control functions of the central executive and the functions Barkley described as response inhibition. The strengths of the SAS model in explaining the links between working memory and executive function are that it more clearly explains executive attentional mechanisms than the CE, and thus appears to be able to explain more clearly the findings on separate EF measures. The SAS also goes further than the CE to describe action selection, in addition to control of attention.

7.3.2.4 Summary of the contribution of existing cognitive models to explain the findings

Both Executive Function Models and Working Memory Models are able to contribute to an understanding of cognitive function in children with attentional difficulties. Executive attentional control processes have emerged as predominant in both models, in that inhibitory control dysfunctions are said to be key to understanding attentional difficulties, and the findings presented here do not dispute this. Table 7.2 below provides a summary of the contribution of each of the cognitive models that have been discussed to explaining the findings of the thesis.

Table 7.2: Table demonstrating the contribution of each of the cognitive models to explaining the findings

	Cognitive Models		
Findings of the thesis	**Inhibition Model - Barkley (1997)**	**Working Memory Model – Baddeley and Hitch (1974)**	**Supervisory Attentional System – Norman and Shallice (1980)**
Experiment 1 - Lowered performance by AD group on EF tasks	*Inhibitory dysfunction can explain the findings*	*CE dysfunction can explain the findings*	*SAS dysfunction can explain the findings*
Experiment 2 - Lowered performance by AD group on spatial but not visual tasks	*Inhibitory dysfunction cannot explain differences on only one task type.*	*CE dysfunction can explain the findings.*	*SAS can explain findings in terms of executive function and can explain links to CE*
Experiment 3 - Lowered performance by AD group on CE tasks and EF measures.	*Inhibitory dysfunction cannot fully explain the findings.*	*CE can explain overall performance differences between the groups but cannot explain differences on individual measures of EF*	*SAS can explain overall performance differences and differences on individual EF measures, with reference to SAS functions monitoring, modulation of actions and strategy generation.*

7.4 New Interpretations

7.4.1 A new model

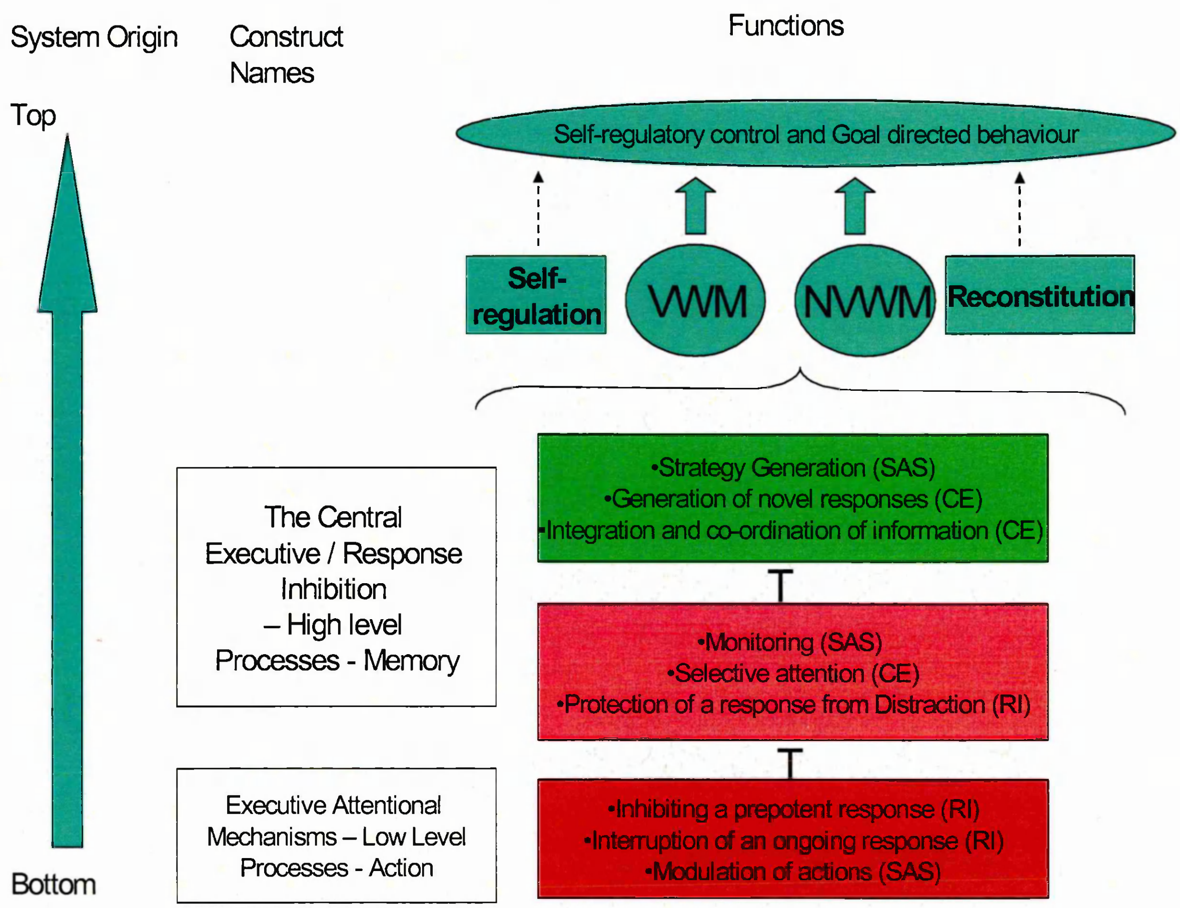
The findings of the thesis provide the basis for the development of a more specific model of cognitive function in children with attentional difficulties. As has been argued in the preceding sections this new model could usefully integrate aspects of three existing models concerned with EF. Barkley's inhibition model (1997), the working memory model (Baddeley and Hitch, 1974; Baddeley, 2000) and the SAS (Norman and Shallice, 1980) each provide a partial explanation for the pattern of performance by AD children, however none of the models in isolation is able to explain the findings reported here.

It is important to note that both the working memory model and the SAS were developed to account for adult data. This emphasises the need for a developmental model of cognitive functioning to account for both children with typical attentional skills and those with attentional difficulties. The problems of using adult models have been highlighted by Jarrold (2001) who suggests that they are static, and thus cannot explain developmental changes in cognitive functioning. The model proposed here could contribute to explaining developmental change in cognitive functioning. The concept of executive attentional control could emerge as key in explaining change and, in particular, the development of inhibitory processes could explain why working memory abilities improve with age. Further research assessing the developmental trajectory of executive attentional mechanisms will contribute to the development of such a model.

The key question regarding this new model to explain cognitive functioning in children with attentional difficulties concerns the relationship between the response inhibition aspect of Barkley's model, the CE of the Baddeley and Hitch working memory model, and the SAS (Norman and Shallice, 1980). The terms 'maintenance' and 'manipulation' are key to understanding where the working memory model fits within the inhibition model. The central executive component of working memory is hypothesised as dealing with both the maintenance and manipulation of information. Maintenance demands memory only, whereas manipulation demands executive function. It appears that inhibitory control is of particular importance where the demands of a task involve manipulation.

Figure 7.2 on the next page demonstrates a hypothetical model to explain lowered CE task performance in children with attentional difficulties observed here. The findings presented both here and elsewhere (Norman and Shallice, 1980; Zelazo and Frye, 1998) make it clear that some form of executive attentional control is demanded at a preliminary stage when undertaking a novel task. The processes of inhibiting a prepotent response and stopping an ongoing response described as functions of inhibitory control in Barkley's model and the modulation of actions in the SAS are described here as 'executive attentional control'. These would be demanded for the initiation of a task seen at the bottom of the system in this model. At the next, protection of a response from distraction or interference control (Barkley's model) is required and could be seen as paralleling the CE function of selective attention, and the monitoring function of the SAS. At the third stage, strategy generation is accomplished by the SAS, perhaps mirroring the general of novel responses function of the CE proposed by Baddeley (1996), together with the integration and coordination function of the CE. The findings of this thesis can only be used to explain performance on working memory tasks, as the dotted lines on the model indicate, further research would be required to demonstrate that problems associated with executive attentional control lead to problems associated with emotional self-regulation and reconstitution.

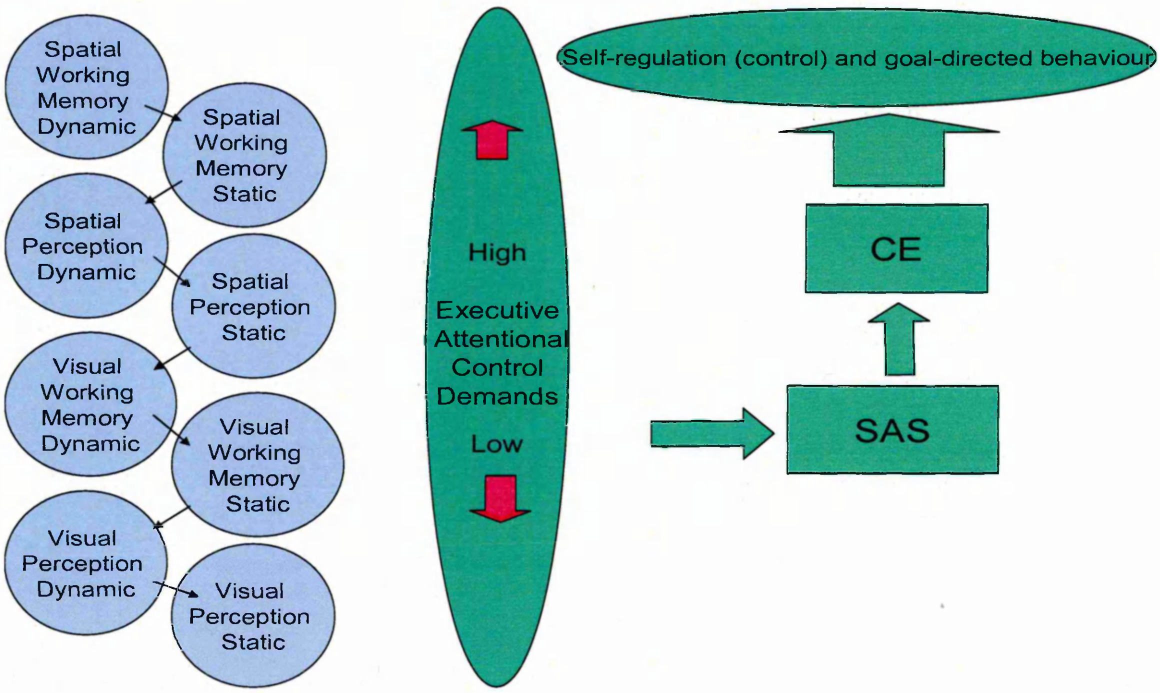
Figure 7.2: A model demonstrating the stages in preparing to undertake a CE task



The model would predict that difficulties at the first level at the bottom of the system, in executive attentional mechanisms, causes difficulties in monitoring and selective attention functions, followed by difficulties in the generation of novel responses, termed strategy generation in the SAS and the integration and coordination of information. This series of problems leads to the behavioural manifestations associated with dysfunctional self-regulatory control and goal-directed behaviour as suggested by Barkley. It is hypothesised that it is in the first stages of preparing to respond to a CE task, where executive attentional control is demanded, that problems for children with attentional difficulties begin.

The findings of both experiments 2 and 3 can be explained using this model. Figure 7.3, below, demonstrates how the conditions of the visuo-spatial tasks used in experiment 2 can be ranked in order dependent on their demands for executive attentional mechanisms. The model also shows how 'executive attentional control' mechanisms facilitate SAS and CE function, and how these subsequently impact on goal-directed behaviour for adequate task completion.

Figure 7.3: A Model demonstrating the executive attentional control demands for each of the conditions of the visual and spatial tasks administered in experiment 2



This model also has important implications for the continuum theory of attention. As Barkley's model suggested, the initial stages of the model, concerned with inhibiting a prepotent response and stopping an ongoing response, are responsible for the subsequent dysfunction relating to both preparing to respond and responding to the novel task. The point at which an individual would be placed on a continuum is, therefore, dependent on their ability to both inhibit a prepotent response and to stop an ongoing response, mechanisms which Sergeant et al. (2003) would describe as 'executive attentional' mechanisms. The findings of the three experiments presented here, therefore, support the idea of an 'executive attentional control' continuum rather then an attentional skills continuum (Conner, 1997).

7.5 Implications of the findings as a contribution to knowledge, theory, and practice

In addressing the main aims of this thesis a number of areas of literature, which have in the past remained relatively separate, have been brought together. The executive function research which relates to attentional difficulties, and the working memory research, although seemingly describing similar constructs, have rarely been used in conjunction in theoretical or empirical work. Further, the thesis has succeeded in bringing together the literature on typical and atypical functioning. The findings of the thesis illustrate the utility of these bodies of literature in describing and advancing the study of attentional difficulties, but further, the findings have demonstrated how theoretical models can be combined to explain cognitive constructs.

The findings of the thesis have suggested a number of ways in which existing cognitive models could be developed. It has been demonstrated that working memory tasks may also be measuring EF. Although it is often assumed in both theoretical and empirical work that measures of working memory do tap executive functioning this point is not always made clear. The findings that the AD group performed at a lower level in comparison to the NC group on measures of EF on CE tasks most clearly brought together the theoretical constructs described in the WM and EF literature. This demonstrated how WM and SAS constructs can usefully explain some of the high-level functions of response inhibition, or put more simply, can explain the processes involved in preparing to respond, and maintaining attention in responding.

Some important contributions to the working memory literature have been made as a result of the findings reported here. The working memory model can be criticised for the lack of theoretical development of the central executive, and it has emerged here that the central executive is insufficient to explain the findings. The findings can, however, suggest advances in the theoretical development of the construct as a result of the findings. The AD group performed at a significantly lower level than the NC group on spatial tasks, but the groups did not differ on visual tasks. Differences were attributed to how heavily the task loaded on the CE, and it was suggested that the differences in task demands, such as demands for inhibitory control, can be used to further explain the CE. Further findings also showed that the central executive component of the working memory model is not sufficient to explain the association between working memory and executive function in children with attentional difficulties. It was concluded, as May (2001) suggests, complexity is required to specify the central executive. The SAS, therefore, has been recruited to explain the findings of differences between the groups on central executive tasks and has been incorporated into a new hypothetical model.

It has been concluded that empirical evidence for the development of working memory, particularly as it relates to central executive function, would enable the further explanation of the findings presented here. Although there is very little evidence in this area, advances have been made recently by Bayliss et al. (2005) who assessed the development of central executive function and concluded that age-related variation in working memory abilities could be accounted for by differences in a general attentional resource or controlled attention ability, thus implicating EF literature to explain their findings.

7.6 Implications of the findings for children with attentional difficulties

Theoretical Implications

Cognitive deficits are reported as core to attentional difficulties (Barkley, 1997). Cognitive deficits have been found to have a detrimental effect on a number of behavioural functions which in turn can lead to lowered self-esteem (Dowdy et al., 1998), difficulty in social interaction (Nixon, 2001), and reduced academic achievement (DuPaul et al., 2001) (see section 1.2.4). If, as claimed in section 3.4, the attentional difficulties observed in this thesis are on a continuum of attentional difficulties, it suggests that the behavioural problems associated with attentional difficulties will vary in a similar manner. This makes the findings applicable to children displaying such behavioural problems.

The executive function profile of the AD group appears to indicate that children with attentional difficulties present a pattern of cognitive dysfunction in comparison to children in the NC group. As outlined previously this is taken as supporting the theory of an attentional skills continuum. The findings of the thesis should further the understanding of not only attentional difficulties but also the developmental literature focussing on typical groups. The development of executive attentional control has emerged as a key to the development of cognitive skills that are dependent on it (Zelazo and Frye, 1998). The findings and methods used in this thesis could provide the basis for investigating executive attentional mechanisms in groups with problems associated with other aspects of working memory such as the phonological loop, for example those with reading difficulties.

The main aim of this thesis was to investigate the cognitive underpinnings of attention in children with attentional difficulties, however there are reports of motor control problems as a direct result of cognitive dysfunction. The findings presented here revealed that motor control did not differentiate AD and NC groups. This finding was interpreted as motor control, measured by dropping jigsaw pieces during the tasks being less dependent on executive attentional control, which explained findings of differences between the groups on cognitive tasks. The lowered performance by the AD group was explained as an inhibitory control failure, or using SAS terms, a failure to interrupt one behaviour and initiate another in situations where tasks are not automatic.

The dependency of motor control on executive attentional control, however, will vary with the extent to which the skill has been learned and become automatic. This has been demonstrated by Garforth et al. (*in press)* who explored executive attention in a neurally controlled simulated robot. They showed that attention-based learning allowed willed selection of appropriate tasks to become increasingly automatic, reducing the need for attentional effort. The motor demands on the tasks used in experiment 3 such as the jigsaw would have been familiar to the children and therefore not dependent on the SAS. The cognitive demands, however would have been novel, placing demands on the SAS. This demonstrates the importance of using familiar tasks like those used here, in order to control for this variable, when assessing cognitive function.

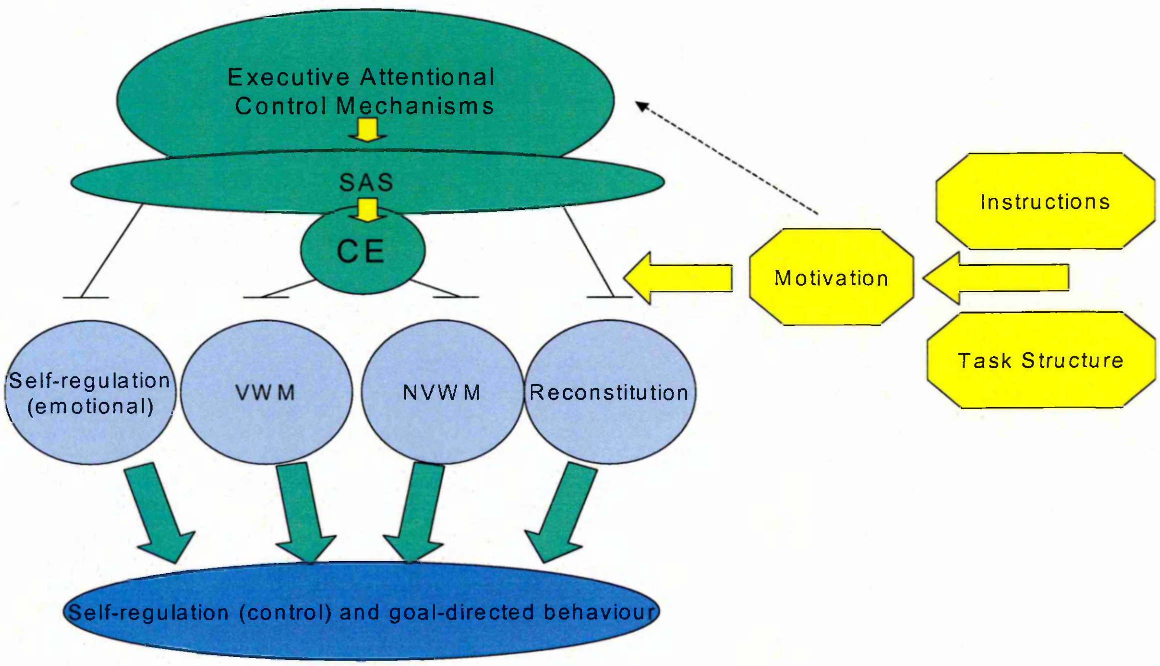
Practical Implications

As section 1.2.4 illustrated, problems associated with attentional difficulties can have a detrimental effect on academic achievement (Day and Peters, 1989; Adams and Snowling, 2001), and, in addition, academic underachievement has been linked to working memory impairments (Gathercole and Pickering, 2000). The findings presented here, therefore, will have implications for academic achievement. As has been outlined, difficulties associated with executive attentional control are core to the findings presented here. The implications of these findings for children with ADs can be taken as positive in terms of improving performance on cognitive tasks, and it would be logical to assume following from this, improving their learning more generally. This would be achieved by providing external support for executive attentional control in the form of extra instructions and clearer task structure.

The findings presented here could also suggest that executive attentional control dysfunction is hindering the acquisition and development of working memory skills. These deductions are made from the findings which showed that children with attentional difficulties can complete certain CE tasks (particularly problem-solving tasks which are thought to have relatively low demands for 'executive attentional control') as well as NC children, when self-regulatory and goal-directed behaviour is moderated externally. This finding has relevance for education as it demonstrates that children can benefit from individual attention. Although this is unsurprising for children in general it is important to have shown this is the case in the AD group. The impact of the executive attentional control dysfunction appears to be reduced by external factors such as providing reiteration of instructions. The external moderation did not appear to affect the number of errors made by the AD group on switching and dual-tasks, although they were able to complete the tasks when the instructions were reiterated to the children each time they were requested. This interpretation would need further testing, however, as there is an alternative explanation, that the AD group are using requests for reiteration of instruction as a strategy.

Barkley (1997) states that response inhibition is needed for the efficient functioning of four executive functions. In turn these EFs are required for self-regulation and goal-directed persistence. This suggests that, in the absence of adequate inhibitory control, external regulation is required. The findings presented here have suggested that although children with attentional difficulties have these difficulties due to reduced executive attentional control, this seems to be externally moderated by (a) increasing the number and quality of task instructions, and by (b) changing task structure to be more interesting or easier to follow, as evidenced by relatively good performance on fluency and problem-solving tasks. This is diagrammatically represented in figure 7.4 below. Although these factors were not directly tested, in that a control condition where no further instructions were given was not employed, it is hypothesised that these factors increase the child's motivation to undertake the task and should go on to facilitate academic achievement.

Figure 7.4: Diagrammatical Representation of the effect of external moderation of executive attentional control on self-regulation and goal-directed behaviour.



The finding that the groups did not differ in overall performance on fluency and problem-solving tasks also provides a rationale for introducing more of these types of tasks in schools. The logic is that the behavioural manifestations associated with failure on academic tasks, such as lowered self-esteem perhaps leading to problems of social interaction with peers, may be reduced if children with attentional difficulties experience success on tasks as has been demonstrated in children with learning difficulties (see Nabuzoka, 2000). Further task success should lead to learning on such tasks that may be extended to other realms. This contention is supported by reports that training on working memory tasks can improve performance on tasks related to prefrontal functioning in children with ADHD (Klingberg et al., 2002), suggesting that prefrontal functioning can be moderated externally.

