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EXECUTIVE FUNCTIONS AND DELAY AVERSION IN PRESCHOOL HYPERACTIVE CHILDREN

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ABSTRACT

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The traditional view of attention-deficit hyperactivity disorder (AD/HD) as an executive dysfunction (EDF) disorder underpinned by a failure of the inhibition system (Barkley, 1997) is to some extent challenged by evidence that suggests EF deficits are context-dependent. In seeking to address this issue Sonuga-Barke has proposed an alternative model that implicates delay aversion (DA) as the core feature of AD/HD. The aim of this thesis was to explore the relationship between AD/HD, EF and DA in a preschool population where maturation is less likely to obscure relationships between early emerging skills. Before this was possible it was necessary to examine normal task performance in the preschool years. Therefore, this thesis contains two studies. The first explored the properties of the task measures and age-related changes in task performance. The second examined the role of hyperactivity in task performance.

In the first study preschool children (N=60) were tested on a range of EF and delay measures. Age-related changes in task performance were explored using multivariate statistical procedures. Age-related increments in task performance were observed for EF, but not delay, tasks. The findings also suggested preschool EFs are similar in structure to that found in school-age children (i.e., are fractionated).

In the second the modified task battery was applied to preschool children (N=157). Within this community sample hyperactive symptoms were assessed using both rating scales and a clinical interview. The relationship between hyperactivity, EF and DA was explored using both median split and clinical cutoffs on the behavioural measures. Results indicated that hyperactivity is associated with delay task performance. This association was evident for both males and females at age 3 and age 5, and was independent of IQ and conduct problems. This robust finding supported the DA hypothesis. In contrast, hyperactivity was not associated with EF performance, but was associated with disinhibition at age 5 years. This finding offered only partial support for the EDF model.

The findings present a challenge to the EDF model as it is clear that this narrow focus ignores other salient factors. This thesis contributes to our understanding of motivational aspects of AD/HD and the role of DA is established as an equally, if not more, important feature of AD/HD in the preschool years.

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I dedicate this thesis to my husband Knut Inge Dalen

LIST OF ABBREVIATIONS

AB	A-B reversal task
ADD	Attention deficit disorder
ADDH	Attention deficit disorder with hyperactivity
AD/HD	Attention deficit hyperactivity disorder
AF	Attentional flexibility
BIS	Behavioral inhibition system
BAS	Behavioral activation system
BAS II	British ability scales version II
CANTAB	Cambridge neuropsychological automated test battery
CBCL	Child behaviour check list
CD	Conduct disorder
ChD	Choice delay task
CPT	Continuous performance task
DA	Delay aversion
DAI	Delay aversion index
DEL	Delay factor (comprising ChD/Teddies task and DRT/Cookie task)
DEL(1)	Delay factor 1 (comprising EvD/Penguin task and VI Schedule/Squares task)
DEL(2)	Delay factor 2 (comprising ChD/Teddies task)
DoG	Delay of gratification
DRD4	Candidate gene for novelty seeking
DRL	Differential reinforcement of low rate responding
DRT	Delayed response task
DSM (-III; -IIIR; -IV)	Diagnostic and statistic manual (version III; III-R; IV)
DT	Display time
DRT	Delayed response task
EDF	Executive dysfunction

EF	Executive function
EFF	Executive function factor
EFF/INH	Executive function/inhibition factor
EvD	Effort vs. delay task
FI	Fixed interval schedule
GCA	General cognitive ability
HV	Health visitor
ICD (-9; -10)	International classification of diseases (version 9; 10)
INH	Inhibition factor
IRT	Inter response times
IQ	Intelligence quotient
LD	Learning disorder
LL	Larger, later reward
MBD	Minimal brain dysfunction
MFFT	Matching familiar figures task
MRI	Magnetic resonance imaging
MRT	Mean reaction time
NIMH	National institute of mental health
NoPRD	No post reward delay
ODD	Oppositional defiant disorder
PACS	Parent account of childhood symptoms (interview)
PCR	Parent conduct rating
PET	Positron emission topography
PHR	Parent hyperactivity rating
P(i)	Probability of inhibition (for stop signal task)
PM	Porteus maze
PPACS	Preschool parent account of childhood symptoms
PRD	Post reward delay
RD	Reading disorder
RT	Reaction time
SES	Socio-economic status
SDQ	Strengths and difficulties questionnaire
SHR	Spontaneous hypertensive rats
SOA	Stimulus onset achronicity

SS	Sooner, smaller reward
SST	Stop signal task
TBI	Traumatic brain injury
ToH	Tower of Hanoi (disk transfer task)
ToL	Tower of London (disk transfer task)
VI Schedule	Variable interval schedule
WCST	Wisconsin card sort task
WM	Working memory
5-HT	Seratonin re-uptake inhibitor

CHAPTER ONE: AN OVERVIEW OF ATTENTION DEFICIT/HYPERACTIVITY DISORDER (AD/HD)

1.1. Introduction

This chapter seeks to introduce the reader to one of the most prevalent of childhood psychological disorders, Attention-Deficit/Hyperactivity Disorder (AD/HD); it explains how the disorder is conceptualised, assessed and treated. It will discuss issues that are the subject of continuous debate among researchers of AD/HD, and briefly introduce the various theories that seek to explain the disorder from a variety of perspectives.

1.2. Definition of AD/HD

AD/HD is the most researched of childhood disorders. The core symptoms are impulsivity, inattention and developmentally inappropriate levels of motor activity. This symptom triad, described by Maag & Reid (1994) as an ill-defined constellation of behaviours, is variously conceptualised as a concrete medical entity and a behavioural disorder, the former implying underlying brain dysfunction and the latter suggestive of maladaptive, but not necessarily pathological, behaviours. These different perspectives give rise to different forms of treatment ranging from stimulant medication to behavioural intervention schemes and parent training. AD/HD children typically show deficits in planning, organisation, flexible thinking and self control (Pennington & Ozonoff, 1996) and appear to be insensitive to control by both consequences and rules (Solanto, 1990). They experience academic failure and appear socially incompetent (Landau & Moore, 1991) which is associated with low peer status (Renshaw & Asher, 1982). The disorder is chronic and is the main source of referrals to clinicians in the USA (Barkley, 1991).

As the symptom cluster is indeed 'ill-defined' it is necessary at the outset to determine exactly what inattention, impulsivity and overactivity are and how clinicians and researchers quantify them. Although the symptoms are presented as different constructs it should be appreciated that there is a degree of content overlap and it is questionable whether they are separable entities in observational terms.

1.2.1. Inattention

In behavioural terms inattention means 'not applying oneself', which may mean not having one's attention captured in the first instance, not sustaining attention throughout a task, or not completing a task. Inattention is difficult to assess as failure to engage in a task may indicate lack of understanding, off-task behaviour may not indicate lack of attention (i.e., a daydreaming child may actually be contemplating the task, and a seemingly engaged child may be occupied with other thoughts), and not finishing tasks may indicate boredom, unreasonable task difficulty or response to a distraction. Typically the way parents and teachers assess attention is related to the outcome; was the task done well and is the information retained?

Attention has been measured using neuropsychological tests which purportedly measure vigilance and stimulus detection such as the Matching Familiar Figures Task (MFFT), Porteus Mazes (PM), Embedded Figure Tests and Stroop Tests. Such tests have been considered too imprecise as performance in such multifaceted tests involves more than attentional capacities (Sergeant, 1989) and a new generation of tests designed to focus on a single aspect of attentional processing has emerged. Attentional processing at the cognitive level comprises of orientation, encoding, re-orientation and focused and divided attention. These elements have been measured using a range of reaction-time (RT) tests; cued detection tasks, letter matching tasks, dichotic listening tasks and signal detection tasks respectively. Attentional capacity is also testable using the dual task and memory recognition paradigms and sustained attention is typically measured on Continuous Performance Tasks (CPT). It is interesting that this change in experimental paradigm has been largely responsible for the claim that AD/HD children do not suffer attentional deficits in orientation, re-orientation, encoding and focused attention (van der Meere, 1996), although the case for AD/HD children's difficulties in sustained attention remains unresolved.