7.7 Areas for Further Research

The most important avenue for further research is the direct testing of the new model proposed here. As suggested earlier in this chapter, developmental studies would be particularly useful in assessing the executive nature of the central executive by assessing the developmental trajectory of the executive attentional mechanisms. This could be achieved by manipulating tasks on levels of executive attentional demand. This would add to and expand on the small body of work (e.g. Bayliss et al., 2005) which has assessed age-related variation in working memory abilities. Longitudinal studies of children with attentional difficulties would also be required to confirm whether developmental differences in executive attentional mechanisms could account for the differences between the groups observed here.

It should also be noted that Barkley's (1997) inhibition model was developed to explain functioning in children with ADHD, and the working memory model (Baddeley and Hitch, 1974) and the SAS (Norman and Shallice, 1980) to explain functioning in adults. As suggested, further research is demanded to extend these models to account for developmental change, but a further question concerns whether a model of typical development is more appropriate to explain functioning in the AD group, and whether this would be appropriate for ADHD children. The findings presented in the thesis support the idea of an attentional skills continuum and it is anticipated that children with ADHD would be placed at a point on this continuum. This supports the idea that a model of typical development could explain ADHD, however, research with ADHD groups would be required to confirm such a suggestion.

A further important point is to assess the contribution of each of the executive function measures used here, it has been highlighted in the thesis that the measures of monitoring, inhibition, and strategy generation may not be as pure as they were intended to be. The measure of reiteration of instructions, for example, may have been measuring a low level strategy employed by the children in the AD group as a result of an inhibitory problem. In future research it will be important to clearly differentiate between executive functions, by using more measures and defining these more clearly. It will also be important to define the term strategy more clearly as this term is used in many different contexts in the literature and can have a variety of different meanings.

The executive attentional demands for certain tasks such as the fluency and problem-solving tasks and measures such as hit rate have been questioned. It has been concluded that the fluency and problem-solving tasks have lower requirements for executive attentional control, however further investigation is needed to assess the possibility that other factors, such as long-term memory, motivational and practice effects are contributing to these findings. It was also demonstrated that the hit rate measure did not differentiate the groups and it was concluded that this could reflect more strongly motor impulsivity rather than cognitive impulsivity. This provides scope for further studies investigating motor inhibition using tasks that have unfamiliar motor elements.

As the aims of the thesis were broad it has not been possible to address all of the questions that have emerged during the execution of the research. In particular it has not been possible to focus on all of the aspects of the working memory model. The findings and methods used in this thesis could also provide the basis for investigating executive attentional mechanisms in groups with problems associated with other aspects of working memory such as the phonological loop, for example those with reading difficulties. Previous literature on attentional difficulties and working memory (Roodendrys et al., 2001; Karatekin, 2004) highlighted the visuo-spatial sketchpad and the central executive components as important for differentiating children with and without attentional difficulties. However, as language development is important for development in other areas of cognition further research should be undertaken to confirm these findings.

7.8 Conclusion

7.8.1 The continuum theory

The findings of the research programme have, overall, offered support for the theory of an attentional skills continuum which was proposed by Conner (1997).

With reference to the findings reported here it has been suggested that it may be more appropriate to refer to an *executive* attentional skills continuum as executive attentional control appears to be the factor affecting the position of the groups on the continuum.

Further support for the continuum comes from the findings suggesting that external factors can improve performance on CE tasks, indicating that the source of the difficulties may not be fixed as in diagnosable disorders such as ADHD. This would support the idea of movement along the continuum based on developmental delay rather than permanent impairment. The findings reported here showed that the performance of the attentional difficulty group on cognitive tasks proposed to be reliant on attentional skills did vary significantly between these groups but did not indicate that the groups represented a typical and an atypical group, whereas scores on EF tasks obtained by ADHD groups are reportedly outside the typical range (Barkley et al., 2001). Previous empirical findings also support the developmental hypothesis. Vuontela et al. (2003) found that improvement on working memory tasks was related to both development and to sex. Boys overall had shorter reaction times and were less accurate than girls. They suggested this reflected slower maturation of higher order cognitive systems in boys and suggested that some ADHD-like symptoms in boys may be due to slower maturation compared to girls. This seems to be reflected in the studies presented in this thesis as a larger number of boys (60%) compared to girls were selected for the AD group. Further, Klingberg, et al. (2002) suggested that training can improve working memory. This suggests that the difficulties observed in the attentional difficulty group in comparison to controls can be overcome.

7.8.2 Executive Attentional Control difficulties can explain the cognitive problems in children with attentional difficulties

The interpretations of the findings of this thesis suggest that children with attentional difficulties have primary difficulties associated with executive attentional control. This executive attentional control, which Barkley would include under the heading of response inhibition, and behavioural inhibition by others, includes inhibition of a prepotent response and the stopping of an ongoing response, and subsequently monitoring. These mechanisms have been previously thought to reside in the prefrontal lobes (Barkley, 1997), although there is some empirical (see Castellanos and Tannock, 2002) and theoretical (Sonuga-Barke, 1994; 2003) work suggesting that these mechanisms may originate from somewhat lower brain regions. This is a point that would require further investigation and was beyond the remit of this thesis.

The interpretations made here are consistent with Barkley's inhibition model, although the construct of response inhibition has had to be further, but not completely, elaborated. The activities attributed to response inhibition by Barkley (1997) appear to reflect those more clearly defined by Baddeley (1996) as under the control of the central executive and these are even more explained by Norman and Shallice (1980) as the responsibilities of the Supervisory Attentional System. These functions that have been described here, and by Sergeant et al. (1999), as executive attentional mechanisms, are thought to be key to explaining lowered performance by children with attentional difficulties compared to controls on central executive tasks.

The position taken is that executive function models such as the SAS may be more useful than Barkley's (1997) inhibition model to explain lowered performance by the AD group on central executive tasks. Further, using these models in combination may be useful in explaining attentional difficulties, and if this can be achieved it may provide the basis for a more flexible educational approach. This would include working on children's strengths and using targeted intervention strategies to improve school functioning in children with attentional difficulties.

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Appendix 1

Consent Letter

Date

Dear Parent/Guardian

I am a Postgraduate research student at Sheffield Hallam University. I am conducting a study that will investigate children's attention and functioning in school.

The study will involve observing the children in the classroom and playground, asking the children to take part in short tasks such as recalling numbers, and taking part in games in small groups and individually.

Your child's participation in this study is voluntary, and you may withdraw your child or your child may request to be withdrawn at any time. The results of the research study may be published, but your child's name will not be used, and no one other than those directly involved with the study will have access to the children's names.

If you do not wish your child to participate in this study please complete the slip below and return it to your child's teacher.

If you have any questions concerning the study or your child's participation, please call me on **0114 2252554 or 07890724289**. Your assistance is greatly appreciated.

Yours sincerely,

Alison Scope
BSc(hons) Pg Cert

I do not wish my son/daughter, ______________________(please enter child's full name), to take part in the school functioning study.

Name______________________ Signature______________________

Appendix 2

The Scope Classroom Observation Checklist – Definitions of behaviours and instructions for administration

Date: **School:** **Observer:**
Child ID: **Lesson:** **N:**
Other Adults Present: Y/N ( )

Type of Activity						
		Frequency of Occurrence of Behaviours				
Behaviour		**1st period (2 mins)**	**2nd period (2 mins)**	**3rd period (2mins)**	**4th period (2mins)**	**Sub Totals**
Off - Task	***Distracted*** Is off-task due to sight or sound.					
	Daydreaming Staring into space, not distracted.					
Fidgety tapping pencil, hands, feet or squirming in seat.						
Out-of-seat Stands up, climbs, and gets down to the floor.						
Interrupting Shouting out, interrupting other children, making excessive noise.						
On-task Working quietly, without disturbing others unnecessarily.						
Teacher Interaction	***P***					
	N					
					Total:	

Definitions of Behaviours

Off-task = Off-task will be recorded if the child is not attending to an academic task, or the teacher giving instructions. This is defined as eyes looking away from the task or the direction of the teacher. Off-task will be divided into two categories;

> Distracted = Distracted is recorded if the child looks away from the academic task or teachers direction due to attending to a sight or sound inside or outside of the classroom, this includes ignoring teachers request or not listening to instructions, for a period of 3 consecutive seconds.
>
> Daydreaming = Daydreaming is recorded when the child appears to be staring into space for 5 consecutive seconds (this allows for thinking time when engaging in an academic task) at any point during the observation. This is defined as eyes looking away from the task or the teacher, and not focussing on anything in particular (e.g. staring out of the window, but not at anything in particular – i.e. has not been distracted by a sight or sound).

Fidgety = Fidgety is recorded when the child displays repetitive movements which appear to be primarily purposeless (e.g. tapping pencils, feet and hands, moving around, twisting or sliding on the surface of their seat, rocking backwards on the chair). This would include touching own or others clothes / hair / body for no apparent reason, and being unable to stand still, kicking or throwing objects.

Out-of-seat = Out-of-seat is recorded when the child stands up from chair at any point, unless specifically requested to by the teacher or needs to be standing to reach an item or to undertake a task (such as colouring the far end of a picture). This includes climbing and getting down on to the floor and being away from seat unnecessarily (e.g. the child is not collecting something, is collecting items too frequently or has been told to remain seated), going to the toilet during lesson time and leaving the room without permission.

Interrupting = Interrupting will be recorded when the child interrupts the teacher whilst he/she is addressing the class or talking to another pupil or to another teacher/adult during this time. If the child shouts out an answer inappropriately (when the teacher requires hands to be raised and picks a child to give an answer). If the child talks or whispers to other children when talking is not allowed, or interrupts other children during permitted discussion. This category will also include talking excessively and making excessive noise in the classroom, and chatting and humming to their self.

On-task = This behaviour is recorded if the child is working on-task, eyes looking at their work or in the direction of the teacher without talking, or disturbing other children or the teacher.

These definitions were adapted from Handen et al's (1998) Restricted Academic Task Observation. The observation which will be carried out here differs from Handen et al's procedure. In the Handen et al. study the child is placed in a room on their own and viewed through a one way mirror. The procedure here, therefore, should take into account the presence of other individuals, who may impact on the child's behaviour, including the teacher, classmates and researcher, plus others who may pass through the classroom. Further categories have been added using the DSM diagnostic features, which aim to account for the classroom environment. Information on the construction of observation checklists has been referred to in order to take account of any eventuality (Dowdy et al., 1998; Sideris, 1998; Martin and Bateson, 1986).

The children will be observed during classroom time, in lessons where they will be requested to listen to instructions regarding an academic task then asked to complete the academic task during the lesson. All children, therefore, will be observed during either literacy or numeracy lessons to keep task requirements as constant as possible for each class.

The child's name will be entered, name of observer, date, a record of any other adults being present in the room (how many other than the teacher and researcher and who they are, e.g. support teacher / research colleague), the lesson being taught and the school name. (These details will be obstructed by the stopwatch at the top of the clip board, in order that children do not feel singled out).

Type of activity will be noted for each period on the observation checklist as follows:

T = Attending to the teacher or other medium such as a video and answering questions asked by the teacher. (The children will be seated at tables or on the carpet and will be required to listen and respond to the teacher.)

G = Working in groups on a task.

I = Working individually on a task.

P = Preparing for another task (putting equipment or work away, collecting equipment).

In the type of activity section, the rater should enter the appropriate letter for type of activity.

Teacher interaction with the child will also be recorded. If the teacher interacts with the child in a positive way, such as giving praise, asking them to collect a book etc, one tally mark in the row labelled P should be recorded. If the teacher interacts with the child in a negative way, such as telling the child off, one tally mark in the row labelled N should be recorded.

The frequency of behaviours occurring during a period of two minutes will be counted (using a tally mark). Distracted, Interrupted, Out-of-seat, and On-task behaviour will be recorded once if it continues for three consecutive seconds and daydreaming will be recorded once if it continues for five consecutive seconds for the initial behaviour and once for every three consecutive seconds after this. If the behaviour ceases after between three and six seconds and continues later for 3 consecutive seconds the behaviour will be counted using two marks, if the behaviour persists for six or more seconds each tally mark for a three second interval will be joined to the next to indicate continuing behaviour. Fidgety will recorded once if this behaviour occurs at all, and if it is continuing behaviour recorded every three seconds in line with the other behaviours. Going to the toilet during lesson time or leaving the room without permission will be recorded as five units of behaviour in the out-of-seat category, as the child will almost certainly be away from the task for at least 15 seconds.

After the two minute observation time there will be a one minute interval to allow for locating the next child and changing observation sheets etc. The focus will be on 5 children per observation session of one hour. Each of the 5 children will be observed for 4 periods of 2 minutes during the hour long session. The two minute intervals will be timed with the use of a stop watch.

The observer will place themselves in a position in which each of the 5 children can be seen easily, in order that they do not need to move during a session and distract the children. Should a child disappear from view during an observation (e.g. asked to leave the room / leaves the room without permission / goes to the toilet), the observer should stop recording the behaviour of the child, and continue recording when they return to the room, in the meantime the observer should record the behaviour of another child. If the child has been sent out of the classroom as a punishment this detail should be noted in the notes section of the checklist.

Appendix 3

Mean inter-observer reliability scores for each behaviour category and for morning and afternoon sessions on the Scope Classroom Observation Checklist

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
distract	31	.900	1.000	.98661	.019549
daydream	31	1.000	1.000	1.00000	.000000
fidgety	31	.950	1.000	.98861	.012714
outofsea	31	.981	1.000	.99761	.005493
interrup	31	.975	1.000	.99148	.007514
ontask	31	.900	1.000	.97252	.026474
Valid N (listwise)	31				

		Count	Minimum	Maximum	Mean	Std Deviation
morning	Distracted	15	.900	1.000	.981	.026
	Daydreaming	15	1.000	1.000	1.000	.000
	Fidgety	15	.950	1.000	.987	.016
	out of seat	15	.981	1.000	.997	.007
	interrupting	15	.981	1.000	.993	.007
	ontask	15	.900	.994	.954	.027
afternoon	Distracted	16	.975	1.000	.992	.009
	Daydreaming	16	1.000	1.000	1.000	.000
	Fidgety	16	.975	1.000	.990	.010
	out of seat	16	.988	1.000	.999	.003
	interrupting	16	.975	1.000	.990	.008
	ontask	16	.975	1.000	.990	.009

Appendix 4

Chi-square analyses of teacher ratings

Chi-square analysis to assess the association between school and concordance rate

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.697[b]	1	.404		
Continuity Correction [a]	.298	1	.585		
Likelihood Ratio	.713	1	.398		
Fisher's Exact Test				.565	.296
Linear-by-Linear Association	.687	1	.407		
N of Valid Cases	72				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6. 44.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.098	.404
	Cramer's V	.098	.404
N of Valid Cases		72	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Chi-square analysis to assess the association between elevated teacher ratings and the different schools

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.610[a]	3	.456
Likelihood Ratio	2.783	3	.426
Linear-by-Linear Association	.797	1	.372
N of Valid Cases	97		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is 1.55.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.164	.456
	Cramer's V	.164	.456
N of Valid Cases		97	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Appendix 5

Analyses of participant selection criteria

Anova to assess sex differences on observation score overall

Group Statistics

	gender	N	Mean	Std. Deviation	Std. Error Mean
obsscore	female	20	-17.2000	102.01527	22.81131
	male	28	-21.2143	102.38141	19.34827

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
obsscore	Equal variances assumed	.036	.850	.134	46	.894	4.01429	29.92998	-56.23163	64.26021
	Equal variances not assumed			.134	41.175	.894	4.01429	29.91172	-56.38586	64.41443

Anova to assess sex differences on observation score within AD group

Group Statistics

	gender	N	Mean	Std. Deviation	Std. Error Mean
obsscore	female	10	78.0000	39.85529	12.60335
	male	14	75.5714	36.54231	9.76634

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
obsscore	Equal variances assumed	.019	.893	.155	22	.879	2.42857	15.70559	-30.14284	34.99998
	Equal variances not assumed			.152	18.448	.881	2.42857	15.94446	-31.01123	35.86838

Anova to assess sex differences on observation score within NC group

Group Statistics

	gender	N	Mean	Std. Deviation	Std. Error Mean
obsscore	female	10	-112.4000	15.55778	4.91980
	male	14	-118.0000	16.08631	4.29925

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
obsscore	Equal variances assumed	.019	.893	.852	22	.403	5.60000	6.57172	-8.02892	19.22892
	Equal variances not assumed			.857	19.943	.402	5.60000	6.53360	-8.03137	19.23137

Anova to assess differences between schools on observation score

Between-Subjects Factors

		Value Label	N
school	1.00	F	15
	2.00	L	15
	3.00	E	10
	4.00	H	8

Tests of Between-Subjects Effects

Dependent Variable: obsscore

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	126569.783[a]	3	42189.928	5.239	.004	.263
Intercept	12539.910	1	12539.910	1.557	.219	.034
school	126569.783	3	42189.928	5.239	.004	.263
Error	354366.133	44	8053.776			
Total	499266.000	48				
Corrected Total	480935.917	47				

a. R Squared = .263 (Adjusted R Squared = .213)

Post hoc analyses to assess differences between schools on observation score

Multiple Comparisons

Dependent Variable: obsscore
Tukey HSD

(I) school	(J) school	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
F	L	124.1333*	32.76945	.002	36.6387	211.6279
	E	70.4000	36.63736	.234	-27.4220	168.2220
	H	24.5000	39.28919	.924	-80.4024	129.4024
L	F	-124.1333*	32.76945	.002	-211.6279	-36.6387
	E	-53.7333	36.63736	.466	-151.5553	44.0886
	H	-99.6333	39.28919	.068	-204.5357	5.2690
E	F	-70.4000	36.63736	.234	-168.2220	27.4220
	L	53.7333	36.63736	.466	-44.0886	151.5553
	H	-45.9000	42.56876	.704	-159.5588	67.7588
H	F	-24.5000	39.28919	.924	-129.4024	80.4024
	L	99.6333	39.28919	.068	-5.2690	204.5357
	E	45.9000	42.56876	.704	-67.7588	159.5588

Based on observed means.

*. The mean difference is significant at the .05 level.

obsscore

Tukey HSD[a,b,c]

school	N	Subset 1	Subset 2
L	15	-86.1333	
E	10	-32.4000	-32.4000
H	8	13.5000	13.5000
F	15		38.0000
Sig.		.056	.263

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 8053.776.

a. Uses Harmonic Mean Sample Size = 11.163.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Anova to assess differences between the groups in age and nonverbal ability.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
age0603	Between Groups	52.083	1	52.083	1.417	.240
	Within Groups	1690.583	46	36.752		
	Total	1742.667	47			
nvrscore	Between Groups	432.000	1	432.000	2.729	.105
	Within Groups	7282.667	46	158.319		
	Total	7714.667	47			

Appendix 6

Pearson's correlations for each variable pair to assess multicollinearity

Correlations

		Plcom	vsspcom	cecom	verbflue	nvfluenc	ideaflue	omission	comission	hit rate	variability	hit rate standard error
Plcom	Pearson Correlation	1	.485**	.675**	.079	.003	.017	-.102	-.130	.055	.073	.083
	Sig. (2-tailed)		.000	.000	.595	.984	.910	.488	.377	.708	.623	.576
	N	48	48	48	48	48	48	48	48	48	48	48
vsspcom	Pearson Correlation	.485**	1	.648**	.380**	.196	.121	-.229	-.052	-.188	-.131	-.161
	Sig. (2-tailed)	.000		.000	.008	.181	.411	.117	.724	.202	.376	.274
	N	48	48	48	48	48	48	48	48	48	48	48
cecom	Pearson Correlation	.675**	.648**	1	.243	.165	.059	-.014	-.238	.089	-.027	-.048
	Sig. (2-tailed)	.000	.000		.096	.262	.689	.923	.103	.548	.858	.745
	N	48	48	48	48	48	48	48	48	48	48	48
verbflue	Pearson Correlation	.079	.380**	.243	1	.549**	.498**	-.027	-.029	-.055	-.082	-.052
	Sig. (2-tailed)	.595	.008	.096		.000	.000	.853	.847	.712	.580	.727
	N	48	48	48	48	48	48	48	48	48	48	48
nvfluenc	Pearson Correlation	.003	.196	.165	.549**	1	.333*	-.271	.242	-.120	-.018	-.040
	Sig. (2-tailed)	.984	.181	.262	.000		.021	.062	.098	.415	.905	.785
	N	48	48	48	48	48	48	48	48	48	48	48
ideaflue	Pearson Correlation	.017	.121	.059	.498**	.333*	1	-.084	.090	-.151	-.002	.027
	Sig. (2-tailed)	.910	.411	.689	.000	.021		.569	.544	.306	.991	.857
	N	48	48	48	48	48	48	48	48	48	48	48
omission	Pearson Correlation	-.102	-.229	-.014	-.027	-.271	-.084	1	-.450**	.403**	.432**	.477**
	Sig. (2-tailed)	.488	.117	.923	.853	.062	.569		.001	.005	.002	.001
	N	48	48	48	48	48	48	48	48	48	48	48
comission	Pearson Correlation	-.130	-.052	-.238	-.029	.242	.090	-.450**	1	-.500**	-.318*	-.222
	Sig. (2-tailed)	.377	.724	.103	.847	.098	.544	.001		.000	.028	.130
	N	48	48	48	48	48	48	48	48	48	48	48
hit rate	Pearson Correlation	.055	-.188	.089	-.055	-.120	-.151	.403**	-.500**	1	.713**	.574**
	Sig. (2-tailed)	.708	.202	.548	.712	.415	.306	.005	.000		.000	.000
	N	48	48	48	48	48	48	48	48	48	48	48
variability	Pearson Correlation	.073	-.131	-.027	-.082	-.018	-.002	.432**	-.318*	.713**	1	.933**
	Sig. (2-tailed)	.623	.376	.858	.580	.905	.991	.002	.028	.000		.000
	N	48	48	48	48	48	48	48	48	48	48	48
hit rate standard error	Pearson Correlation	.083	-.161	-.048	-.052	-.040	.027	.477**	-.222	.574**	.933**	1
	Sig. (2-tailed)	.576	.274	.745	.727	.785	.857	.001	.130	.000	.000	
	N	48	48	48	48	48	48	48	48	48	48	48

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

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

Appendix 7

Manova analysis for experiment 1

Between-Subjects Factors

		Value Label	N
group	1.00	Inattentive	24
	2.00	Control	24

Box's Test of Equality of Covariance Matrices[a]