Concern has been expressed over the ecological validity of laboratory tests, which are seen as limited in range given that many tests tap one facet of attention, that many are highly sophisticated and may require training, and the fact that experimenters are almost always present therefore on-task behaviour may be affected by increased motivation (van der Meere, 1996; review in Corkum & Siegel, 1993). It is argued that salient aspects of AD/HD may, in fact, be filtered out under such conditions.

1.2.2. Impulsivity

In behavioural terms impulsivity is 'not thinking before acting'. This may mean acting prematurely before instructions or questions are given in full, interrupting others, or making inappropriate responses. This is observable behaviour but it is confounded by disruptive behaviour, which may indicate lack of compliance rather than lack of thought. Impulsivity is considered by many to be the cardinal deficit of AD/HD (Sonuga-Barke, 1994; Barkley, 1990; Quay, 1997) but as a construct it has proved difficult to define. It has been operationalised in many different ways: response perseveration (stopping an action that has been initiated), response inhibition (not responding) and self control (waiting to respond). Premature responding and commission errors are a common indicator of impulsivity in the laboratory setting.

Many of the aforementioned attentional measures (MFFT, PM, etc.) have also been used to measure inhibition on the premise that inaccurate responding indicates impulsivity. CPT and Direct Reinforcement of Low Rates of Responding (DRL) have also been used to assess impulse control and became the first commercially available tests of AD/HD (Gordon, 1983). Performance on these tests contributed to the popular notion of AD/HD children as fast (premature), inaccurate responders. The difficulty in interpreting results on a CPT which also demands vigilance, and the fact that DRL performance remained unaffected with the introduction of medication, stimulated a search for more valid measures of impulsivity (Barkley, 1988). Measures of impulsivity derived from a response inhibition paradigm require that an action is suppressed until a signal is given, as in the Go/No-go Task, or a prepotent response to be inhibited as in the Stop-Signal Task (SST)(Logan, Cowen & Davis, 1984), or to perform reverse actions as in Luria's handgame. Such tests have contributed to the large body of evidence for inhibitory deficits in AD/HD. More recently forced-choice paradigms and fixed reinforcement schedules have tapped the concept of premature responding rather than the inhibition of an ongoing response. There is considerable support for the disinhibition in AD/HD children (Barkley, 1997a) but when the cost of premature responding is manipulated, it has been found that AD/HD children are able to inhibit premature responding (Sonuga-Barke *et al*, 1996; Solanto, 1990).

1.2.3. Overactivity

In behavioural terms this means to be constantly 'on the move', to be physically restless as in fidgeting and squirming, to have an excess of energy. As activity levels are context-specific (i.e., a child may be active during playtime and calm during class and both may be appropriate to the setting) it is important that the definition states *inappropriate* motor activity. This is clearly observable and teachers and parents may assess this on the basis of whether the activity is appropriate to the task or whether it interferes with its execution. However, if a child chooses games/toys/situations for which high activity levels are appropriate, and avoids situations which constrain activity, this may mask the problem. Parents of such a child may not consider their child overactive, yet the child rarely engages in structured play. Gender and cultural issues also confound the notion of what is appropriate. It is a truism that boys are expected to be more active than girls and will engage in more rough play, and different cultures have different notions of what is appropriate activity (e.g., traditionally, Italian children are encouraged to talk and move freely during a protracted mealtime whereas English children are expected to sit quietly and still at the table).

Activity levels can be measured using actometers, which are mechanical devices that attach to limbs and record gross body movement. Studies using this technique have shown AD/HD children to be more active than non-AD/HD children (Taylor *et al.*, 1991). Observational recording is also possible when strict definitions of target behaviours can be agreed. Roberts (1979) developed a laboratory playroom observation code that was found to successfully discriminate AD/HD children from normal and aggressive children, and was sensitive to stimulant medication. Both these methods are time consuming and are less likely to be adopted in clinical settings therefore reliance is still placed on parent/teacher reports. A recent study by Stevenson *et al.* (2000) investigated the role of food additives in hyperactivity and found parent ratings were sensitive to behavioural changes which were not identified using laboratory measures including actometers. This was attributed to the fact that parent ratings reflect the children's behaviour in a wide variety of settings and conditions. This highlights the importance of situational aspects of AD/HD.

1.2.4. Developmental change and context

From a developmental perspective it is important to appreciate that attention span, impulsivity and activity levels change over time. Older children will have longer attention spans, greater self control and become less restless than younger children, so judgement of what is appropriate must take into account the age of the child. This issue is of special importance when behavioural measures are used to assess children of different ages, as thresholds which apply to older children may not be appropriate for younger children. It is also necessary to appreciate the specific context of the behaviour (e.g., one parent may have different rules than the other) and the motivation of the child (e.g., an apparently inattentive child may simply be uninterested). Despite these complexities in the recognition of the components of AD/HD, the disorder itself is commonly identified. AD/HD constitutes the largest proportion of clinical referrals of all childhood disorders, and clinical cases are only a proportion of the numbers of AD/HD children in the general population.

1.3. Prevalence of AD/HD

Estimates of the prevalence of AD/HD range from 3 to 11% (Zametkin & Ernst, 1999). Differences in estimates can be attributed to differences in diagnostic criteria but it is widely accepted that approximately 4% of all children are affected. There is a gender difference in that boys are overrepresented in clinical samples. AD/HD is more prevalent in boys than girls by factors ranging from 2:1 to 9:1 (Barkley, 1990). Evidence suggests that hyperactive boys present with more behaviour problems than hyperactive girls despite both groups suffering attentional problems (deHaas 1986; deHaas & Young 1984) and girls are more likely to be diagnosed with predominantly inattentive type (Biederman *et al.*, 1999; Baumgaertel *et al.*, 1995). This suggests that hyperactive girls are not identified because they are less impulsive, but evidence is inconclusive with animal studies (Sagvolden & Berger, 1996) and human studies (Ackerman, Dykman & Oglesby, 1983) showing females to be more impulsive than males, some studies showing no differences (Reed, Pien & Rothbart, 1984; Campbell *et al.*, 1982) and others finding females less impulsive than males (Ahadi, Rothbart & Ye, 1993; Silverman & Ragusa, 1990).

Olsen, Bates and Bayles (1990) suggest there are different predictors of inhibitory control in girls and boys, but Biederman *et al.* (1999) find the magnitude of the core symptoms of AD/HD and associated deficits in girls similar to those found in boys which suggests phenotypic similarities. However, Biederman *et al.*, (1991) found that AD/HD girls have a preponderance of attention deficits and a greater likelihood of mood/anxiety comordibities over disruptive behaviour disorders. As disruptive disorders drive referrals, and comorbid anxiety may ameliorate effects of concurrent conduct disorder (CD) and oppositional defiant disorder (ODD) and the expression of impulsivity (Jensen *et al.*, 2001), it is highly probable that fewer AD/HD girls are referred because certain benefits are conferred by the comorbid pattern rather than girls having lesser symptoms. In a sense this is very problematic for AD/HD girls who may not access help despite being equally severely affected and equally at risk as AD/HD boys. That so many children are identified as AD/HD represents a serious social concern when the short-term and long-term sequalae are considered.

1.4. Long-term and short-term sequalae

In childhood AD/HD onset typically occurs before the age of 7 years and the Diagnostic and Statistic Manual (DSM IV) suggests onset before the age of 4 years is common. Prospective studies spanning up to 5 years show symptoms persist in 64%-85% of cases (August, Braswell & Thuras, 1998; Biederman *et al.*, 1996; Hart *et al.*, 1995; Taylor *et al.*, 1991). In school years AD/HD children are more likely than their peers to experience educational under-achievement, social isolation and anti-social behaviour (Biederman *et al.*, 1996). It appears that boys and girls suffer equally from peer problems and academic difficulties associated with AD/HD despite presenting with different patterns of problem behaviour (Biederman *et al.*, 1999; de Haas, 1986). Longitudinal studies have suggested poor psychiatric outcomes for AD/HD children: Preschool externalising problems are a risk factor for later Conduct Disorder (CD), Opposition Defiant Disorder (ODD) and AD/HD during adolescence (Pierce, Ewing & Campbell, 1999) with a preponderance of anxiety/mood disorders for girls and aggressive/conduct problems for boys (Willcutt *et al.*, 1999). AD/HD is also associated with lower socioeconomic status, lower occupational rank, criminality and early drug use (Stevenson & Goodman, 2001; Chilcoat & Breslau, 1999; Manuzza *et al.*, 1993). The evidence suggests the risk of alcohol and substance abuse is greater for AD/HD females (Biederman *et al.*, 1999) whilst criminality is greater for AD/HD males (Babinski, Hartsough & Lambert, 1999). In general, AD/HD children will go on to have significant difficulties in the post-school years (Manuzza *et al.*, 1998; Lyman, 1996) and this risk to development is associated with AD/HD irrespective of degree of severity (August, Braswell & Thuras, 1998; Fergusson, Horwood & Lynskey, 1993). The disorder may continue into adult life in 10%-60% of childhood cases (Taylor *et al.*, 1991).