Box's M	98.309
F	1.105
df1	66
df2	6746.946
Sig.	.262

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept+group

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.998	1458.124[a]	11.000	36.000	.000	.998
	Wilks' Lambda	.002	1458.124[a]	11.000	36.000	.000	.998
	Hotelling's Trace	445.538	1458.124[a]	11.000	36.000	.000	.998
	Roy's Largest Root	445.538	1458.124[a]	11.000	36.000	.000	.998
group	Pillai's Trace	.829	15.895[a]	11.000	36.000	.000	.829
	Wilks' Lambda	.171	15.895[a]	11.000	36.000	.000	.829
	Hotelling's Trace	4.857	15.895[a]	11.000	36.000	.000	.829
	Roy's Largest Root	4.857	15.895[a]	11.000	36.000	.000	.829

a. Exact statistic

b. Design: Intercept+group

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
Plcom	2.362	1	46	.131
vsspcom	.051	1	46	.823
cecom	4.489	1	46	.040
verbflue	.912	1	46	.344
nvfluenc	2.935	1	46	.093
ideaflue	5.000	1	46	.030
omission	6.224	1	46	.016
comission	.063	1	46	.803
hit rate	1.144	1	46	.290
variability	6.256	1	46	.016
hit rate standard error	2.558	1	46	.117

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+group

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Plcom	6888.021[a]	1	6888.021	20.690	.000	.310
	vsspcom	7350.750[b]	1	7350.750	36.482	.000	.442
	cecom	17671.687[c]	1	17671.687	64.964	.000	.585
	verbflue	33.333[d]	1	33.333	1.018	.318	.022
	nvfluenc	1.021[e]	1	1.021	.057	.813	.001
	ideaflue	1.688[f]	1	1.688	.072	.790	.002
	omission	100.978[g]	1	100.978	1.658	.204	.035
	comission	496.782[h]	1	496.782	10.579	.002	.187
	hit rate	13.771[i]	1	13.771	.114	.738	.002
	variability	88.400[j]	1	88.400	.982	.327	.021
	hit rate standard error	219.308[k]	1	219.308	2.847	.098	.058
Intercept	Plcom	582341.021	1	582341.021	1749.233	.000	.974
	vsspcom	535518.750	1	535518.750	2657.805	.000	.983
	cecom	538692.188	1	538692.188	1980.308	.000	.977
	verbflue	16800.083	1	16800.083	512.951	.000	.918
	nvfluenc	8138.021	1	8138.021	451.045	.000	.907
	ideaflue	10531.688	1	10531.688	447.071	.000	.907
	omission	147463.755	1	147463.755	2421.974	.000	.981
	comission	151825.504	1	151825.504	3232.995	.000	.986
	hit rate	116855.869	1	116855.869	964.728	.000	.954
	variability	136541.867	1	136541.867	1516.308	.000	.971
	hit rate standard error	136573.870	1	136573.870	1772.705	.000	.975
group	Plcom	6888.021	1	6888.021	20.690	.000	.310
	vsspcom	7350.750	1	7350.750	36.482	.000	.442
	cecom	17671.688	1	17671.688	64.964	.000	.585
	verbflue	33.333	1	33.333	1.018	.318	.022
	nvfluenc	1.021	1	1.021	.057	.813	.001
	ideaflue	1.688	1	1.688	.072	.790	.002
	omission	100.978	1	100.978	1.658	.204	.035
	comission	496.782	1	496.782	10.579	.002	.187
	hit rate	13.771	1	13.771	.114	.738	.002
	variability	88.400	1	88.400	.982	.327	.021
	hit rate standard error	219.308	1	219.308	2.847	.098	.058
Error	Plcom	15313.958	46	332.912			
	vsspcom	9268.500	46	201.489			
	cecom	12513.125	46	272.024			
	verbflue	1506.583	46	32.752			
	nvfluenc	829.958	46	18.043			
	ideaflue	1083.625	46	23.557			
	omission	2800.746	46	60.886			
	comission	2160.218	46	46.961			
	hit rate	5571.904	46	121.128			
	variability	4142.248	46	90.049			
	hit rate standard error	3543.961	46	77.043			
Total	Plcom	604543.000	48				
	vsspcom	552138.000	48				
	cecom	568877.000	48				
	verbflue	18340.000	48				
	nvfluenc	8969.000	48				
	ideaflue	11617.000	48				
	omission	150365.479	48				
	comission	154482.504	48				
	hit rate	122441.544	48				
	variability	140772.515	48				
	hit rate standard error	140337.138	48				
Corrected Total	Plcom	22201.979	47				
	vsspcom	16619.250	47				
	cecom	30184.812	47				
	verbflue	1539.917	47				
	nvfluenc	830.979	47				
	ideaflue	1085.313	47				
	omission	2901.724	47				
	comission	2657.000	47				
	hit rate	5585.675	47				
	variability	4230.649	47				
	hit rate standard error	3763.268	47				

a. R Squared = .310 (Adjusted R Squared = .295)

b. R Squared = .442 (Adjusted R Squared = .430)

c. R Squared = .585 (Adjusted R Squared = .576)

d. R Squared = .022 (Adjusted R Squared = .000)

e. R Squared = .001 (Adjusted R Squared = -.020)

f. R Squared = .002 (Adjusted R Squared = -.020)

g. R Squared = .035 (Adjusted R Squared = .014)

h. R Squared = .187 (Adjusted R Squared = .169)

i. R Squared = .002 (Adjusted R Squared = -.019)

j. R Squared = .021 (Adjusted R Squared = .000)

k. R Squared = .058 (Adjusted R Squared = .038)

Mann-Whitney test for experiment 1- differences between the groups on the self-regulation score

Ranks

	group	N	Mean Rank	Sum of Ranks
self regulation score	Inattentive	24	29.23	701.50
	Control	24	19.77	474.50
	Total	48		

Test Statistics[a]

	self regulation score
Mann-Whitney U	174.500
Wilcoxon W	474.500
Z	-2.391
Asymp. Sig. (2-tailed)	.017

a. Grouping Variable: group

Discriminant function analysis

Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
Plcom	.690	20.690	1	46	.000
vsspcom	.558	36.482	1	46	.000
cecom	.415	64.964	1	46	.000
verbflue	.978	1.018	1	46	.318
nvfluenc	.999	.057	1	46	.813
ideaflue	.998	.072	1	46	.790
omission	.965	1.658	1	46	.204
comission	.813	10.579	1	46	.002
hit rate	.998	.114	1	46	.738
variability	.979	.982	1	46	.327
hit rate standard error	.942	2.847	1	46	.098

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	4.857[a]	100.0	100.0	.911

a. First 1 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.171	71.587	11	.000

Standardized Canonical Discriminant Function Coefficients

	Function
	1
Plcom	-.133
vsspcom	-.545
cecom	-.774
verbflue	.198
nvfluenc	.021
ideaflue	.087
omission	.600
comission	1.021
hit rate	-.033
variability	-.230
hit rate standard error	.663

Structure Matrix

	Function
	1
cecom	-.539
vsspcom	-.404
Plcom	-.304
comission	.218
hit rate standard error	.113
omission	.086
verbflue	-.067
variability	.066
hit rate	-.023
ideaflue	.018
nvfluenc	-.016

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.

Classification Results[a]

			Predicted Group Membership		
		group	Inattentive	Control	Total
Original	Count	Inattentive	24	0	24
		Control	0	24	24
	%	Inattentive	100.0	.0	100.0
		Control	.0	100.0	100.0

a. 100.0% of original grouped cases correctly classified.

Appendix 8

Mancova analysis for experiment 1

Between-Subjects Factors

		Value Label	N
group	1.00	Inattentive	24
	2.00	Control	24

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.883	23.982[a]	11.000	35.000	.000	.883
	Wilks' Lambda	.117	23.982[a]	11.000	35.000	.000	.883
	Hotelling's Trace	7.537	23.982[a]	11.000	35.000	.000	.883
	Roy's Largest Root	7.537	23.982[a]	11.000	35.000	.000	.883
nvrscore	Pillai's Trace	.249	1.056[a]	11.000	35.000	.422	.249
	Wilks' Lambda	.751	1.056[a]	11.000	35.000	.422	.249
	Hotelling's Trace	.332	1.056[a]	11.000	35.000	.422	.249
	Roy's Largest Root	.332	1.056[a]	11.000	35.000	.422	.249
group	Pillai's Trace	.822	14.675[a]	11.000	35.000	.000	.822
	Wilks' Lambda	.178	14.675[a]	11.000	35.000	.000	.822
	Hotelling's Trace	4.612	14.675[a]	11.000	35.000	.000	.822
	Roy's Largest Root	4.612	14.675[a]	11.000	35.000	.000	.822

a. Exact statistic

b. Design: Intercept+nvrscore+group

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Plcom	7401.529[a]	2	3700.765	11.252	.000	.333
	vsspcom	7533.928[b]	2	3766.964	18.658	.000	.453
	cecom	18812.589[c]	2	9406.295	37.221	.000	.623
	verbflue	33.668[d]	2	16.834	.503	.608	.022
	nvfluenc	23.785[e]	2	11.893	.663	.520	.029
	ideaflue	6.936[f]	2	3.468	.145	.866	.006
	omission	193.337[g]	2	96.668	1.606	.212	.067
	comission	562.718[h]	2	281.359	6.046	.005	.212
	hit rate	206.024[i]	2	103.012	.862	.429	.037
	variability	95.610[j]	2	47.805	.520	.598	.023
	hit rate standard error	228.556[k]	2	114.278	1.455	.244	.061
Intercept	Plcom	5400.618	1	5400.618	16.420	.000	.267
	vsspcom	11121.305	1	11121.305	55.084	.000	.550
	cecom	3456.727	1	3456.727	13.678	.001	.233
	verbflue	247.339	1	247.339	7.389	.009	.141
	nvfluenc	258.512	1	258.512	14.412	.000	.243
	ideaflue	113.069	1	113.069	4.718	.035	.095
	omission	1502.290	1	1502.290	24.961	.000	.357
	comission	3255.624	1	3255.624	69.954	.000	.609
	hit rate	854.678	1	854.678	7.149	.010	.137
	variability	1919.041	1	1919.041	20.884	.000	.317
	hit rate standard error	1888.697	1	1888.697	24.045	.000	.348
nvrscore	Plcom	513.509	1	513.509	1.561	.218	.034
	vsspcom	183.178	1	183.178	.907	.346	.020
	cecom	1140.902	1	1140.902	4.515	.039	.091
	verbflue	.334	1	.334	.010	.921	.000
	nvfluenc	22.764	1	22.764	1.269	.266	.027
	ideaflue	5.248	1	5.248	.219	.642	.005
	omission	92.359	1	92.359	1.535	.222	.033
	comission	65.936	1	65.936	1.417	.240	.031
	hit rate	192.253	1	192.253	1.608	.211	.035
	variability	7.210	1	7.210	.078	.781	.002
	hit rate standard error	9.248	1	9.248	.118	.733	.003
group	Plcom	5666.255	1	5666.255	17.228	.000	.277
	vsspcom	7482.969	1	7482.969	37.063	.000	.452
	cecom	14681.280	1	14681.280	58.094	.000	.564
	verbflue	29.951	1	29.951	.895	.349	.019
	nvfluenc	4.455	1	4.455	.248	.621	.005
	ideaflue	3.255	1	3.255	.136	.714	.003
	omission	144.902	1	144.902	2.408	.128	.051
	comission	389.433	1	389.433	8.368	.006	.157
	hit rate	.105	1	.105	.001	.976	.000
	variability	95.463	1	95.463	1.039	.314	.023
	hit rate standard error	228.253	1	228.253	2.906	.095	.061
Error	Plcom	14800.450	45	328.899			
	vsspcom	9085.322	45	201.896			
	cecom	11372.223	45	252.716			
	verbflue	1506.249	45	33.472			
	nvfluenc	807.194	45	17.938			
	ideaflue	1078.377	45	23.964			
	omission	2708.387	45	60.186			
	comission	2094.282	45	46.540			
	hit rate	5379.651	45	119.548			
	variability	4135.039	45	91.890			
	hit rate standard error	3534.713	45	78.549			
Total	Plcom	604543.000	48				
	vsspcom	552138.000	48				
	cecom	568877.000	48				
	verbflue	18340.000	48				
	nvfluenc	8969.000	48				
	ideaflue	11617.000	48				
	omission	150365.479	48				
	comission	154482.504	48				
	hit rate	122441.544	48				
	variability	140772.515	48				
	hit rate standard error	140337.138	48				
Corrected Total	Plcom	22201.979	47				
	vsspcom	16619.250	47				
	cecom	30184.812	47				
	verbflue	1539.917	47				
	nvfluenc	830.979	47				
	ideaflue	1085.313	47				
	omission	2901.724	47				
	comission	2657.000	47				
	hit rate	5585.675	47				
	variability	4230.649	47				
	hit rate standard error	3763.268	47				

a. R Squared = .333 (Adjusted R Squared = .304)
b. R Squared = .453 (Adjusted R Squared = .429)
c. R Squared = .623 (Adjusted R Squared = .607)
d. R Squared = .022 (Adjusted R Squared = -.022)
e. R Squared = .029 (Adjusted R Squared = -.015)
f. R Squared = .006 (Adjusted R Squared = -.038)
g. R Squared = .067 (Adjusted R Squared = .025)
h. R Squared = .212 (Adjusted R Squared = .177)
i. R Squared = .037 (Adjusted R Squared = -.006)
j. R Squared = .023 (Adjusted R Squared = -.021)
k. R Squared = .061 (Adjusted R Squared = .019)

Appendix 9

Examples of fluency task data

Fluency Score Sheet

Name: - AD Group **School:** **Date:**

Letters	Shapes	Objects
F Fun, football, fans, flags, funny, family, friends.	House, wheel barrow, eyes and mouth, shaded eyes, arrow, eye patch, instrument, star, moon, t.v, pyramid, cape, sausage, bricks, book, bag.	**Bucket** Carry sand, carry water, washing self, drinking, watering plants, washing clothes.
A Apple, apron, ape, anything, anybody, anyone.		**Rope** Climbing, abseiling, use in a well, skipping, tying, catching fish, making things.
S Sailor, someone, somebody, slam, smash, snake, sniper, screech, scratch, shirt, spring, squirrels, shotgun, shoot, shot, suffocate.		**Brick** Building houses, walls, make shapes, use for a seat, fill ditches.

Fluency Score Sheet

Name: - NC group **School:** **Date:**

Letters	Shapes	Objects
F Frog, foot, fruit, folders, finger, fish.	Table, window, temple, ball, t.v, computer, tyre, cone, house.	**Bucket** Carrying, washing, sitting on, putting things in, bin.
A Apple, aeroplane, airport, ambulance, arcade, ant.		**Rope** Skipping, pulling, lead, climbing, tying, hanging things up.
S Squirrel, sock, street, snake, shop, scores, school.		**Brick** Building, stand on it, weight.

Appendix 10

Visual and spatial task score sheets

Visual Task - Static and Dynamic - Score Sheet
Name: School: Date:

Block			Static Recognition (Y/N)	Dynamic Recognition (Y/N)	Order Appeared (Y/N)
1	I	1			1
	-	2			1
	I	3			2
	-	4			1
	I	5			1
	-	6			1
2	-	1			1
	I	2			1
	\	3			2
	\	4			3
	I	5			1
	\	6			2
3	/	1			2
	\	2			2
	-	3			3
	I	4			2
	/	5			4
	\	6			2
4	-	1			5
	II	2			4
	\	3			2
	/	4			2
	II	5			2
	-	6			1
5	\\	1			3
	I	2			1
	II	3			5
	/	4			4
	II	5			6
	\\	6			4
6	II	1			3
	//	2			6
	I	3			1
	/	4			4
	\	5			4
	\\	6			7
7	//	1			5
	II	2			4
	-	3			4
	\\	4			2
	\	5			4
	/	6			4
8	=	1			5
	//	2			3
	II	3			7
	-	4			5
	//	5			2
	\\	6			8

Spatial Task - Static and Dynamic - Score Sheet

Name: School: Date:

Block		Static Any order (Y/N)	Dynamic (Y/N)	Correct order (Y/N)
1	1	1		
	2	5		
	3	3		
	4	1		
	5	6		
	6	6		
2	1	1 8		
	2	7 3		
	3	3 4		
	4	6 5		
	5	2 8		
	6	5 9		
3	1	9 5 3		
	2	7 9 6		
	3	1 6 5		
	4	2 9 4		
	5	6 7 2		
	6	3 7 5		
4	1	1 8 3 9		
	2	3 4 5 9		
	3	5 3 1 4		
	4	3 7 1 6		
	5	5 3 1 8		
	6	3 9 1 6		
5	1	6 5 7 9 1		
	2	6 4 8 9 3		
	3	6 9 1 4 5		
	4	3 7 2 5 4		
	5	2 8 1 6 9		
	6	6 5 2 4 3		
6	1	3 2 4 9 8 5		
	2	6 1 5 4 7 2		
	3	6 4 2 5 9 3		
	4	5 7 2 4 6 8		
	5	8 3 4 2 5 9		
	6	2 9 5 6 1 3		
7	1	3 8 7 1 5 6 9		
	2	8 2 1 9 6 5 3		
	3	5 7 1 3 9 2 4		
	4	7 6 3 5 4 9 2		
	5	1 5 4 9 7 3 6		
	6	9 2 3 6 7 1 5		
8	1	2 1 8 5 4 9 6 7		
	2	9 3 4 2 1 7 8 6		
	3	5 2 4 6 1 7 9 8		
	4	7 9 4 5 8 1 3 6		
	5	6 7 8 1 3 9 4 2		
	6	1 8 7 3 2 5 9 4		

Appendix 11

Analyses to assess performance on tasks used in experiment 2 prior to the amendment of outliers

Anova to assess visual tasks prior to the amendment of outliers on analysis 1 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	VPS
	2	VPD
2	1	VWMS
	2	VWMD

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	581.818	1	581.818	24.259	.000	.366
	Greenhouse-Geisser	581.818	1.000	581.818	24.259	.000	.366
	Huynh-Feldt	581.818	1.000	581.818	24.259	.000	.366
	Lower-bound	581.818	1.000	581.818	24.259	.000	.366
FORMAT * GROUP	Sphericity Assumed	7.364	1	7.364	.307	.582	.007
	Greenhouse-Geisser	7.364	1.000	7.364	.307	.582	.007
	Huynh-Feldt	7.364	1.000	7.364	.307	.582	.007
	Lower-bound	7.364	1.000	7.364	.307	.582	.007
Error(FORMAT)	Sphericity Assumed	1007.318	42	23.984			
	Greenhouse-Geisser	1007.318	42.000	23.984			
	Huynh-Feldt	1007.318	42.000	23.984			
	Lower-bound	1007.318	42.000	23.984			
COND	Sphericity Assumed	4124.455	1	4124.455	169.460	.000	.801
	Greenhouse-Geisser	4124.455	1.000	4124.455	169.460	.000	.801
	Huynh-Feldt	4124.455	1.000	4124.455	169.460	.000	.801
	Lower-bound	4124.455	1.000	4124.455	169.460	.000	.801
COND * GROUP	Sphericity Assumed	17.818	1	17.818	.732	.397	.017
	Greenhouse-Geisser	17.818	1.000	17.818	.732	.397	.017
	Huynh-Feldt	17.818	1.000	17.818	.732	.397	.017
	Lower-bound	17.818	1.000	17.818	.732	.397	.017
Error(COND)	Sphericity Assumed	1022.227	42	24.339			
	Greenhouse-Geisser	1022.227	42.000	24.339			
	Huynh-Feldt	1022.227	42.000	24.339			
	Lower-bound	1022.227	42.000	24.339			
FORMAT * COND	Sphericity Assumed	184.091	1	184.091	11.503	.002	.215
	Greenhouse-Geisser	184.091	1.000	184.091	11.503	.002	.215
	Huynh-Feldt	184.091	1.000	184.091	11.503	.002	.215
	Lower-bound	184.091	1.000	184.091	11.503	.002	.215
FORMAT * COND * GROUP	Sphericity Assumed	3.273	1	3.273	.205	.653	.005
	Greenhouse-Geisser	3.273	1.000	3.273	.205	.653	.005
	Huynh-Feldt	3.273	1.000	3.273	.205	.653	.005
	Lower-bound	3.273	1.000	3.273	.205	.653	.005
Error(FORMAT*COND)	Sphericity Assumed	672.136	42	16.003			
	Greenhouse-Geisser	672.136	42.000	16.003			
	Huynh-Feldt	672.136	42.000	16.003			
	Lower-bound	672.136	42.000	16.003			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	136866.273	1	136866.273	612.564	.000	.936
GROUP	909.091	1	909.091	4.069	.050	.088
Error	9384.136	42	223.432			

Anova to assess spatial tasks prior to the amendment of outliers on analysis 1 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	SPS
	2	SPD
2	1	SWMS
	2	SWMD

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	1140.364	1	1140.364	67.303	.000	.616
	Greenhouse-Geisser	1140.364	1.000	1140.364	67.303	.000	.616
	Huynh-Feldt	1140.364	1.000	1140.364	67.303	.000	.616
	Lower-bound	1140.364	1.000	1140.364	67.303	.000	.616
FORMAT * GROUP	Sphericity Assumed	11.000	1	11.000	.649	.425	.015
	Greenhouse-Geisser	11.000	1.000	11.000	.649	.425	.015
	Huynh-Feldt	11.000	1.000	11.000	.649	.425	.015
	Lower-bound	11.000	1.000	11.000	.649	.425	.015
Error(FORMAT)	Sphericity Assumed	711.636	42	16.944			
	Greenhouse-Geisser	711.636	42.000	16.944			
	Huynh-Feldt	711.636	42.000	16.944			
	Lower-bound	711.636	42.000	16.944			
COND	Sphericity Assumed	2565.818	1	2565.818	134.050	.000	.761
	Greenhouse-Geisser	2565.818	1.000	2565.818	134.050	.000	.761
	Huynh-Feldt	2565.818	1.000	2565.818	134.050	.000	.761
	Lower-bound	2565.818	1.000	2565.818	134.050	.000	.761
COND * GROUP	Sphericity Assumed	66.273	1	66.273	3.462	.070	.076
	Greenhouse-Geisser	66.273	1.000	66.273	3.462	.070	.076
	Huynh-Feldt	66.273	1.000	66.273	3.462	.070	.076
	Lower-bound	66.273	1.000	66.273	3.462	.070	.076
Error(COND)	Sphericity Assumed	803.909	42	19.141			
	Greenhouse-Geisser	803.909	42.000	19.141			
	Huynh-Feldt	803.909	42.000	19.141			
	Lower-bound	803.909	42.000	19.141			
FORMAT * COND	Sphericity Assumed	93.091	1	93.091	7.478	.009	.151
	Greenhouse-Geisser	93.091	1.000	93.091	7.478	.009	.151
	Huynh-Feldt	93.091	1.000	93.091	7.478	.009	.151
	Lower-bound	93.091	1.000	93.091	7.478	.009	.151
FORMAT * COND * GROUP	Sphericity Assumed	105.091	1	105.091	8.442	.006	.167
	Greenhouse-Geisser	105.091	1.000	105.091	8.442	.006	.167
	Huynh-Feldt	105.091	1.000	105.091	8.442	.006	.167
	Lower-bound	105.091	1.000	105.091	8.442	.006	.167
Error(FORMAT*COND)	Sphericity Assumed	522.818	42	12.448			
	Greenhouse-Geisser	522.818	42.000	12.448			
	Huynh-Feldt	522.818	42.000	12.448			
	Lower-bound	522.818	42.000	12.448			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	88920.091	1	88920.091	669.335	.000	.941
GROUP	1706.273	1	1706.273	12.844	.001	.234
Error	5579.636	42	132.848			

Anova to assess visual tasks without order on dynamic conditions prior to the amendment of outliers on analysis 2 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	VPS
	2	VPDWO
2	1	VWMS
	2	VWMDWO

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	1120.091	1	1120.091	44.305	.000	.513
	Greenhouse-Geisser	1120.091	1.000	1120.091	44.305	.000	.513
	Huynh-Feldt	1120.091	1.000	1120.091	44.305	.000	.513
	Lower-bound	1120.091	1.000	1120.091	44.305	.000	.513
FORMAT * GROUP	Sphericity Assumed	13.091	1	13.091	.518	.476	.012
	Greenhouse-Geisser	13.091	1.000	13.091	.518	.476	.012
	Huynh-Feldt	13.091	1.000	13.091	.518	.476	.012
	Lower-bound	13.091	1.000	13.091	.518	.476	.012
Error(FORMAT)	Sphericity Assumed	1061.818	42	25.281			
	Greenhouse-Geisser	1061.818	42.000	25.281			
	Huynh-Feldt	1061.818	42.000	25.281			
	Lower-bound	1061.818	42.000	25.281			
COND	Sphericity Assumed	390.023	1	390.023	38.285	.000	.477
	Greenhouse-Geisser	390.023	1.000	390.023	38.285	.000	.477
	Huynh-Feldt	390.023	1.000	390.023	38.285	.000	.477
	Lower-bound	390.023	1.000	390.023	38.285	.000	.477
COND * GROUP	Sphericity Assumed	5.114	1	5.114	.502	.483	.012
	Greenhouse-Geisser	5.114	1.000	5.114	.502	.483	.012
	Huynh-Feldt	5.114	1.000	5.114	.502	.483	.012
	Lower-bound	5.114	1.000	5.114	.502	.483	.012
Error(COND)	Sphericity Assumed	427.864	42	10.187			
	Greenhouse-Geisser	427.864	42.000	10.187			
	Huynh-Feldt	427.864	42.000	10.187			
	Lower-bound	427.864	42.000	10.187			
FORMAT * COND	Sphericity Assumed	17.818	1	17.818	2.863	.098	.064
	Greenhouse-Geisser	17.818	1.000	17.818	2.863	.098	.064
	Huynh-Feldt	17.818	1.000	17.818	2.863	.098	.064
	Lower-bound	17.818	1.000	17.818	2.863	.098	.064
FORMAT * COND * GROUP	Sphericity Assumed	.818	1	.818	.131	.719	.003
	Greenhouse-Geisser	.818	1.000	.818	.131	.719	.003
	Huynh-Feldt	.818	1.000	.818	.131	.719	.003
	Lower-bound	.818	1.000	.818	.131	.719	.003
Error(FORMAT*COND)	Sphericity Assumed	261.364	42	6.223			
	Greenhouse-Geisser	261.364	42.000	6.223			
	Huynh-Feldt	261.364	42.000	6.223			
	Lower-bound	261.364	42.000	6.223			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	171750.023	1	171750.023	816.633	.000	.951
GROUP	794.750	1	794.750	3.779	.059	.083
Error	8833.227	42	210.315			

Anova to assess spatial tasks without order on dynamic conditions prior to the amendment of outliers on analysis 2 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	SPS
	2	SPDWO
2	1	SWMS
	2	SWMDWO

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	1403.460	1	1403.460	71.832	.000	.631
	Greenhouse-Geisser	1403.460	1.000	1403.460	71.832	.000	.631
	Huynh-Feldt	1403.460	1.000	1403.460	71.832	.000	.631
	Lower-bound	1403.460	1.000	1403.460	71.832	.000	.631
FORMAT * GROUP	Sphericity Assumed	6.187	1	6.187	.317	.577	.007
	Greenhouse-Geisser	6.187	1.000	6.187	.317	.577	.007
	Huynh-Feldt	6.187	1.000	6.187	.317	.577	.007
	Lower-bound	6.187	1.000	6.187	.317	.577	.007
Error(FORMAT)	Sphericity Assumed	820.602	42	19.538			
	Greenhouse-Geisser	820.602	42.000	19.538			
	Huynh-Feldt	820.602	42.000	19.538			
	Lower-bound	820.602	42.000	19.538			
COND	Sphericity Assumed	234.142	1	234.142	41.388	.000	.496
	Greenhouse-Geisser	234.142	1.000	234.142	41.388	.000	.496
	Huynh-Feldt	234.142	1.000	234.142	41.388	.000	.496
	Lower-bound	234.142	1.000	234.142	41.388	.000	.496
COND * GROUP	Sphericity Assumed	11.506	1	11.506	2.034	.161	.046
	Greenhouse-Geisser	11.506	1.000	11.506	2.034	.161	.046
	Huynh-Feldt	11.506	1.000	11.506	2.034	.161	.046
	Lower-bound	11.506	1.000	11.506	2.034	.161	.046
Error(COND)	Sphericity Assumed	237.602	42	5.657			
	Greenhouse-Geisser	237.602	42.000	5.657			
	Huynh-Feldt	237.602	42.000	5.657			
	Lower-bound	237.602	42.000	5.657			
FORMAT * COND	Sphericity Assumed	35.460	1	35.460	6.739	.013	.138
	Greenhouse-Geisser	35.460	1.000	35.460	6.739	.013	.138
	Huynh-Feldt	35.460	1.000	35.460	6.739	.013	.138
	Lower-bound	35.460	1.000	35.460	6.739	.013	.138
FORMAT * COND * GROUP	Sphericity Assumed	19.778	1	19.778	3.759	.059	.082
	Greenhouse-Geisser	19.778	1.000	19.778	3.759	.059	.082
	Huynh-Feldt	19.778	1.000	19.778	3.759	.059	.082
	Lower-bound	19.778	1.000	19.778	3.759	.059	.082
Error(FORMAT*COND)	Sphericity Assumed	221.011	42	5.262			
	Greenhouse-Geisser	221.011	42.000	5.262			
	Huynh-Feldt	221.011	42.000	5.262			
	Lower-bound	221.011	42.000	5.262			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	111253.551	1	111253.551	644.810	.000	.939
GROUP	2121.142	1	2121.142	12.294	.001	.226
Error	7246.557	42	172.537			

Anova to assess visual tasks with articulatory suppression on working memory formats prior to the amendment of outliers on analysis 3 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	VPS
	2	VPD
2	1	VWMSAS
	2	VWMDAS

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	6228.460	1	6228.460	93.007	.000	.689
	Greenhouse-Geisser	6228.460	1.000	6228.460	93.007	.000	.689
	Huynh-Feldt	6228.460	1.000	6228.460	93.007	.000	.689
	Lower-bound	6228.460	1.000	6228.460	93.007	.000	.689
FORMAT * GROUP	Sphericity Assumed	28.642	1	28.642	.428	.517	.010
	Greenhouse-Geisser	28.642	1.000	28.642	.428	.517	.010
	Huynh-Feldt	28.642	1.000	28.642	.428	.517	.010
	Lower-bound	28.642	1.000	28.642	.428	.517	.010
Error(FORMAT)	Sphericity Assumed	2812.648	42	66.968			
	Greenhouse-Geisser	2812.648	42.000	66.968			
	Huynh-Feldt	2812.648	42.000	66.968			
	Lower-bound	2812.648	42.000	66.968			
COND	Sphericity Assumed	4370.051	1	4370.051	447.651	.000	.914
	Greenhouse-Geisser	4370.051	1.000	4370.051	447.651	.000	.914
	Huynh-Feldt	4370.051	1.000	4370.051	447.651	.000	.914
	Lower-bound	4370.051	1.000	4370.051	447.651	.000	.914
COND * GROUP	Sphericity Assumed	.688	1	.688	.070	.792	.002
	Greenhouse-Geisser	.688	1.000	.688	.070	.792	.002
	Huynh-Feldt	.688	1.000	.688	.070	.792	.002
	Lower-bound	.688	1.000	.688	.070	.792	.002
Error(COND)	Sphericity Assumed	410.011	42	9.762			
	Greenhouse-Geisser	410.011	42.000	9.762			
	Huynh-Feldt	410.011	42.000	9.762			
	Lower-bound	410.011	42.000	9.762			
FORMAT * COND	Sphericity Assumed	136.506	1	136.506	12.015	.001	.222
	Greenhouse-Geisser	136.506	1.000	136.506	12.015	.001	.222
	Huynh-Feldt	136.506	1.000	136.506	12.015	.001	.222
	Lower-bound	136.506	1.000	136.506	12.015	.001	.222
FORMAT * COND * GROUP	Sphericity Assumed	47.051	1	47.051	4.141	.048	.090
	Greenhouse-Geisser	47.051	1.000	47.051	4.141	.048	.090
	Huynh-Feldt	47.051	1.000	47.051	4.141	.048	.090
	Lower-bound	47.051	1.000	47.051	4.141	.048	.090
Error(FORMAT*COND)	Sphericity Assumed	477.193	42	11.362			
	Greenhouse-Geisser	477.193	42.000	11.362			
	Huynh-Feldt	477.193	42.000	11.362			
	Lower-bound	477.193	42.000	11.362			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	99322.506	1	99322.506	1123.164	.000	.964
GROUP	1075.142	1	1075.142	12.158	.001	.224
Error	3714.102	42	88.431			

Anova to assess spatial tasks with articulatory suppression on working memory formats prior to the amendment of outliers on analysis 3 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	SPS
	2	SPD
2	1	SWMSAS
	2	SWMDAS

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	5922.960	1	5922.960	124.373	.000	.748
	Greenhouse-Geisser	5922.960	1.000	5922.960	124.373	.000	.748
	Huynh-Feldt	5922.960	1.000	5922.960	124.373	.000	.748
	Lower-bound	5922.960	1.000	5922.960	124.373	.000	.748
FORMAT * GROUP	Sphericity Assumed	13.642	1	13.642	.286	.595	.007
	Greenhouse-Geisser	13.642	1.000	13.642	.286	.595	.007
	Huynh-Feldt	13.642	1.000	13.642	.286	.595	.007
	Lower-bound	13.642	1.000	13.642	.286	.595	.007
Error(FORMAT)	Sphericity Assumed	2000.148	42	47.623			
	Greenhouse-Geisser	2000.148	42.000	47.623			
	Huynh-Feldt	2000.148	42.000	47.623			
	Lower-bound	2000.148	42.000	47.623			
COND	Sphericity Assumed	2712.960	1	2712.960	247.650	.000	.855
	Greenhouse-Geisser	2712.960	1.000	2712.960	247.650	.000	.855
	Huynh-Feldt	2712.960	1.000	2712.960	247.650	.000	.855
	Lower-bound	2712.960	1.000	2712.960	247.650	.000	.855
COND * GROUP	Sphericity Assumed	55.687	1	55.687	5.083	.029	.108
	Greenhouse-Geisser	55.687	1.000	55.687	5.083	.029	.108
	Huynh-Feldt	55.687	1.000	55.687	5.083	.029	.108
	Lower-bound	55.687	1.000	55.687	5.083	.029	.108
Error(COND)	Sphericity Assumed	460.102	42	10.955			
	Greenhouse-Geisser	460.102	42.000	10.955			
	Huynh-Feldt	460.102	42.000	10.955			
	Lower-bound	460.102	42.000	10.955			
FORMAT * COND	Sphericity Assumed	67.506	1	67.506	8.373	.006	.166
	Greenhouse-Geisser	67.506	1.000	67.506	8.373	.006	.166
	Huynh-Feldt	67.506	1.000	67.506	8.373	.006	.166
	Lower-bound	67.506	1.000	67.506	8.373	.006	.166
FORMAT * COND * GROUP	Sphericity Assumed	91.642	1	91.642	11.367	.002	.213
	Greenhouse-Geisser	91.642	1.000	91.642	11.367	.002	.213
	Huynh-Feldt	91.642	1.000	91.642	11.367	.002	.213
	Lower-bound	91.642	1.000	91.642	11.367	.002	.213
Error(FORMAT*COND)	Sphericity Assumed	338.602	42	8.062			
	Greenhouse-Geisser	338.602	42.000	8.062			
	Huynh-Feldt	338.602	42.000	8.062			
	Lower-bound	338.602	42.000	8.062			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	65026.642	1	65026.642	1118.472	.000	.964
GROUP	1675.278	1	1675.278	28.815	.000	.407
Error	2441.830	42	58.139			

Appendix 12

Analyses to assess performance on tasks used in experiment 2 after the removal of outliers

Anova to assess visual tasks in analysis 1 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	VPS
	2	VPD
2	1	VWMS
	2	VWMD

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	581.818	1	581.818	24.259	.000	.366
	Greenhouse-Geisser	581.818	1.000	581.818	24.259	.000	.366
	Huynh-Feldt	581.818	1.000	581.818	24.259	.000	.366
	Lower-bound	581.818	1.000	581.818	24.259	.000	.366
FORMAT * GROUP	Sphericity Assumed	7.364	1	7.364	.307	.582	.007
	Greenhouse-Geisser	7.364	1.000	7.364	.307	.582	.007
	Huynh-Feldt	7.364	1.000	7.364	.307	.582	.007
	Lower-bound	7.364	1.000	7.364	.307	.582	.007
Error(FORMAT)	Sphericity Assumed	1007.318	42	23.984			
	Greenhouse-Geisser	1007.318	42.000	23.984			
	Huynh-Feldt	1007.318	42.000	23.984			
	Lower-bound	1007.318	42.000	23.984			
COND	Sphericity Assumed	4124.455	1	4124.455	169.460	.000	.801
	Greenhouse-Geisser	4124.455	1.000	4124.455	169.460	.000	.801
	Huynh-Feldt	4124.455	1.000	4124.455	169.460	.000	.801
	Lower-bound	4124.455	1.000	4124.455	169.460	.000	.801
COND * GROUP	Sphericity Assumed	17.818	1	17.818	.732	.397	.017
	Greenhouse-Geisser	17.818	1.000	17.818	.732	.397	.017
	Huynh-Feldt	17.818	1.000	17.818	.732	.397	.017
	Lower-bound	17.818	1.000	17.818	.732	.397	.017
Error(COND)	Sphericity Assumed	1022.227	42	24.339			
	Greenhouse-Geisser	1022.227	42.000	24.339			
	Huynh-Feldt	1022.227	42.000	24.339			
	Lower-bound	1022.227	42.000	24.339			
FORMAT * COND	Sphericity Assumed	184.091	1	184.091	11.503	.002	.215
	Greenhouse-Geisser	184.091	1.000	184.091	11.503	.002	.215
	Huynh-Feldt	184.091	1.000	184.091	11.503	.002	.215
	Lower-bound	184.091	1.000	184.091	11.503	.002	.215
FORMAT * COND * GROUP	Sphericity Assumed	3.273	1	3.273	.205	.653	.005
	Greenhouse-Geisser	3.273	1.000	3.273	.205	.653	.005
	Huynh-Feldt	3.273	1.000	3.273	.205	.653	.005
	Lower-bound	3.273	1.000	3.273	.205	.653	.005
Error(FORMAT*COND)	Sphericity Assumed	672.136	42	16.003			
	Greenhouse-Geisser	672.136	42.000	16.003			
	Huynh-Feldt	672.136	42.000	16.003			
	Lower-bound	672.136	42.000	16.003			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	136866.273	1	136866.273	612.564	.000	.936
GROUP	909.091	1	909.091	4.069	.050	.088
Error	9384.136	42	223.432			

Post hoc analyses to assess visual tasks

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	visual perception static	35.5682	44	7.54027	1.13674
	visual perception dynamic	23.8409	44	9.36580	1.41195
Pair 2	visual working memory static	29.8864	44	8.70235	1.31193
	visual working memory dynamic	22.2500	44	9.08647	1.36984
Pair 3	visual perception static	35.5682	44	7.54027	1.13674
	visual working memory static	29.8864	44	8.70235	1.31193
Pair 4	visual perception dynamic	23.8409	44	9.36580	1.41195
	visual working memory dynamic	22.2500	44	9.08647	1.36984

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	visual perception stat visual perception dyn	11.7273	5.61296	.84619	10.0208	13.4338	13.859	43	.000
Pair 2	visual working memo static - visual working memory dynamic	7.6364	6.94862	1.04754	5.5238	9.7489	7.290	43	.000
Pair 3	visual perception stat visual working memo static	5.6818	5.06595	.76372	4.1416	7.2220	7.440	43	.000
Pair 4	visual perception dyn - visual working mem dynamic	1.5909	7.27633	1.09695	-.6213	3.8031	1.450	43	.154

Anova to assess spatial tasks in analysis 1 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	SPS
	2	SPD
2	1	SWMS
	2	SWMD

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	1160.818	1	1160.818	70.752	.000	.628
	Greenhouse-Geisser	1160.818	1.000	1160.818	70.752	.000	.628
	Huynh-Feldt	1160.818	1.000	1160.818	70.752	.000	.628
	Lower-bound	1160.818	1.000	1160.818	70.752	.000	.628
FORMAT * GROUP	Sphericity Assumed	9.091	1	9.091	.554	.461	.013
	Greenhouse-Geisser	9.091	1.000	9.091	.554	.461	.013
	Huynh-Feldt	9.091	1.000	9.091	.554	.461	.013
	Lower-bound	9.091	1.000	9.091	.554	.461	.013
Error(FORMAT)	Sphericity Assumed	689.091	42	16.407			
	Greenhouse-Geisser	689.091	42.000	16.407			
	Huynh-Feldt	689.091	42.000	16.407			
	Lower-bound	689.091	42.000	16.407			
COND	Sphericity Assumed	2705.114	1	2705.114	155.029	.000	.787
	Greenhouse-Geisser	2705.114	1.000	2705.114	155.029	.000	.787
	Huynh-Feldt	2705.114	1.000	2705.114	155.029	.000	.787
	Lower-bound	2705.114	1.000	2705.114	155.029	.000	.787
COND * GROUP	Sphericity Assumed	46.023	1	46.023	2.638	.112	.059
	Greenhouse-Geisser	46.023	1.000	46.023	2.638	.112	.059
	Huynh-Feldt	46.023	1.000	46.023	2.638	.112	.059
	Lower-bound	46.023	1.000	46.023	2.638	.112	.059
Error(COND)	Sphericity Assumed	732.864	42	17.449			
	Greenhouse-Geisser	732.864	42.000	17.449			
	Huynh-Feldt	732.864	42.000	17.449			
	Lower-bound	732.864	42.000	17.449			
FORMAT * COND	Sphericity Assumed	111.364	1	111.364	9.295	.004	.181
	Greenhouse-Geisser	111.364	1.000	111.364	9.295	.004	.181
	Huynh-Feldt	111.364	1.000	111.364	9.295	.004	.181
	Lower-bound	111.364	1.000	111.364	9.295	.004	.181
FORMAT * COND * GROUP	Sphericity Assumed	124.455	1	124.455	10.388	.002	.198
	Greenhouse-Geisser	124.455	1.000	124.455	10.388	.002	.198
	Huynh-Feldt	124.455	1.000	124.455	10.388	.002	.198
	Lower-bound	124.455	1.000	124.455	10.388	.002	.198
Error(FORMAT*COND)	Sphericity Assumed	503.182	42	11.981			
	Greenhouse-Geisser	503.182	42.000	11.981			
	Huynh-Feldt	503.182	42.000	11.981			
	Lower-bound	503.182	42.000	11.981			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	90092.750	1	90092.750	769.860	.000	.948
GROUP	1548.205	1	1548.205	13.230	.001	.240
Error	4915.045	42	117.025			

Post hoc analyses to assess spatial tasks

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
spatial perception static	Between Groups	360.818	1	360.818	7.973	.007
	Within Groups	1900.818	42	45.258		
	Total	2261.636	43			
spatial perception dynamic	Between Groups	546.023	1	546.023	12.594	.001
	Within Groups	1820.955	42	43.356		
	Total	2366.977	43			
spatial working memory static	Between Groups	736.364	1	736.364	20.452	.000
	Within Groups	1512.182	42	36.004		
	Total	2248.545	43			
spatial working memory dynamic	Between Groups	84.568	1	84.568	2.211	.144
	Within Groups	1606.227	42	38.244		
	Total	1690.795	43			

Anova for AD group data

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	SPS
	2	SPD
2	1	SWMS
	2	SWMD