1.5. Treatment

The treatment method of choice is stimulant medication and although the efficacy of drugs such as methylphenidate (Ritalin) has been demonstrated in many studies, the fact remains that, on average, treatment with stimulant medication lasts 2 years or less, and there is little evidence of subsequent long-term improvement in academic or social spheres (Swanson *et al.*, 1993). Cognitive-behavioural techniques promote development of self-directed speech for purposes of self-monitoring and self-evaluation but evidence suggests clinical groups are especially resistant to this type of therapy (Abikoff, 1987). Despite this there is evidence to suggest executive function training improves inhibitory control in preschoolers (Dowsett & Livesey, 2000).

Programs for parent training (Sonuga-Barke *et al.*, 2001), classroom management (Barkley *et al.*, 2000) and social skills training (Hinshaw *et al.*, 1984) have been developed and although successes are claimed, it is likely that these therapies are most effective for mild cases. As these therapies were derived from techniques used for children with conduct problems, and given the high degree of symptom overlap, it is also possible to assume positive outcomes may be carried by symptoms associated with the comorbid disorder. Notwithstanding this criticism a preschool study has shown parent training improved symptoms – evidenced by clinical and observational measures – which were maintained for 15 weeks and, importantly, were clinically significant in 50% of cases (Sonuga-Barke *et al.*, 2001). It is of particular importance that this study also reported dramatic improvements in mothers' wellbeing.

A statement by the National Institute of Health (2000) concludes that treatment involving medication or psychosocial therapies rarely achieve improvements beyond the core symptoms and although psychostimulants are most effective in treating core symptoms and aggression they do not 'normalise' the entire range of behaviour problems. There is little evidence to suggest psychosocial treatments offer improvements beyond that achieved with medication alone, and the lack of knowledge concerning the causes of AD/HD means there is no strategy for the prevention of AD/HD. Nevertheless, the high risk of mental health and academic problems as well as occupational and social underachievement, together with the generally poor efficacy of a range of treatments, means AD/HD represents a considerable cost to the National Health Service and society. It is suggested that early diagnosis and intervention in the preschool years may offer better outcomes.

1.6. Diagnostic criteria

The Diagnostic and Statistic Manual DSM IV (American Psychiatric Association, 1994) identifies three subcategories of AD/HD: Combined Type, Predominantly Inattentive Type and Predominantly Hyperactive-Impulsive Type, which allows diagnosis on the basis of hyperactive or attentional difficulties. The impulsive subtype is associated with comorbid disruptive disorders and the inattentive subtype with comorbid anxiety, depression and lower intelligence, with the combined type exhibiting the deficits of both in an additive fashion (Willcutt *et al.*, 1999). Symptom differences between subtypes are considered to be due to non-familial, environmental causes because although there is a higher prevalence of AD/HD in relatives of AD/HD probands generally, it is not specific to any one subtype (Faraone, Biederman & Friedman, 2000).

The DSM IV classification has evolved from the early classifications that reflected the relative importance of attention as a central feature of the disorder. The concept of AD/HD can be traced to the minimal brain dysfunction syndrome (MBD) which encompassed behaviour and/or learning problems, through Attention Deficit Disorder (ADD) with-or-without Hyperactivity (DSM III, 1980) which emphasised attention problems as the core feature, and the revised edition which reinstated hyperactivity by proposing a unidimensional definition requiring a minimum of 8 of 14 symptoms in all three domains (overactivity, impulsivity and inattention) to be present for the diagnosis of Attention Deficit Disorder with Hyperactivity ADDH (DSM III-R, 1987). In contrast the other widely used diagnostic manual, the International Classification of Diseases ICD 10 (World Health Organisation, 1994), does not employ the same criteria for a diagnosis, as inattentiveness remains prerequisite (with overactivity and impulsivity being secondary characteristics) for the diagnosis of Hyperkinetic Disorder. This diagnosis only stands in the absence of any other associated disorder. Furthermore, ICD 10 includes pervasiveness as a principle criterion whereas DSM IV accepts inattentive and hyperactive/impulsive impairment in two or more situations and values teacher reports over other sources. These differences in core symptoms, pervasiveness and comorbid disorders may explain variations in epidemiological studies as the ICD 10 diagnosis will obviously identify fewer cases, but it is also noted that changes within a single classification system over time have also resulted in increases in diagnosed cases. Such differences have no doubt confounded the interpretation of research using clinical samples, especially as information concerning the diagnostic criteria is often not specified.

1.6.1. Symptom overlap and comorbid disorders

The symptoms characteristic of AD/HD, ODD and CD are highly correlated and have perhaps a 50% overlap (Hinshaw, 1987). This symptom overlap raises questions about the utility of AD/HD as a discrete diagnostic category as observed deficits may be carried by the secondary diagnosis. However, recent evidence from a large-scale study (N = 498) suggests the core symptoms are high in AD/HD children irrespective of comorbidities including anxiety which is presumed to ameliorate AD/HD symptoms (Newcorn *et al.*, 2001). Comorbid disorders occur in 50%-80% of cases, with ODD and CD being the most frequent comorbidities occurring in 40%-90% of comorbid cases (Jensen, Martin & Cantwell, 1997). This poses a considerable problem for researchers who rarely secure a homogenous sample. Jensen argues that the comorbid condition may not simply co-exist but interact with and change the nature of the disorder. However, there is evidence that neuropsychological deficits observed in AD/HD children with comorbid CD and reading disorder are specific to ADHD and are not accounted for by the comorbid condition (Nigg *et al.*, 1998). The high incidence of comorbid disorders raises issues in terms of assessment methods, which must discriminate AD/HD from other disorders as well as controls. It also suggests that the impact of a comorbid condition needs thorough consideration before claims relating to the impact of AD/HD can be confidently made.

1.6.2. Is AD/HD a discrete disorder?

The category (diagnostic) and continuum (trait) approach has been investigated by Levy *et al.* (1997) who found high heritability estimates for AD/HD (0.75-0.91) which applied equally to those identified by diagnostic category or trait. Hudziac *et al.* (1999) tackled the same question using latent class analysis and found three levels of symptom severity in both clinic and non-clinic samples, and Scahill *et al.* (1999) found AD/HD symptoms in the subthreshold group of a community sample were clinically meaningful. These findings support the notion of AD/HD as a continuously distributed phenomena rather than a discrete category. Such a view implies that AD/HD research should be based on a community sample approach rather than using clinically diagnosed groups. A further indication that community sampling may be appropriate comes from evidence that factors other than AD/HD, such as parental coping, child emotional disturbance and school relationship problems, predicted whether or not an AD/HD child was referred (Woodward, Dowdney & Taylor, 1997). This implies that a clinical sample may differ in systematic ways from a non-referred group in terms of a preponderance of comorbid disorders (Nigg *et al.*, 1998) and these differences will undoubtedly impact upon test performance. It is considered here that children displaying AD/HD-like symptoms are valid subjects for research rather than the clinically diagnosed group, providing the sample can be characterised against population norms for meaningful interpretation.

1.7. Assessment

Clinicians and researchers typically use two assessment methods: behaviour rating scales and clinical interviews. Currently such rating scales and interviews do not have different thresholds for boys and girls.

1.7.1. Behaviour rating scales

Behaviour rating scales are quick to use and easy to apply which make them a valuable tool for clinicians. The Child Behaviour Checklist (CBCL; Achenbach & Edelbrock, 1983) has been widely adopted for the assessment of child psychopathology and rating scales specific to AD/HD have been developed such as the ADHD Rating Scale (DuPaul, 1990). They demonstrate good test-retest reliability, and typically have a stable factor structure regardless of the type of sample, the age of the subject and the rater (Taylor & Sandberg, 1987). Questionnaires have a particular advantage when different informants (usually teacher and parent) are used as this controls for person bias and indicates pervasiveness and situation specificity although lower correlations are often observed between parent and teacher ratings (Achenbach *et al.*, 1987).