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	482.227	1	482.227	39.593	.000	.653
	Greenhouse-Geisser	482.227	1.000	482.227	39.593	.000	.653
	Huynh-Feldt	482.227	1.000	482.227	39.593	.000	.653
	Lower-bound	482.227	1.000	482.227	39.593	.000	.653
Error(FORMAT)	Sphericity Assumed	255.773	21	12.180			
	Greenhouse-Geisser	255.773	21.000	12.180			
	Huynh-Feldt	255.773	21.000	12.180			
	Lower-bound	255.773	21.000	12.180			
COND	Sphericity Assumed	1022.727	1	1022.727	73.736	.000	.778
	Greenhouse-Geisser	1022.727	1.000	1022.727	73.736	.000	.778
	Huynh-Feldt	1022.727	1.000	1022.727	73.736	.000	.778
	Lower-bound	1022.727	1.000	1022.727	73.736	.000	.778
Error(COND)	Sphericity Assumed	291.273	21	13.870			
	Greenhouse-Geisser	291.273	21.000	13.870			
	Huynh-Feldt	291.273	21.000	13.870			
	Lower-bound	291.273	21.000	13.870			
FORMAT * COND	Sphericity Assumed	235.636	1	235.636	19.844	.000	.486
	Greenhouse-Geisser	235.636	1.000	235.636	19.844	.000	.486
	Huynh-Feldt	235.636	1.000	235.636	19.844	.000	.486
	Lower-bound	235.636	1.000	235.636	19.844	.000	.486
Error(FORMAT*COND)	Sphericity Assumed	249.364	21	11.874			
	Greenhouse-Geisser	249.364	21.000	11.874			
	Huynh-Feldt	249.364	21.000	11.874			
	Lower-bound	249.364	21.000	11.874			

Anova for NC group data

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	SPS
	2	SPD
2	1	SWMS
	2	SWMD

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	687.682	1	687.682	33.327	.000	.613
	Greenhouse-Geisser	687.682	1.000	687.682	33.327	.000	.613
	Huynh-Feldt	687.682	1.000	687.682	33.327	.000	.613
	Lower-bound	687.682	1.000	687.682	33.327	.000	.613
Error(FORMAT)	Sphericity Assumed	433.318	21	20.634			
	Greenhouse-Geisser	433.318	21.000	20.634			
	Huynh-Feldt	433.318	21.000	20.634			
	Lower-bound	433.318	21.000	20.634			
COND	Sphericity Assumed	1728.409	1	1728.409	82.195	.000	.797
	Greenhouse-Geisser	1728.409	1.000	1728.409	82.195	.000	.797
	Huynh-Feldt	1728.409	1.000	1728.409	82.195	.000	.797
	Lower-bound	1728.409	1.000	1728.409	82.195	.000	.797
Error(COND)	Sphericity Assumed	441.591	21	21.028			
	Greenhouse-Geisser	441.591	21.000	21.028			
	Huynh-Feldt	441.591	21.000	21.028			
	Lower-bound	441.591	21.000	21.028			
FORMAT * COND	Sphericity Assumed	.182	1	.182	.015	.904	.001
	Greenhouse-Geisser	.182	1.000	.182	.015	.904	.001
	Huynh-Feldt	.182	1.000	.182	.015	.904	.001
	Lower-bound	.182	1.000	.182	.015	.904	.001
Error(FORMAT*COND)	Sphericity Assumed	253.818	21	12.087			
	Greenhouse-Geisser	253.818	21.000	12.087			
	Huynh-Feldt	253.818	21.000	12.087			
	Lower-bound	253.818	21.000	12.087			

Appendix 13

Analyses to assess performance on tasks used in experiment 2 after the exclusion of order recall errors

Anova for visual tasks without order in analysis 2 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	VPS
	2	VPDWO
2	1	VWMS
	2	VWMDWO

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	1140.364	1	1140.364	45.559	.000	.520
	Greenhouse-Geisser	1140.364	1.000	1140.364	45.559	.000	.520
	Huynh-Feldt	1140.364	1.000	1140.364	45.559	.000	.520
	Lower-bound	1140.364	1.000	1140.364	45.559	.000	.520
FORMAT * GROUP	Sphericity Assumed	15.364	1	15.364	.614	.438	.014
	Greenhouse-Geisser	15.364	1.000	15.364	.614	.438	.014
	Huynh-Feldt	15.364	1.000	15.364	.614	.438	.014
	Lower-bound	15.364	1.000	15.364	.614	.438	.014
Error(FORMAT)	Sphericity Assumed	1051.273	42	25.030			
	Greenhouse-Geisser	1051.273	42.000	25.030			
	Huynh-Feldt	1051.273	42.000	25.030			
	Lower-bound	1051.273	42.000	25.030			
COND	Sphericity Assumed	378.205	1	378.205	36.689	.000	.466
	Greenhouse-Geisser	378.205	1.000	378.205	36.689	.000	.466
	Huynh-Feldt	378.205	1.000	378.205	36.689	.000	.466
	Lower-bound	378.205	1.000	378.205	36.689	.000	.466
COND * GROUP	Sphericity Assumed	3.841	1	3.841	.373	.545	.009
	Greenhouse-Geisser	3.841	1.000	3.841	.373	.545	.009
	Huynh-Feldt	3.841	1.000	3.841	.373	.545	.009
	Lower-bound	3.841	1.000	3.841	.373	.545	.009
Error(COND)	Sphericity Assumed	432.955	42	10.308			
	Greenhouse-Geisser	432.955	42.000	10.308			
	Huynh-Feldt	432.955	42.000	10.308			
	Lower-bound	432.955	42.000	10.308			
FORMAT * COND	Sphericity Assumed	15.364	1	15.364	2.518	.120	.057
	Greenhouse-Geisser	15.364	1.000	15.364	2.518	.120	.057
	Huynh-Feldt	15.364	1.000	15.364	2.518	.120	.057
	Lower-bound	15.364	1.000	15.364	2.518	.120	.057
FORMAT * COND * GROUP	Sphericity Assumed	.364	1	.364	.060	.808	.001
	Greenhouse-Geisser	.364	1.000	.364	.060	.808	.001
	Huynh-Feldt	.364	1.000	.364	.060	.808	.001
	Lower-bound	.364	1.000	.364	.060	.808	.001
Error(FORMAT*COND)	Sphericity Assumed	256.273	42	6.102			
	Greenhouse-Geisser	256.273	42.000	6.102			
	Huynh-Feldt	256.273	42.000	6.102			
	Lower-bound	256.273	42.000	6.102			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	172000.023	1	172000.023	828.808	.000	.952
GROUP	777.841	1	777.841	3.748	.060	.082
Error	8716.136	42	207.527			

Anova for spatial tasks without order in analysis 2 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

FORMAT	COND	Dependent Variable
1	1	SPS
	2	SPDWO
2	1	SWMS
	2	SWMDWO

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
FORMAT	Sphericity Assumed	1437.551	1	1437.551	76.713	.000	.646
	Greenhouse-Geisser	1437.551	1.000	1437.551	76.713	.000	.646
	Huynh-Feldt	1437.551	1.000	1437.551	76.713	.000	.646
	Lower-bound	1437.551	1.000	1437.551	76.713	.000	.646
FORMAT * GROUP	Sphericity Assumed	8.642	1	8.642	.461	.501	.011
	Greenhouse-Geisser	8.642	1.000	8.642	.461	.501	.011
	Huynh-Feldt	8.642	1.000	8.642	.461	.501	.011
	Lower-bound	8.642	1.000	8.642	.461	.501	.011
Error(FORMAT)	Sphericity Assumed	787.057	42	18.739			
	Greenhouse-Geisser	787.057	42.000	18.739			
	Huynh-Feldt	787.057	42.000	18.739			
	Lower-bound	787.057	42.000	18.739			
COND	Sphericity Assumed	282.551	1	282.551	51.788	.000	.552
	Greenhouse-Geisser	282.551	1.000	282.551	51.788	.000	.552
	Huynh-Feldt	282.551	1.000	282.551	51.788	.000	.552
	Lower-bound	282.551	1.000	282.551	51.788	.000	.552
COND * GROUP	Sphericity Assumed	3.551	1	3.551	.651	.424	.015
	Greenhouse-Geisser	3.551	1.000	3.551	.651	.424	.015
	Huynh-Feldt	3.551	1.000	3.551	.651	.424	.015
	Lower-bound	3.551	1.000	3.551	.651	.424	.015
Error(COND)	Sphericity Assumed	229.148	42	5.456			
	Greenhouse-Geisser	229.148	42.000	5.456			
	Huynh-Feldt	229.148	42.000	5.456			
	Lower-bound	229.148	42.000	5.456			
FORMAT * COND	Sphericity Assumed	45.006	1	45.006	8.469	.006	.168
	Greenhouse-Geisser	45.006	1.000	45.006	8.469	.006	.168
	Huynh-Feldt	45.006	1.000	45.006	8.469	.006	.168
	Lower-bound	45.006	1.000	45.006	8.469	.006	.168
FORMAT * COND * GROUP	Sphericity Assumed	27.051	1	27.051	5.090	.029	.108
	Greenhouse-Geisser	27.051	1.000	27.051	5.090	.029	.108
	Huynh-Feldt	27.051	1.000	27.051	5.090	.029	.108
	Lower-bound	27.051	1.000	27.051	5.090	.029	.108
Error(FORMAT*COND)	Sphericity Assumed	223.193	42	5.314			
	Greenhouse-Geisser	223.193	42.000	5.314			
	Huynh-Feldt	223.193	42.000	5.314			
	Lower-bound	223.193	42.000	5.314			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	112463.642	1	112463.642	720.720	.000	.945
GROUP	1957.778	1	1957.778	12.546	.001	.230
Error	6553.830	42	156.044			

Post hoc analyses to assess differences between groups on each of the dynamic tasks without order

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
spatial perception dynamic without order	Between Groups	497.818	1	497.818	7.669	.008
	Within Groups	2726.364	42	64.913		
	Total	3224.182	43			
spatial working memory dynamic without order	Between Groups	402.023	1	402.023	10.209	.003
	Within Groups	1653.864	42	39.378		
	Total	2055.886	43			

Anova to assess the AD group only

Within-Subjects Factors

Measure: MEASURE_1

format	cond	Dependent Variable
1	1	sps
	2	spdwo
2	1	swms
	2	swmdwo

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
format	Sphericity Assumed	834.557	1	834.557	34.018	.000	.618
	Greenhouse-Geisser	834.557	1.000	834.557	34.018	.000	.618
	Huynh-Feldt	834.557	1.000	834.557	34.018	.000	.618
	Lower-bound	834.557	1.000	834.557	34.018	.000	.618
Error(format)	Sphericity Assumed	515.193	21	24.533			
	Greenhouse-Geisser	515.193	21.000	24.533			
	Huynh-Feldt	515.193	21.000	24.533			
	Lower-bound	515.193	21.000	24.533			
cond	Sphericity Assumed	111.375	1	111.375	15.979	.001	.432
	Greenhouse-Geisser	111.375	1.000	111.375	15.979	.001	.432
	Huynh-Feldt	111.375	1.000	111.375	15.979	.001	.432
	Lower-bound	111.375	1.000	111.375	15.979	.001	.432
Error(cond)	Sphericity Assumed	146.375	21	6.970			
	Greenhouse-Geisser	146.375	21.000	6.970			
	Huynh-Feldt	146.375	21.000	6.970			
	Lower-bound	146.375	21.000	6.970			
format * cond	Sphericity Assumed	70.920	1	70.920	13.941	.001	.399
	Greenhouse-Geisser	70.920	1.000	70.920	13.941	.001	.399
	Huynh-Feldt	70.920	1.000	70.920	13.941	.001	.399
	Lower-bound	70.920	1.000	70.920	13.941	.001	.399
Error(format*cond)	Sphericity Assumed	106.830	21	5.087			
	Greenhouse-Geisser	106.830	21.000	5.087			
	Huynh-Feldt	106.830	21.000	5.087			
	Lower-bound	106.830	21.000	5.087			

Anova to assess the NC group only

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
format	Sphericity Assumed	611.636	1	611.636	47.246	.000	.692
	Greenhouse-Geisser	611.636	1.000	611.636	47.246	.000	.692
	Huynh-Feldt	611.636	1.000	611.636	47.246	.000	.692
	Lower-bound	611.636	1.000	611.636	47.246	.000	.692
Error(format)	Sphericity Assumed	271.864	21	12.946			
	Greenhouse-Geisser	271.864	21.000	12.946			
	Huynh-Feldt	271.864	21.000	12.946			
	Lower-bound	271.864	21.000	12.946			
cond	Sphericity Assumed	174.727	1	174.727	44.329	.000	.679
	Greenhouse-Geisser	174.727	1.000	174.727	44.329	.000	.679
	Huynh-Feldt	174.727	1.000	174.727	44.329	.000	.679
	Lower-bound	174.727	1.000	174.727	44.329	.000	.679
Error(cond)	Sphericity Assumed	82.773	21	3.942			
	Greenhouse-Geisser	82.773	21.000	3.942			
	Huynh-Feldt	82.773	21.000	3.942			
	Lower-bound	82.773	21.000	3.942			
format * cond	Sphericity Assumed	1.136	1	1.136	.205	.655	.010
	Greenhouse-Geisser	1.136	1.000	1.136	.205	.655	.010
	Huynh-Feldt	1.136	1.000	1.136	.205	.655	.010
	Lower-bound	1.136	1.000	1.136	.205	.655	.010
Error(format*cond)	Sphericity Assumed	116.364	21	5.541			
	Greenhouse-Geisser	116.364	21.000	5.541			
	Huynh-Feldt	116.364	21.000	5.541			
	Lower-bound	116.364	21.000	5.541			

Appendix 14

Summary of Analysis 3 - Analysis to assess performance on tasks used in experiment 2

The mean and standard deviations for these four tasks are presented in the table below, along with the mean and standard deviations for the perception tasks, taken from the previous analysis, for comparison purposes.

Table to demonstrate the mean scores of number of correct trials (and standard deviations) on the eight tasks undertaken

Task Type	AD Group Mean (SD) (N=22)	NC Group Mean (SD) (N=22)	Overall Mean (SD) (N=44)
Visual Perception Static (VPS)	33.95 (8.79)	37.18 (5.81)	35.57 (7.54)
Visual Perception Dynamic (VPD)	21.32 (9.93)	26.36 (8.23)	23.84 (9.37)
Spatial Perception Static (VPS)	27.05 (8.34)	32.77 (4.58)	29.91 (7.25)
Spatial Perception Dynamic (VPD)	16.95 (7.56)	24.00 (5.43)	20.48 (7.42)
Visual Working Memory Static - Articulatory Suppression (VWMS/AS)	18.45 (3.63)	24.64 (4.38)	21.55 (5.06)
Visual Working Memory Dynamic - Articulatory Suppression (VWMD/AS)	11.41 (3.11)	15.64 (4.01)	13.52 (4.14)
Spatial Working Memory Static - Articulatory Suppression (SWMS/AS)	12.64 (2.63)	20.82 (3.42)	16.73 (5.12)
Spatial Working Memory Dynamic - Articulatory Suppression (SWMD/AS)	8.59 (3.75)	11.64 (4.17)	10.11 (4.21)

Again, the NC group achieved higher scores than the AD group on all of the tasks. Overall, higher scores were gained on the perception tasks in comparison to the working memory tasks. This is unsurprising as the articulatory suppression condition was applied only to the working memory tasks and would be expected to result in lowered performance in comparison to the perception tasks in both groups. Again spatial tasks appear to be more difficult overall in comparison to visual tasks. The working memory tasks resulted in higher scores were gained for the static tasks, with much lower scores for the dynamic tasks. This pattern occurred for both the visual and spatial tasks. The standard deviations for the working memory scores are somewhat smaller than the perception task standard deviations, suggesting that the scores were less varied. This can probably be explained as the maximum scores are lower, therefore, the overall possible variance is lower.

As the descriptive statistics have demonstrated, the AD group children performed at a lower level when compared to NC group children on the working memory tasks in the articulatory suppression condition. The scores for each of working memory tasks with articulatory suppression and the perception task scores were analysed separately dependent on task type (visual/spatial) using mixed 2x2x2 analyses of variance (ANOVAs). The within participants variables were task format, perception or working memory; and task condition, static or dynamic, and the between participants variable was group, either AD or NC group.

Visual Tasks

For the visual tasks the mixed ANOVA revealed a significant main effect of group $F(1,42) = 11.354, p<0.01, \mu^2=.213$, in that the children with attentional difficulties performed at a significantly lower level than NC children on the visual tasks. Previous analysis (analyses 1 and 2) revealed no main effects of group on the visual tasks and the current analysis confirmed that there were no significant differences on the perception tasks, however, the working memory tasks incorporating articulatory suppression did significantly differentiate the groups. There was a significant difference between the groups on the VWMS/AS $F(1,42)=25.943, <0.001, \mu^2=.382$, indicating that children in the AD group gained lower scores than children in the NC group. There was also a significant difference between the groups on the VWMD/AS $F(1,42) = 15.277, <0.001, \mu^2=.267$, again indicating lower scores for children in the AD group.

There was a significant main effect of task format (perception or working memory), $F(1,42) = 104.799, p<0.001, \mu^2=.714$, reflecting better scores for the perception versions of the tasks. There was also a significant main effect of condition (static or dynamic) $F(1,42) = 448.268, p<0.001, \mu^2=.914$, indicating better performance on the static tasks in comparison to the dynamic tasks. A significant condition by format interaction was found, $F(1,42)=13.246, p<0.01, \mu^2=.240$, and there were no significant interactions of format by group, condition by group, or format by condition by group.

Four paired-samples t-tests were used to test the interaction of condition by format. When the Bonferroni correction was applied, significant differences were observed between the VPS and the VPD task scores $t(43)\ 13.859, p<0.0125$, and the VWMS/AS and the VWMD/AS task scores $t(43)\ 15.846, p<0.0125$, indicating better performance on the static versions of both the perception and working memory tasks.

There was also a significant difference between the scores on the VPS and the VWMS/AS tasks $t(43)\ 12.076, p<0.0125$, indicating better performance on the perception version of the static tasks. There were also significant differences between the VPD and the VWMD/AS tasks $t(43)\ 7.345, p<0.0125$, indicating differences between scores on the dynamic versions of the task dependent on format. As all four t-tests were significant they were not able to indicate why a significant interaction had emerged, on observation of the descriptive statistics, however, it appears that the interaction may represent a greater difference between working memory and perception tasks for static than for dynamic articulatory suppression conditions.

Spatial Tasks

For the spatial tasks a significant main effect of group was found $F(1,42) = 29.628, p<0.001, \mu^2=.414,$ in that the children with attentional difficulties performed at a significantly lower level than NC children on the spatial tasks. To test this main effect a one-way ANOVA was implemented. The previous analyses had revealed significant differences between the groups on both the SPS task and the SPD task. The current analysis revealed a significant difference between the groups on the SWMS/AS $F(1,42)=79.227, p<0.001, \mu^2=.654,$ and also a significant difference between the groups on the SWMD/AS $F(1,42)=6.488, p<0.05, \mu^2=.134.$

There was also a significant main effect of task format (perception or working memory), $F(1,42) = 141.027, p<0.001, \mu^2=.771,$ reflecting better scores for the perception versions of the tasks. There was also a significant main effect of condition (static or dynamic) $F(1,42) = 281.936, p<0.001, \mu^2=.870,$ indicating better performance on the static tasks in comparison to the dynamic tasks. A significant condition by format interaction was found, $F(1,42)=12.693, p<0.01, \mu^2=.232,$ and a significant format by condition by group interaction was also found, $F(1,42) =16.646, p<0.001, \mu^2=.284.$ There were no significant interactions of format by group or condition by group.

In order to assess the interactions of format by condition and format by condition by group it was necessary to perform a repeated measures ANOVA on the data for each group separately. Within the AD group there was a significant main effect of format $F(1,21)=54.282, p<0.001, \mu^2=.721,$ indicating better scores on the perception task in comparison to the working memory task, a significant main effect of condition $F(1,21)=110.095, p<0.001, \mu^2=.840,$ indicating better scores on the static condition in comparison to the dynamic condition, and a significant interaction of format by condition $F(1,21)=30.647, p<0.001, \mu^2=.593.$ Within the NC group there was a significant main effect of format $F(1,21)=95.839, p<0.001, \mu^2=.820,$ indicating better scores on the perception in comparison to the working memory format, a significant main effect of condition $F(1,21)=175.431, p<0.001, \mu^2=.893,$ indicating better scores on the static in comparison to the dynamic condition, but no significant interaction of format by condition.

Paired samples t-tests were further employed to test the interaction of format by condition within the AD group. When the Bonferroni correction was applied, significant differences were observed between the SPS and the SPD task scores $t(21)\ 9.070, p<0.0125$, and the SWMS/AS and the SWMD/AS task scores $t(21)\ 7.842, p<0.0125$, indicating better performance on the static versions of both the perception and working memory tasks.

There was also a significant difference between the scores on the SPS and the SWMS/AS tasks $t(21)\ 8.221, p<0.0125$, indicating better performance on the perception version of the static tasks. There were also significant differences between the SPD and the SWMD/AS tasks $t(21)\ 5.514, p<0.0125$, indicating differences between scores on the dynamic versions of the task dependent on format. Like the visual task analysis as all four t-tests were significant they were not able to indicate why a significant interaction had emerged, on observation of the descriptive statistics, however, it appears that the interaction may represent a greater difference between working memory and perception tasks for static than for dynamic articulatory suppression conditions.

These post hoc analyses can explain the overall significant interaction of condition by format, and the significant format by condition by group interaction, as the format by condition interaction was only significant within the AD group. Again, overall and within the AD group only, the effect of the dynamic condition on the perception task was much more dramatically detrimental than on the working memory task.