The validity of rating scales is more questionable as there is evidence that similar dimensions on different rating scales yield low correlations (Sandberg, Wieselberg & Shaffer, 1980) and high correlations exist between hyperactivity and conduct problem measures on the same scale (Goodman & Stevenson, 1989). Notwithstanding the high co-morbidity between AD/HD and CD, it is possible that rater bias exists (i.e., difficult behaviour gives rise to an expectation of problem behaviour identified in both subscales) which results in the 'halo effect' observed in many studies. One inherent problem with behaviour scales relates to the rater's inability to discriminate between or tease apart complex behaviours (i.e., disruptive behaviour in class may be attributed to either short attention span or non-compliance). Where raters use undifferentiated concepts in their subjective ratings, children with Learning Disability (LD), CD or even clumsiness may erroneously acquire the AD/HD label. Attribution bias may impact on ratings where an intimate knowledge of the child, his or her motivation and the context of the behaviour is taken into account, and this will inevitably lead to low correlations between test performance and child ratings. Multiple informants may minimise this difficulty. A further challenge to validity comes Reid *et al.* (1998) who found African American children were rated as more hyperactive then their caucasian counterparts by teachers using the AD/HD Rating Scale School version. This study showed scales do not perform identically across groups and there is a different relationship between items across groups. Because the rating scale was not conceptually equivalent for different ethnic groups, and a halo effect due to oppositional behaviours was also apparent for the African American group, it is clear that factors other than behaviour affect AD/HD ratings.

Nevertheless, within a homogenous sample many rating scales have performed well. The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) has proved a powerful discriminative tool, comparing favourably with the longer CBCL in discriminating psychiatric cases and superior at detecting inattention and hyperactivity (Goodman & Scott, 1999). The SDQ is standardised in the normal population and will be encountered later in the thesis.

1.7.2. Clinical interviews

A clinical interview overcomes the aforementioned threats to validity. Greater objectivity is introduced as the experimenter makes a judgement about the presence of target behaviours based on the descriptions of the child's behaviour by the parent. A structured interview allows detailed questioning of the informant to establish the severity and frequency of a range of behaviours whilst taking account of salient contextual cues (e.g., an abrasive relationship with a particular sibling which impacts on aggression ratings). Most importantly, the clinical interview refers to the behaviours in multiple defined settings, which indicates situation specificity and pervasiveness and further informs the interviewer as to the typicality of the behaviour in question. The acknowledged difficulty of the clinical interview is low inter-rater reliability but this can be improved with the introduction of specific definitions of behaviour and key lines of questioning. The Parental Account of Childhood Symptoms (PACS) developed by Taylor, Schachar and Heptinstall (1993) has yielded inter-rater reliability scores of 0.9 (Taylor *et al.*, 1986) and the preschool version PPACS of the original has yielded similar results (Sonuga-Barke *et al.*, 2001). The PPACS will be encountered later in the thesis.

1.8. Preschool AD/HD

Despite the assumption that AD/HD develops during the preschool years, with DSM IV claiming onset before the age of 4, relatively few studies have investigated the nature and course of AD/HD in preschoolers (Campbell *et al.*, 1984). Parents identify AD/HD preschoolers as restless and highly active, frequently having difficulties sleeping, and prone to tantrums; even at this early stage of social development such children display a marked lack of empathy (Prior, Leonard & Wood, 1983). This overactivity and restlessness was found in 13% of 3-year-olds in an epidemiological study, and was related to behaviour problems at age 8 (Richman, Stevenson & Graham, 1982). It appears that preschool AD/HD is reminiscent of school-age AD/HD in terms of symptoms severity, comorbid psychopathology and impaired functioning (Wilens *et al.,* 2002). Such children are at risk for later delinquency, substance abuse and academic failure as shown in longitudinal studies (Biederman *et al.*, 1996; Manuzza *et al.,*1993). This risk to future development is now confirmed in several studies which find stability and continuity of preschool AD/HD symptoms through school entry (Winsler *et al.*, 2000; Shelton *et al.*, 1998; Campbell, Endman & Bernfeld, 1997; Sonuga-Barke *et al.*, 1997; Campbell, 1994) and into adolescence where up to 75% still met criteria for AD/HD and other psychiatric disorders (McGee *et al.*, 1991). The high risk nature of preschool AD/HD is not only confined to the individual but also involves risk to the parents of AD/HD preschoolers who are more likely to develop psychological problems (Shelton *et al.*, 1998) and to society in general as externalising problems at age 3, particularly overactivity and temper tantrums, are specifically associated with adult criminality (Stevenson & Goodman, 2001).

Although Campbell and colleagues suggest preschool children exhibit behavioural rather than cognitive difficulties, and Hughes *et al.* (2000) find antisocial behaviour and peer problems are not secondary to cognitive problems, preschool AD/HD children exhibit deficits in planning and inhibition (Hughes *et al.*, 2000; Hughes, White and Dunn, 1998) and working memory (Mariani & Barkley, 1997). This may account for lower academic achievement observed in AD/HD preschoolers which is particularly resistant to behavioural intervention (Barkley *et al.*, 2000) despite the efficacy of preschool parent training in reducing behavioural symptoms (Sonuga-Barke *et al.*, 2001). As in older children, preschool AD/HD is associated with low IQ, low socio-economic status and family adversity (Sonuga-Barke *et al.*, 1996; Campbell, 1994) and this may be a confound as Hughes *et al.* (2000) found planning deficits were not significantly associated with hyperactivity after IQ and SES were accounted for.

Certainly the evidence suggests that hyperactivity can be reliably measured in preschool children, that such measures differentiate externalising from internalising problems, and are predictive of differential outcomes (Mesman, Bongers & Koot; 2001; Sonuga-Barke *et al.*, 1997; Campbell, 1994). Preschool behaviour problems cluster in meaningful ways although Sonuga-Barke points out that clinically significant levels of disturbance are usually associated with comorbid disorders. The validity of preschool AD/HD is further supported by Baving, Laucht and Schmidt (1999) who confirmed atypical frontal activation in AD/HD children as young as 4 years. Behavioural and social problems characterise the preschool syndrome which, in most cases, persist into adolescence and although cognitive deficits in any single domain are less well established, lower IQ is relatively specific to AD/HD and not ODD and CD (see Hinshaw, 1992, 1987, for reviews).

1.9. Causes of AD/HD

The dominance of the medical model has generated the search for pathological causes of AD/HD and recent advances in technology have led to a plethora of studies attempting to locate specific areas in the brain which map onto behaviours associated with AD/HD. Although causality cannot be established because differences in the structure and function of the brain may be a consequence, rather than cause, of behaviour and experience, the brain-behaviour associations have theoretical and practical implications in terms of models which seek to explain the process underpinning AD/HD, and the treatment of the disorder. Thus a range of theories that seek to explain the causes of AD/HD are not necessarily mutually exclusive; many are overlapping and all seek to ground explanations in terms of underlying psychopathology. A useful framework in which to consider the various accounts of AD/HD is the Morton and Frith (1996) Model of Causal Explanations. This model distinguishes between different levels of analysis that are primary/biological (eg., AD/HD is explained by a single or multiple biological cause such as genes, diet or environment) or intermediate/cognitive (eg., AD/HD is explained by a single cognitive construct such as inhibitory control, executive function or motivation/arousal). Within this framework, explanations at one level of analysis are not comparable with those at other levels so they do not compete with each other. It is possible that single or multiple biological causes may underpin those cognitive processes at the intermediate level therefore a pathological account of the symptom genesis is intact. Equally a single psychological system may explain the observed deficiencies in terms of maladaptive, but not necessarily pathological, behaviours.

1.9.1. Primary causal explanations

Primary causal explanations are concerned with brain structures and functions. Historically the frontal lobes have been implicated in AD/HD due to the pattern of deficits that appear similar to those found in brain-damaged adults.

1.9.1.1. Genetic

Family genetic studies have established evidence for a strong genetic component for AD/HD. Twin studies estimate heritability for both high activity levels and attention deficits (Stevenson, 1991; 1992) and estimates range from 71% (Kuntsi & Stevenson, 2001) to 90% (Levy *et al.*, 1997) based on parent ratings. These studies find estimates based on teacher ratings are consistently lower although still significant, which possibly reflects rater bias. High risk assessment studies of children of parents with adult AD/HD also support the genetic model, finding 57% of at-risk children met criteria for AD/HD of whom 75% were referred for treatment (Biederman *et al.*, 1995). Studies that attempt to locate a candidate gene have had encouraging results with the increased prevalence of the 7-repeat allele polymorphism of the DRD4 gene associated with novelty-seeking behaviour in AD/HD adults (La Hoste *et al.*, 1996). Whilst there is evidence for a genetic component to AD/HD, it is not sufficient nor has it been established that it is a necessary condition. In particular it is not possible to ascertain that there is a gene affecting executive performance as non-referred siblings of AD/HD children show only a general trend to poor executive functions, not a significant dysfunction, which may be construed as an environmental effect (Seidman *et al.*, 2000). This is supported by Kuntsi and Stevenson (2001) who have found genetic effects for variability in task performance on the SST but not delay and working memory (WM) tasks.

1.9.1.2. Neurobiological

Neurobiological studies have focused on the right prefrontal cortex of the caudate nucleus in the striatum. Studies employing Positron Imaging Topography (PET) and Magnetic Resonance Imaging (MRI) have attempted to map brain structure and cerebral activation in AD/HD children. Results have established that there are changes in the structure and function of the right frontal cortex in AD/HD (Castellanos *et al.*, 1996) which, in terms of SST performance, results in both poor initiation of response inhibition and poor processing of 'Go' signals. (Pliszka, Liotti & Woldorff, 2000). It remains unclear whether these changes are indications of inhibitory control problems or orienting of attention which precedes inhibition (Brandeis *et al.*, 1998). The differences observed in normal and AD/HD prefrontal activation are attributed by some researchers to delayed maturation of the prefrontal cortex (Rubia *et al.*, 2000).

1.9.1.3. Neurochemical

Neurochemical studies have focused on the role of dopamine, largely because the stimulant drug methylphenidate (Ritalin) impacts upon dopamine systems. Evidence from neurological studies suggests there is no brain damage per se, but hypo-efficient dopamine systems producing neurochemical imbalances (Sagvolden & Sergeant, 1998). Sagvolden proposes that genetically-based hypodopamine function results in a shorter delay-of-reinforcement gradient and an altered reinforcement process. In this case, AD/HD children require immediate rewards to shape behaviour. This shorter reinforcement gradient is observed in spontaneously hypertensive rats (SHR) and AD/HD children (Sagvolden *et al.*, 1998; Sagvolden *et al.*, 1992).

The role of seratonin has also been investigated and several studies have suggested that delay tolerance, and therefore behavioural impulsiveness in terms of both delayed reinforcement and delayed response, is associated with deficient functioning of the seratonin uptake inhibitor (5-HT) pathways in the brain in rats (Bizot *et al.*, 1999; Ho *et al.*, 1998). The evidence for increased impulsivity in humans after exposure to the recreational drug 'Ecstacy' further supports this hypothesis as the drug is known to reduce seratonin levels (Morgan, 1998).

1.9.2. Intermediate causal explanations

The causal explanations at the intermediate level are concerned with processes, but in most cases explanations involving hypothetical processes are still embedded in primary level explanations as biological and neurological evidence is used to validate the hypothetical construct. Despite this, recent research has challenged the notion of brain dysfunction or specific neurological precursors of AD/HD, supported by evidence from studies utilising behavioural rather than neuropsychological tests which demonstrate that attentional and inhibitory deficits associated with AD/HD are not constant, but vary with changes in the environment.

1.9.2.1. AD/HD as poor regulation of state

Jaap van der Meere argues that AD/HD children do not suffer attentional deficits in a range of tasks designed to tap orientation, re-orientation and sustained attention (van der Meere, 1996). AD/HD children's task performance is sensitive to stimulus presentation rates, where slow presentation rates elicit slow-inaccurate responding and fast presentation rates elicit fast-inaccurate responding (van der Meere, 1995). Using Sanders 1983 cognitive energetic model as a conceptual framework, this temporal sensitivity in explained in terms of the arousal/activation/effort state system. The normal development of state regulation in early school years was demonstrated using the Go/No-go task with younger children (age 7/8 years) displaying poor impulse control compared to older children (age 9/12 years). AD/HD children are presumed to have non-optimal levels of arousal which, under conditions of low stimulation, impact upon the activation system resulting in motor-output deficiency (van der Meere & Stemerdink, 1999).

1.9.2.2. AD/HD as a failure of the behavioural inhibition system

Using Gray's activation/inhibition model as a conceptual framework, Quay (1997; 1989) argues that AD/HD is a failure of the frontal and temporal limbic lobe-mediated behavioural inhibition system (BIS). In this case the BIS, which is activated by punishment and non-reward, is underactive in AD/HD resulting in an increase in failures of passive avoidance. Although this theory is not specific to AD/HD and makes predictions regarding internalising/externalising disorders generally, it is supported by evidence from SST and Go/No-go inhibition tasks which are consistently found to differentiate hyperactives from normal controls (Rubia *et al.*,

1998) although evidence using the same tests suggests there is a more pervasive impairment of cognitive functioning than inhibition alone (Oosterlaan, Logan & Sergeant, 1998).

1.9.2.3. AD/HD as delay aversion

In a novel framework Sonuga-Barke (1994) challenges the notion of inhibition deficits and asserts that, when viewed in context, apparent impulsive acts are functional in terms of delay reduction. This is supported by studies showing AD/HD children capable of inhibiting responses on a range of inhibition tasks (Sonuga-Barke *et al.*, 1996; Sonuga-Barke *et al.*, 1991). The Delay Aversion (DA) model proposes that AD/HD children acquire a behavioural style that is explained by their need to avoid or reduce the subjective experience of waiting during periods of delay. This aversion to delay is assumed to be underpinned by conditioning, but may arise from temporal processing deficits.

1.9.2.4. AD/HD as executive dysfunction

As the frontal cortex is associated with executive functioning and AD/HD performance on executive function (EF) tasks is similar to that of brain damaged adults, Barkley interprets AD/HD as an executive dysfunction disorder arising from a failure of the inhibition system. This influential executive dysfunction (EDF) model remains the most widely accepted account of AD/HD and is supported by findings of consistent performance deficits in AD/HD children on a range of EF measures. However, executive and frontal tasks are not the same thing. Although functional equivalence is assumed on the basis of the presumed theoretical link between frontal brain regions and executive performance, it is accepted that all executive functions may not be prefrontal, and not all prefrontal function is executive (Denckla, 1994; Welsh, Pennington & Groisser, 1991).

1.10. Chapter summary

It has been established here that AD/HD represents a heterogeneous population with regard to the variability of the symptom cluster, the degree of impairment and the associated comorbid disorders. The wisdom of employing a community sampling approach in AD/HD research has been discussed and multiple assessment methods examined. The existence of preschool AD/HD has been supported by behavioural and neurological evidence. Theories which seek to explain AD/HD at the primary and intermediate level have been briefly introduced with the purpose of demonstrating the recent trend towards motivational accounts of AD/HD. Motivational theories have not necessarily challenged the traditional neurological theories but they have demonstrated that, when different paradigms are applied, the assumptions of gross deficits underpinning the symptom triad may not be upheld.

The aim of this research is to investigate the relationship between cognitive and motivational factors and AD/HD. The basis for this investigation will be the claims made by two models: the dominant model which implicates cognitive factors in AD/HD (Barkley's EDF model), and the most radical alternative which implicates motivational factors in AD/HD (Sonuga-Barke's DA model). Chapter Two will describe the models in detail so the context and rationale for the studies presented in this thesis may be clearly specified.

CHAPTER TWO: COGNITION AND MOTIVATION IN PSYCHOLOGICAL MODELS OF AD/HD

2.1. Introduction

This chapter seeks to establish a line of reasoning that underpins the experiments presented in this thesis. It will explain the emergence of the dominant model of AD/HD and review the empirical evidence that has supported this model. It will raise questions regarding that which is not explained by the EDF hypothesis and explore alternative paradigms that extend the scope of research and highlight the role of non-cognitive variables in AD/HD performance.