Appendix 15

Analyses to assess performance on tasks used in experiment 2 with articulatory suppression

Anova to assess performance on visual tasks in analysis 3 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

format	cond	Dependent Variable
1	1	vps
	2	vpd
2	1	vwmsas
	2	vwmdas

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
format	Sphericity Assumed	6517.278	1	6517.278	104.799	.000	.714
	Greenhouse-Geisser	6517.278	1.000	6517.278	104.799	.000	.714
	Huynh-Feldt	6517.278	1.000	6517.278	104.799	.000	.714
	Lower-bound	6517.278	1.000	6517.278	104.799	.000	.714
format * group	Sphericity Assumed	12.551	1	12.551	.202	.656	.005
	Greenhouse-Geisser	12.551	1.000	12.551	.202	.656	.005
	Huynh-Feldt	12.551	1.000	12.551	.202	.656	.005
	Lower-bound	12.551	1.000	12.551	.202	.656	.005
Error(format)	Sphericity Assumed	2611.920	42	62.189			
	Greenhouse-Geisser	2611.920	42.000	62.189			
	Huynh-Feldt	2611.920	42.000	62.189			
	Lower-bound	2611.920	42.000	62.189			
cond	Sphericity Assumed	4290.688	1	4290.688	448.268	.000	.914
	Greenhouse-Geisser	4290.688	1.000	4290.688	448.268	.000	.914
	Huynh-Feldt	4290.688	1.000	4290.688	448.268	.000	.914
	Lower-bound	4290.688	1.000	4290.688	448.268	.000	.914
cond * group	Sphericity Assumed	.051	1	.051	.005	.942	.000
	Greenhouse-Geisser	.051	1.000	.051	.005	.942	.000
	Huynh-Feldt	.051	1.000	.051	.005	.942	.000
	Lower-bound	.051	1.000	.051	.005	.942	.000
Error(cond)	Sphericity Assumed	402.011	42	9.572			
	Greenhouse-Geisser	402.011	42.000	9.572			
	Huynh-Feldt	402.011	42.000	9.572			
	Lower-bound	402.011	42.000	9.572			
format * cond	Sphericity Assumed	150.960	1	150.960	13.246	.001	.240
	Greenhouse-Geisser	150.960	1.000	150.960	13.246	.001	.240
	Huynh-Feldt	150.960	1.000	150.960	13.246	.001	.240
	Lower-bound	150.960	1.000	150.960	13.246	.001	.240
format * cond * group	Sphericity Assumed	39.142	1	39.142	3.435	.071	.076
	Greenhouse-Geisser	39.142	1.000	39.142	3.435	.071	.076
	Huynh-Feldt	39.142	1.000	39.142	3.435	.071	.076
	Lower-bound	39.142	1.000	39.142	3.435	.071	.076
Error(format*cond)	Sphericity Assumed	478.648	42	11.396			
	Greenhouse-Geisser	478.648	42.000	11.396			
	Huynh-Feldt	478.648	42.000	11.396			
	Lower-bound	478.648	42.000	11.396			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	98185.506	1	98185.506	1161.479	.000	.965
group	959.778	1	959.778	11.354	.002	.213
Error	3550.466	42	84.535			

Post hoc analyses of the visual tasks

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
visual perception static	Between Groups	114.568	1	114.568	2.065	.158
	Within Groups	2330.227	42	55.482		
	Total	2444.795	43			
visual perception dynamic	Between Groups	280.023	1	280.023	3.368	.074
	Within Groups	3491.864	42	83.140		
	Total	3771.886	43			
visual working memory static articulatory suppression condition	Between Groups	420.364	1	420.364	25.943	.000
	Within Groups	680.545	42	16.203		
	Total	1100.909	43			
visual working memory dynamic articulatory suppression condition	Between Groups	196.568	1	196.568	15.277	.000
	Within Groups	540.409	42	12.867		
	Total	736.977	43			

Paired-samples t-tests to test the interaction of condition by format on the visual tasks

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	visual perception static	35.5682	44	7.54027	1.13674
	visual perception dynamic	23.8409	44	9.36580	1.41195
Pair 2	visual working memory static articulatory suppression condition	21.5455	44	5.05989	.76281
	visual working memory dynamic articulatory suppression condition	13.5227	44	4.13993	.62412
Pair 3	visual perception static	35.5682	44	7.54027	1.13674
	visual working memory static articulatory suppression condition	21.5455	44	5.05989	.76281
Pair 4	visual perception dynamic	23.8409	44	9.36580	1.41195
	visual working memory dynamic articulatory suppression condition	13.5227	44	4.13993	.62412

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	visual perception static - visual perception dynamic	11.72727	5.61296	.84619	10.02078	13.43377	13.859	43	.000
Pair 2	visual working memory static articulatory suppression condition - visual working memory dynamic articulatory suppression condition	8.02273	3.35835	.50629	7.00169	9.04376	15.846	43	.000
Pair 3	visual perception static - visual working memory static articulatory suppression condition	14.02273	7.70228	1.16116	11.68102	16.36443	12.076	43	.000
Pair 4	visual perception dynamic - visual working memory dynamic articulatory suppression condition	10.31818	9.31808	1.40475	7.48523	13.15114	7.345	43	.000

Anova to assess the performance on spatial tasks in analysis 3 of experiment 2

Within-Subjects Factors

Measure: MEASURE_1

format	cond	Dependent Variable
1	1	sps
	2	spd
2	1	swmsas
	2	swmdas

Between-Subjects Factors

		Value Label	N
group	1.00	Attentional Difficutly	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
format	Sphericity Assumed	6098.273	1	6098.273	141.027	.000	.771
	Greenhouse-Geisser	6098.273	1.000	6098.273	141.027	.000	.771
	Huynh-Feldt	6098.273	1.000	6098.273	141.027	.000	.771
	Lower-bound	6098.273	1.000	6098.273	141.027	.000	.771
format * group	Sphericity Assumed	6.568	1	6.568	.152	.699	.004
	Greenhouse-Geisser	6.568	1.000	6.568	.152	.699	.004
	Huynh-Feldt	6.568	1.000	6.568	.152	.699	.004
	Lower-bound	6.568	1.000	6.568	.152	.699	.004
Error(format)	Sphericity Assumed	1816.159	42	43.242			
	Greenhouse-Geisser	1816.159	42.000	43.242			
	Huynh-Feldt	1816.159	42.000	43.242			
	Lower-bound	1816.159	42.000	43.242			
cond	Sphericity Assumed	2832.023	1	2832.023	281.936	.000	.870
	Greenhouse-Geisser	2832.023	1.000	2832.023	281.936	.000	.870
	Huynh-Feldt	2832.023	1.000	2832.023	281.936	.000	.870
	Lower-bound	2832.023	1.000	2832.023	281.936	.000	.870
cond * group	Sphericity Assumed	40.091	1	40.091	3.991	.052	.087
	Greenhouse-Geisser	40.091	1.000	40.091	3.991	.052	.087
	Huynh-Feldt	40.091	1.000	40.091	3.991	.052	.087
	Lower-bound	40.091	1.000	40.091	3.991	.052	.087
Error(cond)	Sphericity Assumed	421.886	42	10.045			
	Greenhouse-Geisser	421.886	42.000	10.045			
	Huynh-Feldt	421.886	42.000	10.045			
	Lower-bound	421.886	42.000	10.045			
format * cond	Sphericity Assumed	87.364	1	87.364	12.693	.001	.232
	Greenhouse-Geisser	87.364	1.000	87.364	12.693	.001	.232
	Huynh-Feldt	87.364	1.000	87.364	12.693	.001	.232
	Lower-bound	87.364	1.000	87.364	12.693	.001	.232
format * cond * group	Sphericity Assumed	114.568	1	114.568	16.646	.000	.284
	Greenhouse-Geisser	114.568	1.000	114.568	16.646	.000	.284
	Huynh-Feldt	114.568	1.000	114.568	16.646	.000	.284
	Lower-bound	114.568	1.000	114.568	16.646	.000	.284
Error(format*cond)	Sphericity Assumed	289.068	42	6.883			
	Greenhouse-Geisser	289.068	42.000	6.883			
	Huynh-Feldt	289.068	42.000	6.883			
	Lower-bound	289.068	42.000	6.883			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	65604.568	1	65604.568	1227.110	.000	.967
group	1584.000	1	1584.000	29.628	.000	.414
Error	2245.432	42	53.463			

Post hoc analyses to assess performance on spatial tasks

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
spatial perception static	Between Groups	360.818	1	360.818	7.973	.007
	Within Groups	1900.818	42	45.258		
	Total	2261.636	43			
spatial perception dynamic	Between Groups	546.023	1	546.023	12.594	.001
	Within Groups	1820.955	42	43.356		
	Total	2366.977	43			
spatial working memory static articulatory suppression condition	Between Groups	736.364	1	736.364	79.227	.000
	Within Groups	390.364	42	9.294		
	Total	1126.727	43			
spatial working memory dynamic articulatory suppression condition	Between Groups	102.023	1	102.023	6.488	.015
	Within Groups	660.409	42	15.724		
	Total	762.432	43			

Anova on AD group only for spatial tasks to assess interaction of format by condition, and format by condition by group

Within-Subjects Factors

Measure: MEASURE_1

format	cond	Dependent Variable
1	1	sps
	2	spd
2	1	swmsas
	2	swmdas

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
format	1.000	.000	0	.	1.000	1.000	1.000
cond	1.000	.000	0	.	1.000	1.000	1.000
format * cond	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: format+cond+format*cond

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
format	Sphericity Assumed	2852.284	1	2852.284	54.282	.000	.721
	Greenhouse-Geisser	2852.284	1.000	2852.284	54.282	.000	.721
	Huynh-Feldt	2852.284	1.000	2852.284	54.282	.000	.721
	Lower-bound	2852.284	1.000	2852.284	54.282	.000	.721
Error(format)	Sphericity Assumed	1103.466	21	52.546			
	Greenhouse-Geisser	1103.466	21.000	52.546			
	Huynh-Feldt	1103.466	21.000	52.546			
	Lower-bound	1103.466	21.000	52.546			
cond	Sphericity Assumed	1099.102	1	1099.102	110.095	.000	.840
	Greenhouse-Geisser	1099.102	1.000	1099.102	110.095	.000	.840
	Huynh-Feldt	1099.102	1.000	1099.102	110.095	.000	.840
	Lower-bound	1099.102	1.000	1099.102	110.095	.000	.840
Error(cond)	Sphericity Assumed	209.648	21	9.983			
	Greenhouse-Geisser	209.648	21.000	9.983			
	Huynh-Feldt	209.648	21.000	9.983			
	Lower-bound	209.648	21.000	9.983			
format * cond	Sphericity Assumed	201.011	1	201.011	30.647	.000	.593
	Greenhouse-Geisser	201.011	1.000	201.011	30.647	.000	.593
	Huynh-Feldt	201.011	1.000	201.011	30.647	.000	.593
	Lower-bound	201.011	1.000	201.011	30.647	.000	.593
Error(format*cond)	Sphericity Assumed	137.739	21	6.559			
	Greenhouse-Geisser	137.739	21.000	6.559			
	Huynh-Feldt	137.739	21.000	6.559			
	Lower-bound	137.739	21.000	6.559			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	23400.284	1	23400.284	297.557	.000	.934
Error	1651.466	21	78.641			

Anova on NC group only on spatial tasks to assess interaction of format by condition, and format by condition by group

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
format	Sphericity Assumed	3252.557	1	3252.557	95.839	.000	.820
	Greenhouse-Geisser	3252.557	1.000	3252.557	95.839	.000	.820
	Huynh-Feldt	3252.557	1.000	3252.557	95.839	.000	.820
	Lower-bound	3252.557	1.000	3252.557	95.839	.000	.820
Error(format)	Sphericity Assumed	712.693	21	33.938			
	Greenhouse-Geisser	712.693	21.000	33.938			
	Huynh-Feldt	712.693	21.000	33.938			
	Lower-bound	712.693	21.000	33.938			
cond	Sphericity Assumed	1773.011	1	1773.011	175.431	.000	.893
	Greenhouse-Geisser	1773.011	1.000	1773.011	175.431	.000	.893
	Huynh-Feldt	1773.011	1.000	1773.011	175.431	.000	.893
	Lower-bound	1773.011	1.000	1773.011	175.431	.000	.893
Error(cond)	Sphericity Assumed	212.239	21	10.107			
	Greenhouse-Geisser	212.239	21.000	10.107			
	Huynh-Feldt	212.239	21.000	10.107			
	Lower-bound	212.239	21.000	10.107			
format * cond	Sphericity Assumed	.920	1	.920	.128	.724	.006
	Greenhouse-Geisser	.920	1.000	.920	.128	.724	.006
	Huynh-Feldt	.920	1.000	.920	.128	.724	.006
	Lower-bound	.920	1.000	.920	.128	.724	.006
Error(format*cond)	Sphericity Assumed	151.330	21	7.206			
	Greenhouse-Geisser	151.330	21.000	7.206			
	Huynh-Feldt	151.330	21.000	7.206			
	Lower-bound	151.330	21.000	7.206			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	43788.284	1	43788.284	1548.160	.000	.987
Error	593.966	21	28.284			

Paired samples t-tests for AD group only

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	spatial perception static - spatial perception dynamic	10.09091	5.21818	1.11252	7.77730	12.40452	9.070	21	.000
Pair 2	spatial working memory static articulatory suppression condition - spatial working memory dynamic articulatory suppression condition	4.04545	2.41971	.51588	2.97262	5.11829	7.842	21	.000
Pair 3	spatial perception static - spatial working memory static articulatory suppression condition	14.40909	8.22111	1.75275	10.76406	18.05413	8.221	21	.000
Pair 4	spatial perception dynamic - spatial working memory dynamic articulatory suppression condition	8.36364	7.11501	1.51693	5.20902	11.51826	5.514	21	.000

Appendix 16

<u>Semi-structured interview questions for experiment 3</u>

Which of the 'games' we have just done did you like the most?

Which hand do you use to write with?

Switching

Which pairs game did you think was the easiest?
Why?

Which did you think was the hardest?
Why?

How did you match all the pairs so quickly?

Dual-tasking

<u>Pairs</u>
How did you remember where the matching pairs were?

Did you find it easy or difficult?

Jigsaw

Have you seen the characters on the jigsaw before? Where? When? Etc

How did you go about doing the jigsaw?

What do you think is the best way to do a jigsaw?

Was the jigsaw easy or difficult?

Dual Task

Which of these do you prefer, jigsaw or pairs game?

Which task was the hardest?

How did you decide when to change and do the other game?

Did the clock help you to decide when to switch to the other game?

Problem solving

<u>Farmer Task</u>
Have you seen this task before?

Have you done any similar tasks before?

Did you find it easy or difficult?

How did you work out how to get them all across?

Which part was the hardest?

Eggs and Baskets

Have you done this task before?

Have you done any tasks like it before?

If yes, when did you do these, at home or at school, in which subject?

Did you find it difficult or easy?
Why?

How did you work it out?

Appendix 17

Experiment 3 – Switching Task Operationalisation of Measures

The definitions of the measures taken during each condition are shown in the table below.

Measure	Operationalisation
Pairs turned	the number of occasions when two cards were turned over at any one time. This measure was taken in order that it was possible to assess whether any differences between the groups or conditions were due to the number of pairs they turned over in total. The hypothesis being that this would not differ by group or condition.
Incorrect Rule Use	the number of times a participant told the examiner the rule they were using and this was incorrect (a matching error would not be recorded if the error was consistent with the incorrect rule used.)
Requests for reiteration of instructions	the number of occasions the participant asked the examiner to repeat instructions during the completion of the task. These requests would normally refer to confirmation of the matching rule which was currently in place.
Completion Time	the number of seconds each participant took to match the twelve possible pairs of cards.
Matching Errors	the number of occasions a match was made using the wrong rule on the control conditions, and on the switching condition where this differed from the rule the participant asserted they were using
Turning over too many cards	the number of times more than two cards were upwards facing during the period of the game. This measure was split down into; i) due to the participant breaking the rule ii) due to the cards being accidentally turned or knocked off the table.

Appendix 18

Experiment 3 – Dual-Task Operationalisation of Measures

The definitions of the measures taken during each condition are shown in the table below.

Measure	Operationalisation
Looks towards the timer	the number of occasions the participant looks at the timer in a two minute period
Requests for reiteration of instructions	the number of occasions the participant asked the examiner to repeat instructions during the completion of the task.
Correct Matches	the number of correctly matched pairs after the two minute period had passed.
Incorrect Matches	the number of pairs which had been incorrectly matched after the two minute period had passed.
Jigsaw pieces correctly used	the number of jigsaw pieces which have been selected and categorised (E.g. edges, colours) or pieces fitted together
Total Motor Errors - Pieces dropped and Too many pieces turned	the number of pieces of jigsaw, or pairs cards dropped or turned over accidentally plus the number of occasions more than two pairs cards are turned over at one time.
Pairs turned	the number of occasions when two cards were turned over at any one time. This measure was taken in order that it was possible to assess whether any differences between the groups or conditions were due to the number of pairs they turned over in total. The hypothesis being that this would not differ by group or condition.

Appendix 19

Experiment 3 – Problem-solving task operationalisation of measures

The definitions of the measures taken during the eggs and baskets, and farmer tasks are demonstrated in the table below.

Requests for reiteration of instructions	the number of occasions the participant asked the examiner to repeat instructions during the completion of the task.
Correct Moves	the number of times a piece of either problem-solving task is moved to the correct location, will refer to the correct placement of either character in the farmer tasks or an egg in the eggs and baskets task.
Total moves	the total number of times characters or eggs are moved, including incorrect moves (this is a measure of strategy as less moves indicates greater efficiency)
Incorrect Moves	the number of times characters or eggs are moved to an incorrect location.
Solution time	the number of seconds the participant takes to correctly complete each task starting from the time the first item is moved to completion of the task.

Appendix 20

Farmer task instructions for participants

The farmer needs to get across the river and take the chicken, the fox, and the grain across with him.

The farmer can only take one at a time, as the boat can only carry two.

The farmer can not leave the chicken on her own with the grain, as she will eat it.

The farmer can not leave the fox on his own with the chicken, as he will eat her.

Try to take them all across the river without anyone eating anything else!!

Appendix 21

<u>Eggs and Baskets task instructions for participants</u>

There are six eggs in total.

The blue basket has one more egg than the yellow basket.

The pink basket has one less egg than the yellow basket.

How many eggs are there in each basket?

Place the correct number in each basket.

Answer:

There are three eggs in the blue basket, two eggs in the yellow basket, and one egg in the pink basket.

Appendix 22

Anova to assess differences between groups and conditions on number of pairs turned on switching task

Within-Subjects Factors

Measure: MEASURE_1

turned	Dependent Variable
1	swipairs
2	anipairs
3	colpairs
4	numpairs

Between-Subjects Factors

		Value Label	N
group	1.00	Inattentive	22
	2.00	Control	22

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
turned	Pillai's Trace	.102	1.519[a]	3.000	40.000	.224	.102
	Wilks' Lambda	.898	1.519[a]	3.000	40.000	.224	.102
	Hotelling's Trace	.114	1.519[a]	3.000	40.000	.224	.102
	Roy's Largest Root	.114	1.519[a]	3.000	40.000	.224	.102
turned * group	Pillai's Trace	.054	.768[a]	3.000	40.000	.519	.054
	Wilks' Lambda	.946	.768[a]	3.000	40.000	.519	.054
	Hotelling's Trace	.058	.768[a]	3.000	40.000	.519	.054
	Roy's Largest Root	.058	.768[a]	3.000	40.000	.519	.054

a. Exact statistic

b.

Design: Intercept+group
Within Subjects Design: turned

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
turned	Sphericity Assumed	55.244	3	18.415	2.098	.104	.048
	Greenhouse-Geisser	55.244	2.684	20.579	2.098	.111	.048
	Huynh-Feldt	55.244	2.953	18.705	2.098	.105	.048
	Lower-bound	55.244	1.000	55.244	2.098	.155	.048
turned * group	Sphericity Assumed	24.699	3	8.233	.938	.424	.022
	Greenhouse-Geisser	24.699	2.684	9.201	.938	.417	.022
	Huynh-Feldt	24.699	2.953	8.363	.938	.423	.022
	Lower-bound	24.699	1.000	24.699	.938	.338	.022
Error(turned)	Sphericity Assumed	1105.807	126	8.776			
	Greenhouse-Geisser	1105.807	112.747	9.808			
	Huynh-Feldt	1105.807	124.044	8.915			
	Lower-bound	1105.807	42.000	26.329			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	69086.188	1	69086.188	1195.754	.000	.966
group	158.460	1	158.460	2.743	.105	.061
Error	2426.602	42	57.776			

Appendix 23

Chi-square tests for non-switch conditions of the following measures; incorrect rule use, requests for reiteration of instructions, turning over too many cards, matching errors, and motor errors.

Chi-square test for the incorrect rule use measure of the non-switch animal condition

Crosstab

Count

		Non-switch trial animal - incorrect rule use		
		.00	1.00	Total
group	Inattentive	21	1	22
	Control	21	1	22
Total		42	2	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.000[b]	1	1.000		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.000	1	1.000		
Fisher's Exact Test				1.000	.756
Linear-by-Linear Association	.000	1	1.000		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 1. 00.

Chi-square test for the incorrect rule use measure of the non-switch colour condition

Crosstab

Count

		Non-switch trial colour - incorrect rule use		
		.00	1.00	Total
group	Inattentive	20	2	22
	Control	21	1	22
Total		41	3	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.358[b]	1	.550		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.364	1	.546		
Fisher's Exact Test				1.000	.500
Linear-by-Linear Association	.350	1	.554		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 1.50.

Chi-square test for the incorrect rule use measure of the non-switch number condition

Crosstab

Count

		Non-switch trial number - incorrect rule use		
		.00	1.00	Total
group	Inattentive	20	2	22
	Control	22	0	22
Total		42	2	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.095[b]	1	.148		
Continuity Correction[a]	.524	1	.469		
Likelihood Ratio	2.868	1	.090		
Fisher's Exact Test				.488	.244
Linear-by-Linear Association	2.048	1	.152		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 1.00.

Chi-square test for the requests for reiteration of instructions measure of the non-switch animal condition

Crosstab

Count

		Non-switch trial animal - requests for reiteration of rule		
		.00	1.00	Total
group	Inattentive	14	8	22
	Control	20	2	22
Total		34	10	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.659[b]	1	.031		
Continuity Correction[a]	3.235	1	.072		
Likelihood Ratio	4.919	1	.027		
Fisher's Exact Test				.069	.034
Linear-by-Linear Association	4.553	1	.033		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.00.

Directional Measures

			Value
Nominal by Interval	Eta	group Dependent	.325
		Non-switch trial animal - requests for reiteration of rule Dependent	.325

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.325	.031
	Cramer's V	.325	.031
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Chi-square test for the requests for reiteration of instructions measure of the non-switch colour condition

Crosstab

Count

		Non-switch trial colour - requests for reiteration of rule		
		.00	1.00	Total
group	Inattentive	19	3	22
	Control	21	1	22
Total		40	4	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.100[b]	1	.294		
Continuity Correction[a]	.275	1	.600		
Likelihood Ratio	1.147	1	.284		
Fisher's Exact Test				.607	.303
Linear-by-Linear Association	1.075	1	.300		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.00.

Chi-square test for the requests for reiteration of instructions measure of the non-switch number condition

Crosstab

Count

		Non-switch trial number - requests for reiteration of rule		
		.00	1.00	Total
group	Inattentive	17	5	22
	Control	22	0	22
Total		39	5	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.641[b]	1	.018		
Continuity Correction[a]	3.610	1	.057		
Likelihood Ratio	7.574	1	.006		
Fisher's Exact Test				.048	.024
Linear-by-Linear Association	5.513	1	.019		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.50.