2.2. The relationship between the medical model and the neuropsychological paradigm

The medical model is the conceptual framework derived from medical science and based on identification, assessment, categorisation and treatment of biologically based illnesses. Sonuga-Barke (1998) has argued that this model embodies certain assumptions, namely that childhood disorders are categorical and dysfunctional. In this sense AD/HD children are viewed as qualitatively different from non-AD/HD children, and the AD/HD symptom cluster is regarded as the manifestation of a disorder, distinct from other disorders, which is underpinned by neuropsychological dysfunction. These assumptions constitute the pragmatic basis of clinical practice but also inform the science of psychopathology. The assumptions determine the research questions asked, the methods used and the interpretations given to results. Consequently the AD/HD endophenotype is characterised by endogenous psychological dysfunction associated with specific neuro-cognitive impairment and standard neuropsychological tests, which are purported to reflect specific aspects of brain function, are applied to AD/HD children and deficits are attributed to dysfunction in that domain.

2.3. The relationship between the neuropsychological paradigm and the executive dysfunction hypothesis

The influence of the medical model can be seen in the dominance of the EDF model of AD/HD. EF is conceptualized as goal-directed behavior, defined as appropriate set maintenance to achieve a future goal, and operationalised as planning, impulse control, organized search and flexible strategy employment (Barkley, Grodzinsky & DuPaul, 1992). EF may also be construed as working memory in tasks where a delay between the stimulus and response requires maintenance of internal representations (Goldman-Racik, 1987). Simply put, EFs are higher-order, top-down cognitive processes. Such processes are typically seen as mediated by the prefrontal brain region, although it may transpire that not all EFs are prefrontal and not all prefrontal function is executive (Welsh, Pennington & Groisser, 1991). This neuroanatomical association has created the basis upon which the developmental sensitivity and construct validity of EF assessment is considered (Denckla, 1994). However it is not possible to assume that specific measures of EF are 'pure' measures. Clearly the measures involve to a greater or lesser extent input from other domains (e.g., they are multifaceted tests which are likely to tap more than a single function).

From this neuropsychological perspective much evidence has been adduced for EF deficits in AD/HD children (Barkley, Grodzinsky & DuPaul, 1992) arising from abnormalities within the frontal and prefrontal brain regions (Swanson *et al.*, 1998). A recent review by Hendren, De Backer and Pandina (2000) has largely supported this claim, finding evidence in a range of neuroimaging studies for disturbed cortical activity in AD/HD. This evidence has generated theories that seek to explain AD/HD in terms of the underlying psychopathology, and the specific links between EDF and core AD/HD symptoms. The dominant model developed by Barkley (1997b) regards disinhibition as the primary deficit in AD/HD which leads to secondary impairments in four executive neuropsychological abilities which are dependent upon inhibition for their effective functioning. Before looking in detail at the model it is helpful to outline the nature of those EFs.

2.4. The domains of executive functions

Models of EF structure are broadly of two types. Unified models emphasize a particular component such as inhibitory control (Barkley, 1997) and fractionated models emphasize a number of potentially dissociable processes (Shallice, 1982). In childhood and adolescence, support for the latter model is found from three sources. The first is derived from the study of intercorrelations between measures of EF. Welsh , Pennington and Groisser (1991) factor analysed data from several studies that utilized neuropsychological and developmental measures of EF to identify three distinct aspects of EF: working memory (WM), inhibitory control and attentional flexibility (AF). Although Hughes (1998a) advises caution since factor analysis is notoriously unstable, Denckla (1994) argues that EF is better viewed as a domain, not a unit, and functions within this domain may not always be associated. A second line of support for the fractionated model is the finding of different developmental trajectories for different skills. Denckla (1994) asserts that EFs cleave along developmental lines and several studies (Gnys & Willis, 1991; Levin *et al.*, 1991, Welsh, Pennington & Groisser, 1991) have shown that the developmental trajectories of different executive skills in 6- to 12-year-olds have different patterns of plateaus and inflection points. The third form of evidence for fractionation is the finding of different patterns of associations between various measures of EF and other variables such as IQ and behavioral status (Tannock & Schachar, 1996). Indeed, Pennington and Ozonoff (1996) suggest that different patterns of pathology in childhood are associated with different EFs. For example, they argue that executive deficits can be observed in a range of different conditions, such as AD/HD, autism and CD, whose diverse etiologies produce different forms of executive dysfunction. The key areas for study are those functions which have been identified as specific domains of executive functioning in factor analytic studies.

2.5. Executive dysfunction and AD/HD

It has been previously stated that cognitive deficits observed in AD/HD children are similar to those seen in adults with frontal lesions. The following sections will examine Barkley's explanation of the relationship between EDF and AD/HD.

2.5.1. Barkley's Executive Dysfunction Model

Barkley claims that current AD/HD research is nearly atheoretical, and he has attempted to construct a unifying account of the various cognitive deficits associated with AD/HD (Barkley, 1997). Douglas (1983) had previously specified four major cognitive deficits associated with AD/HD: (a) poor investment and maintenance of effort, (b) deficient modulation of arousal, (c) preference for immediate reinforcement, and (d) poor impulse control, which were attributed to a central impairment in self-regulation (Douglas, 1988). From this largely descriptive work, Barkley (1995) sought an explanation, grounded in the neuropsychological functions of the prefrontal lobes, for this pattern of deficits. In doing so, he theorised about the primacy of behavioral inhibition and the specific nature of the relationship between inhibition and the four cognitive components that contribute to an individual's capacity for self-regulation.

The model is a hybrid of two theories, Bronowski's Theory on the Uniqueness of Human Language (1977) and Fuster's Theory of Prefrontal Functions (1989). The former highlighted the capacity of humans to reflect (e.g., delay not only responses but also the decision to respond) which facilitates reference (working memory), objectivity (separation of affect), consideration of alternatives through inner dialogue (private speech), and analysis and synthesis of information (reconstitution). As these four functions were attributed to the frontal lobes, it was deemed an appropriate link with AD/HD, which was associated with the same brain region. Fuster's theory highlighted the involvement of the prefrontal cortex in the co-ordination, organising and sequencing of behaviour across time, claiming that prefrontal involvement is necessary for the development of novel behaviour structures and the linking of behaviour structures across time. This retrospective and prospective function is similar to WM, which Fuster agrees is vulnerable to poor interference control and insufficient critical thinking time. Crucially both theories hold that time perception would be dependent on WM therefore a link to anticipation and preparation of motor responses is made. Barkley reasoned that executive control is not necessary for the display of basic motor responses but is implicated where novel, complex behaviours with cross-temporal structure are involved.

Barkley's 1997 model is presented within a hierarchical framework (see Figure 2.1). The essential deficit is that of behavioural (response) inhibition. Behavioural inhibition in this context comprises three interrelated processes: (a) inhibition of an initial prepotent reponse, (b) stopping of ongoing responses, and (c) interference control. Because inhibition is necessary in the first instance to allow the time in which to use further self-directed executive actions, it is a prerequisite for their efficient functioning. This primary inhibition deficit therefore leads to secondary deficits in four neuropsychological domains by impeding performance as inhibition occasions the opportunity for executive action. These four domains are comprised of self-regulatory functions (a) working memory, (b) self-regulation of motivation/arousal, (c) internalisation of speech, and (d) reconstitution.

These EF deficits then result in decreased motor control because motor control is contingent upon the internally represented information in these four domains. Motor control is also directly influenced by behavioural inhibition. Thus sensitivity to errors, preparation to act and inhibition of inappropriate responses are functions which, if disrupted, lead to distractibility, hyperactivity and impulsivity.

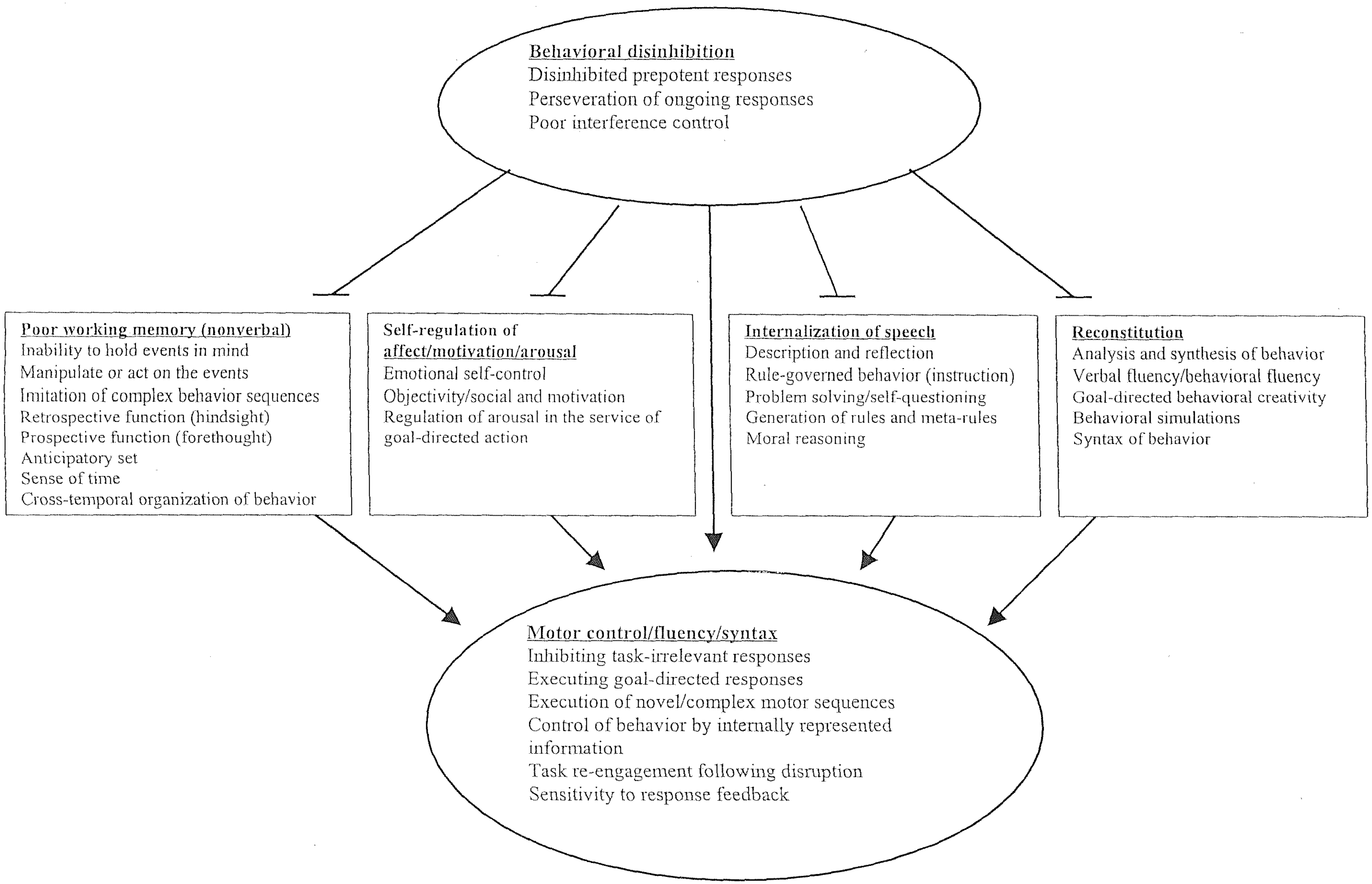

Figure 2.1. A schematic configuration of a conceptual model that links behavioral inhibition with the performance of the four executive function that bring motor control, fluency, and syntax under the control of internally represented information. Barkely, R.A. (1997b). JDBP/August, Vol,18.No,4. Reprinted with permission from the author.

According to this model inattention is perceived as a behavioural manifestation of decreased motor control rather than a true deficit, and the theory does not attempt to account for the predominantly inattentive subtype which is considered qualitatively different than the hyperactive-impulsive or combined types.

Within this model, the hyperactive-impulsive type is seen as a developmental precursor to the combined type, the former being found mainly among preschool children and the latter chiefly in school-age children (Hart *et al.*, 1995). The predominantly inattentive type appears later still and is considered a qualitatively different deficit from the inattention reported in the other two subtypes and associated with deficits in speed of information processing and focused selective attention (Goodyear & Hynd, 1992; Lahey & Carlson, 1992; Barkley, 1990). The dissociation between subtypes is supported by studies that have compared the combined type with inattentive type AD/HD and found a different pattern of impairment for each (Klorman *et al.*, 1999). This partially explains why attention deficits are not found in AD/HD children when the selection criteria do not differentiate between subtypes (Scachar *et al.*, 1993; Sergeant & van der Meere, 1988) and why results from studies purportedly assessing frontal functioning do not find consistency in the pattern of deficits.

The model has particular importance in that it allows specific predictions to be tested, two of which are of special interest in the context of this thesis. Firstly, the model holds that behavioural inhibition is the central impairment found uniquely in AD/HD. Although evidence would suggest that measures of temperament in children as young as 3 years has predictive validity for later externalising disorders (Campbell *et al.*, 1982; Caspi & Silva, 1995) it remains unclear whether disinhibition is uniquely associated with AD/HD, nor whether it is always present in AD/HD. Secondly, the model predicts that cognitive deficits will be evident in multiple EF domains and these domains will be interrelated. The evidence for these hypotheses will be considered in the following section.

2.5.2. Evidence for the executive dysfunction hypothesis

This section takes the form of a literature review of EF research over the past 5 years (1997-2001). Pennington and Ozonoff's (1996) paper reviews the literature up to this point in time. To reiterate, Barkley's model assumes deficits in the four domains of EF which have been identified in factor analytic studies as distinct from each other: inhibition, WM, planning and AF, with behavioural disinhibition as the necessary underpinning feature. Following this structure, evidence for deficits in each domain will be examined. A general EF literature search using Web of Science (BIDS) generated over 60,000 articles, and it was necessary to refine the search. Exploratory searches revealed a single search term to be unhelpful due to the many different terminologies used (e.g., inhibition, disinhibition, inhibitory deficits, self-control, etc.) and the use of generic terms (e.g., planning). Several independent searches were conducted and the lists generated were cross-referenced to ensure the maximum number of relevant articles were captured. Thus, searches were made using the following paths:

(i) executive function*, hyperactiv* and children (118 hits)

(ii) tower of london, hyperactiv* and children (70 hits) combined with planning, hyperactiv* and children (82 hits)

(iii) working memory, hyperactiv* and children (80 hits)

(iv) inhibition, hyperactiv* and children (25 hits)

(v) cognitive flexibility, hyperactiv* and children (46 hits) [Note: Attention* flexibility as a substitute for cognitive flexibility generated an identical list]

The articles included in the tables below were selected on the basis of the abstract specifying (a) an AD/HD experimental group (b) a control group (c) identifiable measures of specific executive functions, and (d) an analysis of group differences on task scores. Studies using school-age participants were included in the tables below and those using preschool participants are dealt with separately in the following chapter. It is acknowledged that many studies of interest did not meet these criteria (e.g., papers which partialled out the effects of comorbid AD/HD, or used physiological measures rather than task scores in analysis). However, the following tables incorporate a range of papers across the four domains and represent a good proportion of AD/HD-EF research. In each case the table is preceded by a brief resume which also refers to helpful papers that did not meet the inclusion criteria and are not included in the tables.

2.5.2.1. Inhibition

According to Barkley, inhibition deficits should be central to, and uniquely associated with, AD/HD. The following review assesses the extent to which recent research has supported this claim generally, and questions whether observed deficits are context dependent (e.g., motivational) or associated with other disorders.