Directional Measures

			Value
Nominal by Interval	Eta	group Dependent	.358
		Non-switch trial number - requests for reiteration of rule Dependent	.358

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.358	.018
	Cramer's V	.358	.018
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Chi-square test for the matching errors measure of the non-switch animal condition

Crosstab

Count

		Non-switch trial animal - matching errors		
		.00	1.00	Total
group	Inattentive	15	7	22
	Control	19	3	22
Total		34	10	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.071[b]	1	.150		
Continuity Correction[a]	1.165	1	.280		
Likelihood Ratio	2.117	1	.146		
Fisher's Exact Test				.281	.140
Linear-by-Linear Association	2.024	1	.155		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5. 00.

Chi-square test for the matching errors measure of the non-switch colour condition

Crosstab

Count

		Non-switch trial colour - matching errors		
		.00	1.00	Total
group	Inattentive	17	5	22
	Control	21	1	22
Total		38	6	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.088[b]	1	.079		
Continuity Correction[a]	1.737	1	.188		
Likelihood Ratio	3.333	1	.068		
Fisher's Exact Test				.185	.093
Linear-by-Linear Association	3.018	1	.082		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3. 00.

Chi-square test for the matching errors measure of the non-switch number condition

Crosstab

Count

		Non-switch trial number - matching errors		
		.00	1.00	Total
group	Inattentive	17	5	22
	Control	21	1	22
Total		38	6	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.088[b]	1	.079		
Continuity Correction[a]	1.737	1	.188		
Likelihood Ratio	3.333	1	.068		
Fisher's Exact Test				.185	.093
Linear-by-Linear Association	3.018	1	.082		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.00.

Chi-square test for the turning over too many cards (inhibition) measure of the non-switch animal condition

Crosstab

Count

		Non-switch trial animal - turning over too many cards		
		.00	1.00	Total
group	Inattentive	17	5	22
	Control	20	2	22
Total		37	7	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.529[b]	1	.216		
Continuity Correction[a]	.680	1	.410		
Likelihood Ratio	1.572	1	.210		
Fisher's Exact Test				.412	.206
Linear-by-Linear Association	1.494	1	.222		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.
50.

Chi-square test for the turning over too many cards (inhibition) measure of the non-switch colour condition

Crosstab

Count

		Non-switch trial colour - turning over too many cards		
		.00	1.00	Total
group	Inattentive	13	9	22
	Control	21	1	22
Total		34	10	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	8.282[b]	1	.004		
Continuity Correction[a]	6.341	1	.012		
Likelihood Ratio	9.261	1	.002		
Fisher's Exact Test				.009	.005
Linear-by-Linear Association	8.094	1	.004		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.
00.

Directional Measures

			Value
Nominal by Interval	Eta	group Dependent	.434
		Non-switch trial colour - turning over too many cards Dependent	.434

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.434	.004
	Cramer's V	.434	.004
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Chi-square test for the turning over too many cards (inhibition) measure of the non-switch number condition

Crosstab

Count

		Non-switch trial number - turning over too many cards		Total
		.00	1.00	
group	Inattentive	16	6	22
	Control	17	5	22
Total		33	11	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.121[b]	1	.728		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.121	1	.728		
Fisher's Exact Test				1.000	.500
Linear-by-Linear Association	.118	1	.731		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5. 50.

Chi-square test for the turning over too many cards (motor error) measure of the non-switch animal condition

Crosstab

Count

		Non-switch trial animal - turning over too many cards - motor mistake		Total
		.00	1.00	
group	Inattentive	19	3	22
	Control	22	0	22
Total		41	3	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.220[b]	1	.073		
Continuity Correction[a]	1.431	1	.232		
Likelihood Ratio	4.379	1	.036		
Fisher's Exact Test				.233	.116
Linear-by-Linear Association	3.146	1	.076		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 1. 50.

Chi-square test for the turning over too many cards (motor error) measure of the non-switch colour condition

Crosstab

Count

		Non-switch trial colour - turning over too many cards - motor mistake		Total
		.00	1.00	
group	Inattentive	18	4	22
	Control	21	1	22
Total		39	5	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.031[b]	1	.154		
Continuity Correction[a]	.903	1	.342		
Likelihood Ratio	2.158	1	.142		
Fisher's Exact Test				.345	.172
Linear-by-Linear Association	1.985	1	.159		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2. 50.

Chi-square test for the turning over too many cards (motor error) measure of the non-switch number condition

Crosstab

Count

		Non-switch trial number - turning over too many cards - motor mistake		Total
		.00	1.00	
group	Inattentive	18	4	22
	Control	20	2	22
Total		38	6	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.772[b]	1	.380		
Continuity Correction[a]	.193	1	.660		
Likelihood Ratio	.785	1	.376		
Fisher's Exact Test				.664	.332
Linear-by-Linear Association	.754	1	.385		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.00.

Appendix 24

Mann-Whitney U Tests for Switching conditions and non-switch animal conditions and non-switch number condition of the requests for reiteration of instructions measure and the non-switch colour condition of the turning over too many cards measure

Ranks

	group	N	Mean Rank	Sum of Ranks
Swiching trial - incorrect rule use	Inattentive	22	24.50	539.00
	Control	22	20.50	451.00
	Total	44		
Swiching trial - requests for reiteration of rule	Inattentive	22	26.00	572.00
	Control	22	19.00	418.00
	Total	44		
Non-switch trial animal - requests for reiteration of rule	Inattentive	22	25.50	561.00
	Control	22	19.50	429.00
	Total	44		
Non-switch trial number - requests for reiteration of rule	Inattentive	22	25.00	550.00
	Control	22	20.00	440.00
	Total	44		
Swiching trial - matching errors	Inattentive	22	29.00	638.00
	Control	22	16.00	352.00
	Total	44		
Swiching trial - turning over too many cards	Inattentive	22	26.00	572.00
	Control	22	19.00	418.00
	Total	44		
Non-switch trial colour - turning over too many cards	Inattentive	22	26.50	583.00
	Control	22	18.50	407.00
	Total	44		
Swiching trial - turning over too many cards - motor mistake	Inattentive	22	23.50	517.00
	Control	22	21.50	473.00
	Total	44		

Test Statistics[a]

	Swiching trial - incorrect rule use	Swiching trial - requests for reiteration of rule	Non-switch trial animal - requests for reiteration of rule	Non-switch trial number - requests for reiteration of rule	Swiching trial - matching errors	Swiching trial - turning over too many cards	Non-switch trial colour - turning over too many cards	Swiching trial - turning over too many cards - motor mistake
Mann-Whitney U	198.000	165.000	176.000	187.000	99.000	165.000	154.000	220.000
Wilcoxon W	451.000	418.000	429.000	440.000	352.000	418.000	407.000	473.000
Z	-1.239	-2.586	-2.134	-2.348	-3.979	-2.287	-2.845	-1.037
Asymp. Sig. (2-tailed)	.215	.010	.033	.019	.000	.022	.004	.300

a. Grouping Variable: group

Appendix 25

Non-parametric analyses for the requests for reiteration of instructions and the turning over too many cards measures

Friedman Test for the requests for reiteration of instructions measure for the AD group only

Ranks

	Mean Rank
Swiching trial - requests for reiteration of rule	2.93
Non-switch trial animal - requests for reiteration of rule	1.55
Non-switch trial number - requests for reiteration of rule	1.52

Test Statistics[a]

N	22
Chi-Square	35.521
df	2
Asymp. Sig.	.000

a. Friedman Test

Friedman Test for the requests for reiteration of instructions measure for the NC group only

Ranks

	Mean Rank
Swiching trial - requests for reiteration of rule	2.59
Non-switch trial animal - requests for reiteration of rule	1.77
Non-switch trial number - requests for reiteration of rule	1.64

Test Statistics[a]

N	22
Chi-Square	23.455
df	2
Asymp. Sig.	.000

a. Friedman Test

Wilcoxon Signed Ranks Test for the requests for reiteration of instructions for the NC group only

Ranks

		N	Mean Rank	Sum of Ranks
Non-switch trial animal - requests for reiteration of rule - Swiching trial - requests for reiteration of rule	Negative Ranks	13[a]	7.31	95.00
	Positive Ranks	1[b]	10.00	10.00
	Ties	8[c]		
	Total	22		
Non-switch trial number - requests for reiteration of rule - Swiching trial - requests for reiteration of rule	Negative Ranks	14[d]	7.50	105.00
	Positive Ranks	0[e]	.00	.00
	Ties	8[f]		
	Total	22		

a. Non-switch trial animal - requests for reiteration of rule < Swiching trial - requests for reiteration of rule

b. Non-switch trial animal - requests for reiteration of rule > Swiching trial - requests for reiteration of rule

c. Non-switch trial animal - requests for reiteration of rule = Swiching trial - requests for reiteration of rule

d. Non-switch trial number - requests for reiteration of rule < Swiching trial - requests for reiteration of rule

e. Non-switch trial number - requests for reiteration of rule > Swiching trial - requests for reiteration of rule

f. Non-switch trial number - requests for reiteration of rule = Swiching trial - requests for reiteration of rule

Test Statistics[b]

	Non-switch trial animal - requests for reiteration of rule - Swiching trial - requests for reiteration of rule	Non-switch trial number - requests for reiteration of rule - Swiching trial - requests for reiteration of rule
Z	-2.691[a]	-3.319[a]
Asymp. Sig. (2-tailed)	.007	.001

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Wilcoxon Signed Ranks Test for the requests for reiteration of instructions for the AD group only

Ranks

		N	Mean Rank	Sum of Ranks
Non-switch trial animal - requests for reiteration of rule - Swiching trial - requests for reiteration of rule	Negative Ranks	21[a]	11.00	231.00
	Positive Ranks	0[b]	.00	.00
	Ties	1[c]		
	Total	22		
Non-switch trial number - requests for reiteration of rule - Swiching trial - requests for reiteration of rule	Negative Ranks	20[d]	10.50	210.00
	Positive Ranks	0[e]	.00	.00
	Ties	2[f]		
	Total	22		

a. Non-switch trial animal - requests for reiteration of rule < Swiching trial - requests for reiteration of rule

b. Non-switch trial animal - requests for reiteration of rule > Swiching trial - requests for reiteration of rule

c. Non-switch trial animal - requests for reiteration of rule = Swiching trial - requests for reiteration of rule

d. Non-switch trial number - requests for reiteration of rule < Swiching trial - requests for reiteration of rule

e. Non-switch trial number - requests for reiteration of rule > Swiching trial - requests for reiteration of rule

f. Non-switch trial number - requests for reiteration of rule = Swiching trial - requests for reiteration of rule

Test Statistics[b]

	Non-switch trial animal - requests for reiteration of rule - Swiching trial - requests for reiteration of rule	Non-switch trial number - requests for reiteration of rule - Swiching trial - requests for reiteration of rule
Z	-4.022[a]	-3.931[a]
Asymp. Sig. (2-tailed)	.000	.000

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

<u>Wilcoxon Signed Ranks Test for turning over too many cards for the AD group only</u>

Ranks

		N	Mean Rank	Sum of Ranks
Non-switch trial colour - turning over too many cards - Swiching trial - turning over too many cards	Negative Ranks	6[a]	5.83	35.00
	Positive Ranks	4[b]	5.00	20.00
	Ties	12[c]		
	Total	22		

a. Non-switch trial colour - turning over too many cards < Swiching trial - turning over too many cards

b. Non-switch trial colour - turning over too many cards > Swiching trial - turning over too many cards

c. Non-switch trial colour - turning over too many cards = Swiching trial - turning over too many cards

Test Statistics[b]

	Non-switch trial colour - turning over too many cards - Swiching trial - turning over too many cards
Z	-.770[a]
Asymp. Sig. (2-tailed)	.441

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Wilcoxon Signed Ranks Test for turning over too many cards for the NC group only

Ranks

		N	Mean Rank	Sum of Ranks
Non-switch trial colour - turning over too many cards - Swiching trial - turning over too many cards	Negative Ranks	2[a]	2.25	4.50
	Positive Ranks	1[b]	1.50	1.50
	Ties	19[c]		
	Total	22		

a. Non-switch trial colour - turning over too many cards < Swiching trial - turning over too many cards

b. Non-switch trial colour - turning over too many cards > Swiching trial - turning over too many cards

c. Non-switch trial colour - turning over too many cards = Swiching trial - turning over too many cards

Test Statistics[b]

	Non-switch trial colour - turning over too many cards - Swiching trial - turning over too many cards
Z	-.816[a]
Asymp. Sig. (2-tailed)	.414

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Appendix 26

Analyses to assess completion time on the switching task

Anova to assess completion time on the switching task

Within-Subjects Factors

Measure: MEASURE_1

time	Dependent Variable
1	swicomp
2	anicomp
3	colcomp
4	numcomp

Between-Subjects Factors

		Value Label	N
group	1.00	Inattentive	22
	2.00	Control	22

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	.598	20.952	5	.001	.759	.824	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+group
Within Subjects Design: time

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	27019.205	3	9006.402	14.110	.000	.251
	Greenhouse-Geisser	27019.205	2.277	11867.372	14.110	.000	.251
	Huynh-Feldt	27019.205	2.472	10932.128	14.110	.000	.251
	Lower-bound	27019.205	1.000	27019.205	14.110	.001	.251
time * group	Sphericity Assumed	4401.318	3	1467.106	2.299	.081	.052
	Greenhouse-Geisser	4401.318	2.277	1933.146	2.299	.099	.052
	Huynh-Feldt	4401.318	2.472	1780.799	2.299	.094	.052
	Lower-bound	4401.318	1.000	4401.318	2.299	.137	.052
Error(time)	Sphericity Assumed	80423.477	126	638.282			
	Greenhouse-Geisser	80423.477	95.624	841.038			
	Huynh-Feldt	80423.477	103.805	774.757			
	Lower-bound	80423.477	42.000	1914.845			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	2899477.841	1	2899477.841	428.279	.000	.911
group	1.455	1	1.455	.000	.988	.000
Error	284342.705	42	6770.064			

Paired samples t-tests to assess differences between switching condition and the three non-switch conditions

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Swiching trial - completion time	149.5000	44	55.63022	8.38657
	Non-switch trial animal - completion time	124.5682	44	43.92562	6.62204
Pair 2	Swiching trial - completion time	149.5000	44	55.63022	8.38657
	Non-switch trial colour - completion time	118.7273	44	40.78894	6.14916
Pair 3	Swiching trial - completion time	149.5000	44	55.63022	8.38657
	Non-switch trial number - completion time	120.6136	44	43.55922	6.56680

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Swiching trial - completion time - Non-switch trial animal - completion time	24.93182	41.75922	6.29544	12.23585	37.62778	3.960	43	.000
Pair 2	Swiching trial - completion time - Non-switch trial colour - completion time	30.77273	47.56922	7.17133	16.31036	45.23509	4.291	43	.000
Pair 3	Swiching trial - completion time - Non-switch trial number - completion time	28.88636	34.54772	5.20826	18.38290	39.38983	5.546	43	.000

Appendix 27

Anova to assess differences between the groups in number of pairs turned over on each condition of the dual task

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Dual-task - number of pairs turned over	Between Groups	52.364	1	52.364	3.138	.084
	Within Groups	700.818	42	16.686		
	Total	753.182	43			
Pairs - number of pairs turned over	Between Groups	.818	1	.818	.031	.862
	Within Groups	1116.364	42	26.580		
	Total	1117.182	43			

Appendix 28

Analyses to assess looks toward the timer on the dual-task

Anova to assess differences between the groups in looks toward timer on the dual-task

Within-Subjects Factors

Measure: MEASURE_1

looks	Dependent Variable
1	duallook
2	pairlook
3	jigslook

Between-Subjects Factors

		Value Label	N
group	1.00	Inattentive	22
	2.00	Control	22

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

					Epsilon[a]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
looks	.554	24.212	2	.000	.692	.725	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+group
Within Subjects Design: looks

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
looks	Sphericity Assumed	.924	2	.462	1.351	.264	.031
	Greenhouse-Geisser	.924	1.383	.668	1.351	.261	.031
	Huynh-Feldt	.924	1.449	.638	1.351	.261	.031
	Lower-bound	.924	1.000	.924	1.351	.252	.031
looks * group	Sphericity Assumed	3.015	2	1.508	4.408	.015	.095
	Greenhouse-Geisser	3.015	1.383	2.180	4.408	.028	.095
	Huynh-Feldt	3.015	1.449	2.081	4.408	.027	.095
	Lower-bound	3.015	1.000	3.015	4.408	.042	.095
Error(looks)	Sphericity Assumed	28.727	84	.342			
	Greenhouse-Geisser	28.727	58.092	.495			
	Huynh-Feldt	28.727	60.863	.472			
	Lower-bound	28.727	42.000	.684			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	179.667	1	179.667	60.855	.000	.592
group	3.667	1	3.667	1.242	.271	.029
Error	124.000	42	2.952			

Paired t-test to assess differences between the conditions in looks toward timer on the dual-task for the AD group only

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Dual-task - looks toward timer	1.3182	22	1.21052	.25808
	Pairs - looks toward timer	.9091	22	1.06499	.22706
Pair 2	Dual-task - looks toward timer	1.3182	22	1.21052	.25808
	Jigsaw - looks toward timer	.7727	22	.92231	.19664

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Dual-task - looks toward timer - Pairs - looks toward timer	.40909	.90812	.19361	.00645	.81173	2.113	21	.047
Pair 2	Dual-task - looks toward timer - Jigsaw - looks toward timer	.54545	1.01076	.21550	.09731	.99360	2.531	21	.019

Paired t-test to assess differences between the conditions in looks toward timer on the dual-task for the NC group only

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Dual-task - looks toward timer	1.2273	22	.92231	.19664
	Pairs - looks toward timer	1.4091	22	1.25960	.26855
Pair 2	Dual-task - looks toward timer	1.2273	22	.92231	.19664
	Jigsaw - looks toward timer	1.3636	22	1.17698	.25093

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Dual-task - looks toward timer - Pairs - looks toward timer	-.18182	1.00647	.21458	-.62806	.26443	-.847	21	.406
Pair 2	Dual-task - looks toward timer - Jigsaw - looks toward timer	-.13636	.88884	.18950	-.53045	.25773	-.720	21	.480

Appendix 29

Analyses to assess correct matches on the dual-task

Anova to assess differences between the groups on the number of correct matches on the dual-task

Within-Subjects Factors

Measure: MEASURE_1

CORRECT	Dependent Variable
1	DUALCORR
2	PAIRCORR

Between-Subjects Factors

		Value Label	N
GROUP	1.00	Inattentive	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
CORRECT	Sphericity Assumed	384.727	1	384.727	184.957	.000	.815
	Greenhouse-Geisser	384.727	1.000	384.727	184.957	.000	.815
	Huynh-Feldt	384.727	1.000	384.727	184.957	.000	.815
	Lower-bound	384.727	1.000	384.727	184.957	.000	.815
CORRECT * GROUP	Sphericity Assumed	2.909	1	2.909	1.399	.244	.032
	Greenhouse-Geisser	2.909	1.000	2.909	1.399	.244	.032
	Huynh-Feldt	2.909	1.000	2.909	1.399	.244	.032
	Lower-bound	2.909	1.000	2.909	1.399	.244	.032
Error(CORRECT)	Sphericity Assumed	87.364	42	2.080			
	Greenhouse-Geisser	87.364	42.000	2.080			
	Huynh-Feldt	87.364	42.000	2.080			
	Lower-bound	87.364	42.000	2.080			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	2042.909	1	2042.909	275.730	.000	.868
GROUP	122.909	1	122.909	16.589	.000	.283
Error	311.182	42	7.409			

Independent samples t-test to assess differences between groups in number of correct matches on each condition of the dual-task

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Dual-task - correct match	Equal variances assumed	6.461	.015	-4.836	42	.000	-2.7273	.56390	-3.86527	-1.58927
	Equal variances not assumed			-4.836	32.259	.000	-2.7273	.56390	-3.87554	-1.57900
Pairs - correct match	Equal variances assumed	.056	.814	-2.710	42	.010	-2.0000	.73802	-3.48938	-.51062
	Equal variances not assumed			-2.710	42.000	.010	-2.0000	.73802	-3.48938	-.51062

Paired samples t-test to assess differences between conditions in number of correct matches in the AD group only

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Dual-task - correct match	1.3636	22	1.25529	.26763
	Pairs - correct match	5.9091	22	2.44772	.52186

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1 Dual-task - correct match - Pairs - correct match	-4.5455	2.19799	.46861	-5.5200	-3.5709	-9.700	21	.000

Paired samples t-test to assess differences between conditions in number of correct matches in the NC group only

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Dual-task - correct match	4.0909	22	2.32807	.49635
	Pairs - correct match	7.9091	22	2.44772	.52186

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1 Dual-task - correct match - Pairs - correct match	-3.8182	1.86793	.39824	-4.6464	-2.9900	-9.588	21	.000

Appendix 30

Analyses to assess total correct jigsaw pieces selected on the dual-task

Anova to assess differences between the groups on total correct jigsaw pieces selected on the dual-task

Within-Subjects Factors

Measure: MEASURE_1

PIECES	Dependent Variable
1	DUALTOTP
2	JIGSTOTP

Between-Subjects Factors

		Value Label	N
GROUP	1.00	Inattentive	22
	2.00	Control	22

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
PIECES	Sphericity Assumed	540.045	1	540.045	106.284	.000	.717
	Greenhouse-Geisser	540.045	1.000	540.045	106.284	.000	.717
	Huynh-Feldt	540.045	1.000	540.045	106.284	.000	.717
	Lower-bound	540.045	1.000	540.045	106.284	.000	.717
PIECES * GROUP	Sphericity Assumed	4.545	1	4.545	.895	.350	.021
	Greenhouse-Geisser	4.545	1.000	4.545	.895	.350	.021
	Huynh-Feldt	4.545	1.000	4.545	.895	.350	.021
	Lower-bound	4.545	1.000	4.545	.895	.350	.021
Error(PIECES)	Sphericity Assumed	213.409	42	5.081			
	Greenhouse-Geisser	213.409	42.000	5.081			
	Huynh-Feldt	213.409	42.000	5.081			
	Lower-bound	213.409	42.000	5.081			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	13352.909	1	13352.909	514.194	.000	.924
GROUP	328.409	1	328.409	12.646	.001	.231
Error	1090.682	42	25.969			

Independent samples t-test to assess differences between groups in total correct jigsaw pieces selected on each condition of the dual-task

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Dual-task - pieces total	Equal variances assumed	.622	.435	-3.701	42	.001	-4.3182	1.16661	-6.67250	-1.96387
	Equal variances not assumed			-3.701	41.961	.001	-4.3182	1.16661	-6.67256	-1.96380
Jigsaw - pieces total	Equal variances assumed	.491	.487	-2.820	42	.007	-3.4091	1.20902	-5.84899	-.96919
	Equal variances not assumed			-2.820	41.630	.007	-3.4091	1.20902	-5.84963	-.96855

Paired samples t-test to assess differences between conditions in total correct jigsaw pieces selected in the AD group only

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Dual-task - pieces total	7.6818	22	3.80959	.81221
	Jigsaw - pieces total	13.0909	22	3.81612	.81360

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1 Dual-task - pieces total - Jigsaw - pieces total	-5.4091	4.05509	.86455	-7.2070	-3.6112	-6.257	21	.000

Paired samples t-test to assess differences between conditions in total correct jigsaw pieces selected in the NC group only

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Dual-task - pieces total	12.0000	22	3.92792	.83744
	Jigsaw - pieces total	16.5000	22	4.19467	.89431

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tai
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1 Dual-task - pieces total - Jigsaw - pieces total	-4.5000	1.97001	.42001	-5.3735	-3.6265	-10.714	21	

Appendix 31

Non-parametric analyses for incorrect matches, motor error, turning over too many pieces, and requests for reiteration of instructions on the dual-task

Mann-Whitney Test to assess differences between the group on incorrect matches

Ranks

	GROUP	N	Mean Rank	Sum of Ranks
Dual-task - incorrect match	Inattentive	22	26.00	572.00
	Control	22	19.00	418.00
	Total	44		
Pairs - incorrect match	Inattentive	22	26.66	586.50
	Control	22	18.34	403.50
	Total	44		

Test Statistics[a]

	Dual-task - incorrect match	Pairs - incorrect match
Mann-Whitney U	165.000	150.500
Wilcoxon W	418.000	403.500
Z	-2.841	-2.927
Asymp. Sig. (2-tailed)	.004	.003

a. Grouping Variable: GROUP

Wilcoxon Signed Ranks Test to assess differences between the conditions in incorrect matches for the AD group only

Ranks

		N	Mean Rank	Sum of Ranks
Pairs - incorrect match - Dual-task - incorrect match	Negative Ranks	6[a]	5.17	31.00
	Positive Ranks	7[b]	8.57	60.00
	Ties	9[c]		
	Total	22		

a. Pairs - incorrect match < Dual-task - incorrect match

b. Pairs - incorrect match > Dual-task - incorrect match

c. Dual-task - incorrect match = Pairs - incorrect match

Test Statistics[b]

	Pairs - incorrect match - Dual-task - incorrect match
Z	-1.020[a]
Asymp. Sig. (2-tailed)	.308

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Wilcoxon Signed Ranks Test to assess differences between the conditions in incorrect matches for the NC group only

Ranks

		N	Mean Rank	Sum of Ranks
Pairs - incorrect match - Dual-task - incorrect match	Negative Ranks	0[a]	.00	.00
	Positive Ranks	1[b]	1.00	1.00
	Ties	21[c]		
	Total	22		

a. Pairs - incorrect match < Dual-task - incorrect match

b. Pairs - incorrect match > Dual-task - incorrect match

c. Dual-task - incorrect match = Pairs - incorrect match

Test Statistics[b]

	Pairs - incorrect match - Dual-task - incorrect match
Z	-1.000[a]
Asymp. Sig. (2-tailed)	.317

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Mann-Whitney Test to assess differences between the groups on motor error

Ranks

	GROUP	N	Mean Rank	Sum of Ranks
dual-task total motor error	Inattentive	22	25.00	550.00
	Control	22	20.00	440.00
	Total	44		
pairs total motor error	Inattentive	22	22.55	496.00
	Control	22	22.45	494.00
	Total	44		
jigsaw total motor error	Inattentive	22	22.50	495.00
	Control	22	22.50	495.00
	Total	44		

Test Statistics[a]

	dual-task total motor error	pairs total motor error	jigsaw total motor error
Mann-Whitney U	187.000	241.000	242.000
Wilcoxon W	440.000	494.000	495.000
Z	-2.342	-.047	.000
Asymp. Sig. (2-tailed)	.019	.962	1.000

a. Grouping Variable: GROUP

Friedman Test to assess differences between the conditions on motor error

Ranks

	Mean Rank
dual-task total motor error	2.07
pairs total motor error	2.03
jigsaw total motor error	1.90

Test Statistics[a]

N	44
Chi-Square	4.667
df	2
Asymp. Sig.	.097

a. Friedman Test

Mann-Whitney Test to assess differences between the groups on turning over too many pieces

Ranks

	GROUP	N	Mean Rank	Sum of Ranks
Dual-task - turning over too many cards	Inattentive	22	25.00	550.00
	Control	22	20.00	440.00
	Total	44		
Pairs - turning over too many cards	Inattentive	22	25.18	554.00
	Control	22	19.82	436.00
	Total	44		

Test Statistics[a]

	Dual-task - turning over too many cards	Pairs - turning over too many cards
Mann-Whitney U	187.000	183.000
Wilcoxon W	440.000	436.000
Z	-2.028	-1.966
Asymp. Sig. (2-tailed)	.043	.049

a. Grouping Variable: GROUP

Wilcoxon Signed Ranks Test to assess differences between conditions on turning over too many pieces

Ranks

		N	Mean Rank	Sum of Ranks
Pairs - turning over too many cards - Dual-task - turning over too many cards	Negative Ranks	4[a]	4.75	19.00
	Positive Ranks	6[b]	6.00	36.00
	Ties	34[c]		
	Total	44		

a. Pairs - turning over too many cards < Dual-task - turning over too many cards

b. Pairs - turning over too many cards > Dual-task - turning over too many cards

c. Dual-task - turning over too many cards = Pairs - turning over too many cards

Test Statistics[b]

	Pairs - turning over too many cards - Dual-task - turning over too many cards
Z	-.872[a]
Asymp. Sig. (2-tailed)	.383

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Mann-Whitney Test to assess differences between the groups on requests for reiteration of instructions

Ranks

	GROUP	N	Mean Rank	Sum of Ranks
Dual-task - reiteration of instructions	Inattentive	22	26.27	578.00
	Control	22	18.73	412.00
	Total	44		
Pairs - reiteration of instructions	Inattentive	22	25.48	560.50
	Control	22	19.52	429.50
	Total	44		
Jigsaw - reiteration of instructions	Inattentive	22	22.00	484.00
	Control	22	23.00	506.00
	Total	44		

Test Statistics[a]

	Dual-task - reiteration of instructions	Pairs - reiteration of instructions	Jigsaw - reiteration of instructions
Mann-Whitney U	159.000	176.500	231.000
Wilcoxon W	412.000	429.500	484.000
Z	-2.359	-1.962	-1.000
Asymp. Sig. (2-tailed)	.018	.050	.317

a. Grouping Variable: GROUP

Friedman Test to assess differences between conditions in requests for reiteration of instructions

Ranks

	Mean Rank
Dual-task - reiteration of instructions	2.25
Pairs - reiteration of instructions	2.03
Jigsaw - reiteration of instructions	1.72

Test Statistics[a]

N	44
Chi-Square	19.276
df	2
Asymp. Sig.	.000

a. Friedman Test

Friedman Test to assess differences between conditions in requests for reiteration of instructions in the AD group only

Ranks

	Mean Rank
Dual-task - reiteration of instructions	2.39
Pairs - reiteration of instructions	2.05
Jigsaw - reiteration of instructions	1.57

Test Statistics[a]

N	22
Chi-Square	18.167
df	2
Asymp. Sig.	.000

a. Friedman Test

Friedman Test to assess differences between conditions in requests for reiteration of instructions in the NC group only

Ranks

	Mean Rank
Dual-task - reiteration of instructions	2.11
Pairs - reiteration of instructions	2.02
Jigsaw - reiteration of instructions	1.86

Test Statistics[a]

N	22
Chi-Square	2.818
df	2
Asymp. Sig.	.244

a. Friedman Test

Wilcoxon Signed Ranks Test to assess differences between paired conditions in requests for reiteration of instructions in the AD group only

Ranks

		N	Mean Rank	Sum of Ranks
Pairs - reiteration of instructions - Dual-task - reiteration of instructions	Negative Ranks	7[a]	4.00	28.00
	Positive Ranks	0[b]	.00	.00
	Ties	15[c]		
	Total	22		
Jigsaw - reiteration of instructions - Dual-task - reiteration of instructions	Negative Ranks	10[d]	5.50	55.00
	Positive Ranks	0[e]	.00	.00
	Ties	12[f]		
	Total	22		

a. Pairs - reiteration of instructions < Dual-task - reiteration of instructions

b. Pairs - reiteration of instructions > Dual-task - reiteration of instructions

c. Dual-task - reiteration of instructions = Pairs - reiteration of instructions

d. Jigsaw - reiteration of instructions < Dual-task - reiteration of instructions

e. Jigsaw - reiteration of instructions > Dual-task - reiteration of instructions

f. Dual-task - reiteration of instructions = Jigsaw - reiteration of instructions

Test Statistics[b]

	Pairs - reiteration of instructions - Dual-task - reiteration of instructions	Jigsaw - reiteration of instructions - Dual-task - reiteration of instructions
Z	-2.392[a]	-2.809[a]
Asymp. Sig. (2-tailed)	.017	.005

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Appendix 32

Manova to assess requests for reiteration of instructions, total moves, incorrect moves and solution time on the farmer task

Between-Subjects Factors

		Value Label	N
GROUP	1.00	Inattentive	22
	2.00	Control	22

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Squar
Intercept	Pillai's Trace	.995	2007.354[a]	4.000	39.000	.000	.
	Wilks' Lambda	.005	2007.354[a]	4.000	39.000	.000	.
	Hotelling's Trace	205.882	2007.354[a]	4.000	39.000	.000	.
	Roy's Largest Root	205.882	2007.354[a]	4.000	39.000	.000	.
GROUP	Pillai's Trace	.270	3.603[a]	4.000	39.000	.014	.
	Wilks' Lambda	.730	3.603[a]	4.000	39.000	.014	.
	Hotelling's Trace	.370	3.603[a]	4.000	39.000	.014	.
	Roy's Largest Root	.370	3.603[a]	4.000	39.000	.014	.

a. Exact statistic

b. Design: Intercept+GROUP

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Farmer task - requests for reiteration of instructions	50.205[a]	1	50.205	10.826	.002	.20
	Farmer task - total moves	.818[b]	1	.818	.435	.513	.01
	Farmer task - solution time	156.568[c]	1	156.568	.095	.760	.00
	Farmer task - incorrect moves	1.114[d]	1	1.114	.525	.473	.01
Intercept	Farmer task - requests for reiteration of instructions	390.023	1	390.023	84.103	.000	.66
	Farmer task - total moves	2018.273	1	2018.273	1074.242	.000	.96
	Farmer task - solution time	394633.841	1	394633.841	238.592	.000	.85
	Farmer task - incorrect moves	134.750	1	134.750	63.493	.000	.60
GROUP	Farmer task - requests for reiteration of instructions	50.205	1	50.205	10.826	.002	.20
	Farmer task - total moves	.818	1	.818	.435	.513	.01
	Farmer task - solution time	156.568	1	156.568	.095	.760	.00
	Farmer task - incorrect moves	1.114	1	1.114	.525	.473	.01
Error	Farmer task - requests for reiteration of instructions	194.773	42	4.637			
	Farmer task - total moves	78.909	42	1.879			
	Farmer task - solution time	69468.591	42	1654.014			
	Farmer task - incorrect moves	89.136	42	2.122			
Total	Farmer task - requests for reiteration of instructions	635.000	44				
	Farmer task - total moves	2098.000	44				
	Farmer task - solution time	464259.000	44				
	Farmer task - incorrect moves	225.000	44				
Corrected Total	Farmer task - requests for reiteration of instructions	244.977	43				
	Farmer task - total moves	79.727	43				
	Farmer task - solution time	69625.159	43				
	Farmer task - incorrect moves	90.250	43				

a. R Squared = .205 (Adjusted R Squared = .186)

b. R Squared = .010 (Adjusted R Squared = -.013)

c. R Squared = .002 (Adjusted R Squared = -.022)

d. R Squared = .012 (Adjusted R Squared = -.011)

Appendix 33

Mann-Whitney Test to assess differences between the groups in correct moves on the farmer task

Ranks

	GROUP	N	Mean Rank	Sum of Ranks
Farmer task - correct moves	Inattentive	22	22.00	484.00
	Control	22	23.00	506.00
	Total	44		

Test Statistics[a]

	Farmer task - correct moves
Mann-Whitney U	231.000
Wilcoxon W	484.000
Z	-.591
Asymp. Sig. (2-tailed)	.555

a. Grouping Variable: GROUP

Appendix 34

Manova to assess total moves, correct moves and solution time on the eggs and baskets task

Between-Subjects Factors

		Value Label	N
GROUP	1.00	Inattentive	22
	2.00	Control	22

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Squar
Intercept	Pillai's Trace	.939	204.643[a]	3.000	40.000	.000	.
	Wilks' Lambda	.061	204.643[a]	3.000	40.000	.000	.
	Hotelling's Trace	15.348	204.643[a]	3.000	40.000	.000	.
	Roy's Largest Root	15.348	204.643[a]	3.000	40.000	.000	.
GROUP	Pillai's Trace	.041	.564[a]	3.000	40.000	.642	.
	Wilks' Lambda	.959	.564[a]	3.000	40.000	.642	.
	Hotelling's Trace	.042	.564[a]	3.000	40.000	.642	.
	Roy's Largest Root	.042	.564[a]	3.000	40.000	.642	.

a. Exact statistic

b. Design: Intercept+GROUP

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Basket and eggs task - total moves	1.841[a]	1	1.841	.389	.536	.009
	Basket and eggs task - solution time	20.455[b]	1	20.455	.091	.765	.002
	Basket and eggs task - correct moves	2.750[c]	1	2.750	1.519	.225	.035
Intercept	Basket and eggs task - total moves	1298.205	1	1298.205	274.056	.000	.867
	Basket and eggs task - solution time	29329.455	1	29329.455	129.885	.000	.756
	Basket and eggs task - correct moves	1130.205	1	1130.205	624.213	.000	.937
GROUP	Basket and eggs task - total moves	1.841	1	1.841	.389	.536	.009
	Basket and eggs task - solution time	20.455	1	20.455	.091	.765	.002
	Basket and eggs task - correct moves	2.750	1	2.750	1.519	.225	.035
Error	Basket and eggs task - total moves	198.955	42	4.737			
	Basket and eggs task - solution time	9484.091	42	225.812			
	Basket and eggs task - correct moves	76.045	42	1.811			
Total	Basket and eggs task - total moves	1499.000	44				
	Basket and eggs task - solution time	38834.000	44				
	Basket and eggs task - correct moves	1209.000	44				
Corrected Total	Basket and eggs task - total moves	200.795	43				
	Basket and eggs task - solution time	9504.545	43				
	Basket and eggs task - correct moves	78.795	43				

a. R Squared = .009 (Adjusted R Squared = -.014)

b. R Squared = .002 (Adjusted R Squared = -.022)

c. R Squared = .035 (Adjusted R Squared = .012)

Appendix 35

Chi-square analyses to assess the association between group and requests for reiteration of instructions, and incorrect moves measures of the eggs and baskets task

Requests for reiteration of instructions

Crosstab

Count

		Basket and eggs task - requests for reiteraction of instructions						
		.00	1.00	2.00	3.00	6.00	8.00	Total
GROUP	Inattentive	12		4	4	1	1	22
	Control	17	4		1			22
Total		29	4	4	5	1	1	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.662[a]	5	.027
Likelihood Ratio	16.657	5	.005
Linear-by-Linear Association	5.619	1	.018
N of Valid Cases	44		

a. 10 cells (83.3%) have expected count less than 5. The minimum expected count is .50.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.536	.027
	Cramer's V	.536	.027
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Incorrect moves

Crosstab

Count

		Basket and eggs task - incorrect moves					
		.00	1.00	2.00	4.00	5.00	Total
GROUP	Inattentive	18	2		1	1	22
	Control	17	2	2		1	22
Total		35	4	2	1	2	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.029[a]	4	.553
Likelihood Ratio	4.187	4	.381
Linear-by-Linear Association	.000	1	1.000
N of Valid Cases	44		

a. 8 cells (80.0%) have expected count less than 5. The minimum expected count is .50.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.262	.553
	Cramer's V	.262	.553
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Appendix 36

Chi-square analyses to assess the association between group and opinions of the tasks in experiment 3

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Group * Which task did you enjoy the most?	44	100.0%	0	.0%	44	100.0%
Group * Which pairs game was the easiest?	44	100.0%	0	.0%	44	100.0%
Group * Which pairs game was the hardest?	44	100.0%	0	.0%	44	100.0%
Group * Dual-task pairs was it easy or difficult?	44	100.0%	0	.0%	44	100.0%
Group * Dual-task jigsaw was it easy or difficult?	44	100.0%	0	.0%	44	100.0%
Group * Farmer task -seen before?	44	100.0%	0	.0%	44	100.0%
Group * Farmer task- easy or difficult?	44	100.0%	0	.0%	44	100.0%
Group * Eggs and baskets - seen before?	44	100.0%	0	.0%	44	100.0%
Group * Eggs and baskets - easy or difficult?	44	100.0%	0	.0%	44	100.0%
Group * Computer task - easy or difficult?	44	100.0%	0	.0%	44	100.0%

Which task did you enjoy the most?

Crosstab

Count

		Which task did you enjoy the most?			Total
		pairs	farmer	computer	
Group	attentional difficulty	8	10	4	22
	control	2	11	9	22
Total		10	21	13	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.571[a]	2	.062
Likelihood Ratio	5.876	2	.053
Linear-by-Linear Association	5.187	1	.023
N of Valid Cases	44		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.00.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.356	.062
	Cramer's V	.356	.062
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Which pairs game was the easiest?

Crosstab

Count

		Which pairs game was the easiest?			Total
		animal	colour	number	
Group	attentional difficulty	4	17	1	22
	control	4	18		22
Total		8	35	1	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.029[a]	2	.598
Likelihood Ratio	1.415	2	.493
Linear-by-Linear Association	.124	1	.725
N of Valid Cases	44		

a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is .50.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.153	.598
	Cramer's V	.153	.598
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Which pairs game was the hardest?

Crosstab

Count

		Which pairs game was the hardest?			Total
		animal	colour	number	
Group	attentional difficulty	5	1	16	22
	control	6		16	22
Total		11	1	32	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.091[a]	2	.580
Likelihood Ratio	1.477	2	.478
Linear-by-Linear Association	.030	1	.863
N of Valid Cases	44		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .50.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.157	.580
	Cramer's V	.157	.580
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Dual-task pairs - was it easy or difficult?

Crosstab

Count

		Dual-task pairs was it easy or difficult?		
		easy	difficult	Total
Group	attentional difficulty	5	17	22
	control	11	11	22
Total		16	28	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.536[b]	1	.060		
Continuity Correction[a]	2.455	1	.117		
Likelihood Ratio	3.602	1	.058		
Fisher's Exact Test				.116	.058
Linear-by-Linear Association	3.455	1	.063		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.00.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.283	.060
	Cramer's V	.283	.060
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Dual-task jigsaw - was it easy or difficult?

Crosstab

Count

		Dual-task jigsaw was it easy or difficult?		
		easy	difficult	Total
Group	attentional difficulty	14	8	22
	control	18	4	22
Total		32	12	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.833[b]	1	.176		
Continuity Correction[a]	1.031	1	.310		
Likelihood Ratio	1.861	1	.173		
Fisher's Exact Test				.310	.155
Linear-by-Linear Association	1.792	1	.181		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.00.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.204	.176
	Cramer's V	.204	.176
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Farmer task – have you seen this task before?

Crosstab

Count

		Farmer task -seen before?	
		no	Total
Group	attentional difficulty	22	22
	control	22	22
Total		44	44

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	44

a. Nō statistics are computed because Farmer task -seen before? is a constant.

Symmetric Measures

		Value
Nominal by Nominal	Phi	.[a]
N of Valid Cases		44

a. No statistics are computed because Farmer task -seen before? is a constant.

Farmer task- easy or difficult?

Crosstab

Count

		Farmer task- easy or difficult?		
		easy	difficult	Total
Group	attentional difficulty	6	16	22
	control	7	15	22
Total		13	31	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.109[b]	1	.741		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.109	1	.741		
Fisher's Exact Test				1.000	.500
Linear-by-Linear Association	.107	1	.744		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.50.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.050	.741
	Cramer's V	.050	.741
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Eggs and baskets – have you seen this task before?

Crosstab

Count

		Eggs and baskets - seen before?	
		no	Total
Group	attentional difficulty	22	22
	control	22	22
Total		44	44

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	44

a. No statistics are computed because Eggs and baskets - seen before? is a constant.

Symmetric Measures

		Value
Nominal by Nominal	Phi	.[a]
N of Valid Cases		44

a. No statistics are computed because Eggs and baskets - seen before? is a constant.

Eggs and baskets - easy or difficult?

Crosstab

Count

		Eggs and baskets - easy or difficult?		
		easy	difficult	Total
Group	attentional difficulty	18	4	22
	control	19	3	22
Total		37	7	44

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.170[b]	1	.680		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.170	1	.680		
Fisher's Exact Test				1.000	.500
Linear-by-Linear Association	.166	1	.684		
N of Valid Cases	44				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.50.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.062	.680
	Cramer's V	.062	.680
N of Valid Cases		44	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

List of Conference Presentations

October 2004

The First Portuguese Forum of Experimental Psychology, The University of Minho, Braga, Portugal

Poster Presentation - Visual and Spatial Perception and Working Memory in Children rated as 'inattentive / hyperactive' in comparison to children with good attentional skills

September 2004

The British Psychological Society Developmental Psychology Conference, Leeds Metropolitan University

Oral Presentation - Visual and Spatial Perception and Working Memory in children rated as 'inattentive' in comparison to children with good attentional skills

July 2003

Psychology Postgraduate Affairs Group Annual Conference 2003, The University of Wolverhampton

Poster Presentation - Differentiation Between Inattentive and Control Children using a Classroom Observation Checklist and Teacher Ratings - *Poster Prize Awarded*