Barkley (1997a) proposed three forms of response inhibition: (1) inhibiting a prepotent response, (2) stopping an ongoing response, and (3) inhibiting interference. Inhibition has typically been assessed using the Go/No-go SST, Reversal Tasks and the Stroop Task which, broadly speaking, reflect these capacities. The Go/No-go task is a reaction time task which requires a subject to respond positively to a Go stimulus (e.g., the letter 'Q') but refrain from responding to the No-go stimulus (e.g., the letter 'O'). The ratio of Go to No-go signals is typically 4:1 so the prepotent response is established. The SST, originally developed by Logan, Cowan and Davis (1984) is conceptually similar to the Go/No-go task but the stop signal occurs *after* presentation of the Go stimulus, so the subject must inhibit an initiated response. The Reversal tasks typically require subjects to reverse a previously learned response. The Stroop test assesses the ability to inhibit a previously salient feature (word) to name the colour in which the word is printed. Barkley asserts that as these tests assess the ability to inhibit a motor response - and in some cases perform a competing response - and as response inhibition is thought to be mediated by the frontal lobes, *by inference* AD/HD is a disorder of disinhibition arising from dysfunction in these brain regions (Barkley, 1992; pp. 173).

Studies employing the Go/No-go task have generally shown AD/HD children make more total errors and omission errors than controls. However, the measured variables which reflect (dis)inhibition are accuracy on inhibition trials (commission errors) and

P(i) (commission errors as a proportion of the No-go trials) and group differences reported here derive from either of these variables. Extensive reviews by Barkley (1992) and Pennington and Ozonoff (1996) find consistent evidence for inhibition deficits on this task, and AD/HD task performance appears to improve with stimulant medication (Trommer, Hoeppner & Zecker, 1991). This robust finding is well supported in the papers under review here, with two out of three (66%) studies reporting significant group differences.

Deficient inhibitory control has also been confirmed in AD/HD children using the SST (Schachar *et al.*, 2000; 1995; Schachar, Tannock & Logan, 1993; Schachar & Logan, 1990). In the studies under review group differences were demonstrated using one of the following units: stop signal reaction time or probability of inhibition (P(i) = efficiency of the inhibitory mechanism controlling for MRT). Using this format, 79% of studies under review that employ SST find deficits in AD/HD children despite MRT differences confirmed in only 50% of these. Although this is an impressive finding it is worth noting that despite Oosterlaan and Sergeant's (1998a) assertion that reward and response cost (the addition or subtraction of a credit) did not impact upon task performance, a later study found group differences were eliminated with the introduction of greater incentives e.g., five credits (Slusarek *et al.*, 2001). This suggests that motivational variables do play a role in task performance even on this robust measure. A further caveat concerns the uniqueness of inhibitory problems which Purvis and Tannock (2000) find in children with Reading Disorder (RD).

Inhibition deficits are found in 67% of studies employing a reversal task (including the Stroop Task), but it is interesting to note that the Stroop Task dependent measure in this case was the color-word interference score. Half of the studies reporting group differences on this measure did not also find differences using the interference score. Studies using CPT (including paper cancellation/underlining) also purport to measure inhibition of salient but distracting information in the traditional signal-detection format. Of the studies under review that employ CPT, deficits are found in only 54%. Interestingly Oades (2000) highlighted the differences between computer-based tasks and paper tests where the former are more likely to elicit group differences. Exactly why this is so remains unclear but it is possible the tasks make different demands in terms of stimulus detection. It is also noted here that certain forms of CPT (e.g., the 'ax' version) involve a WM load that the single signal versions (e.g., the 'x' version) do not, but there is no evidence here that suggests this has any significant impact to findings.

Certain studies have employed alternative measures of inhibition, notably delay tasks which manipulate pre-response and pre-reward delay. Of the three studies employing a delay paradigm, all found deficits in AD/HD children. This suggests delay measures are tapping a salient feature of AD/HD performance and delay, which is inherent in many tasks, should not be ignored. A case has been made for the use of MFFT as an inhibition task based on the assumption that it also requires the inhibition of a previous response set. In this task a subject matches a sample picture to one exactly like it in an array of distracter pictures. Of the studies under review, 66% find deficits in AD/HD children.

These diverse findings possibly reflect the different aspects of inhibition each measure is tapping. This is illustrated by Olsen, Schilling and Bates (1999) who confirmed inhibition deficits in AD/HD children using a range of inhibitory measures which, when factor analysed into subdimensions, reflected executive control, delay of gratification and effort/motivation. The authors claimed a composite score across all domains had validity (consistent with maternal ratings of inhibition) and long-term predictive value. Bayliss and Roodenrys (2000) make a further distinction between disinhibition and impulsivity, suggesting AD/HD children do not have difficulties inhibiting when there is no strongly activated schema, but they do have difficulty in inhibiting strongly triggered responses.

Table 2.1. Review of inhibition studies

(please note this table is continued over the page)

AUTHORS	TASKS EMPLOYED	SAMPLE SIZE	SAMPLE AGE/GENDER	SIGNIFICANT GROUP EFFECTS	OTHER FINDINGS
Adams & Snowling, 2001	(1) Reversal task (2) Cancellation task	21 AD/HD 21 controls	8-11 mixed	Yes (ES = 2.52) Yes (ES = 0.68	No differences in MRT
Bayliss & Roodenrys, 2000	(1) Reversal task (2) Hayling Sentence Completion (3) Random Generation	15 AD/HD 15 control	8-12 mixed	Yes (ES = 0.81) No Yes (ES = 2.98)	
Borger & van der Meere, 2000	(1) Go/No-go	28 AD/HD 22 control	7-12 boys	No	Differences in MRT
Casey et al., 1997	(1) Discrimination task (MFFT) (2) Reversal task (3) Go/No-go	26 AD/HD 26 control	6-13 boys	Yes (ES = 166.67) No Yes (ES = 266.67)	Differences in MRT Differences in MRT
Cornoldi et al., 1999	(1) MFFT	28 AD/HD 28 control	11-14	Yes (ES = 8.12)	Differences in MRT
Houghton et al., 1999	(1) MFFT (2) Stroop	94 AD/HD 28 control	6-12 mixed	No Yes (ES = 0.48)	No differences in interference score
Konrad et al., 2000	(1) SST (2) Delayed Response	31 AD/HD 26 control	8-12 mixed	Yes (ES = 0..97) Yes (ES = 0.13)	No differences in MRT in both task. TBI children more impaired than AD/HD
Kuntsi , Oosterlaan & Stevenson, 2001	(1) SST (2) Choice delay task	51 AD/HD 119 control	7-11 mixed	No Yes (ES = 1.70)	Differences in choice delay task eliminated when conduct problems covaried

Manassis, Tannock & Barbosa, 2000	(1) SST	15 AD/HD 16 control	8-12 mixed	No	
Nigg, 1999	(1) SST	25 AD/HD 25 control	1-6th grade mixed	Yes (ES = 1.32)	No differences in MRT. ES greater for girls than boys
Nigg et al., 1998	(1) Cancellation task	42 AD/HD 71 control	6-12 boys	Yes (ES = 0.48)	
Oades, 2000	(1) Computer CPTx (2) Computer CPTax (2) Cancellation task	14 AD/HD 14 control	7-14 mixed	Yes (No ES) Yes (No ES) No	
Oosterlaan & Sergeant, 1998a	(1) SST	14 AD/HD 21 control	7-13 mixed	Yes (ES = 0.79)	Differences in MRT. Disruptive and anxious groups also impaired (ns)
Oosterlaan & Sergeant, 1998b	(1) SST	10 AD/HD 21 control	8-12	Yes (No ES)	
Oosterlaan, Logan & Sergeant, 1998	(1) SST Meta analysis	8 studies	6-12 mixed	Yes (ES = 0.94)	
Overtoom et al., 1998	(1) CPTax	16 AD/HD 16 controls	6-14 boys	No	Differences in impulsivity, not attention scores
Perugini et al, 2000	(1) Connor's CPT (2) Stroop	21 AD/HD 22 control	6-12 boys	Yes (ES = 1.29) *composite score used* No (trend)	Controls made more impulsive (commission) errors
Pliszka et al, 1997	(1) SST	14 AD/HD 13 control	6-12	Yes (ES = 2.00)	Differences in MRT and errors
Purvis & Tannock, 2000	(1) SST (2) Conner's CPT	17 AD/HD 17 control	7-11 mixed	Yes (ES = 0.50) Yes (ES = 0.39)	Differences in MRT on both tasks.
Rubia et al., 1998	(1) SST	11 AD/HD 11 control	6-12 boys	Yes (no ES)	Differences in MRT and errors
Rubia et al., 2001	(1) Go/No-go (2) SST (3) Reversal task	16 AD/HD 23 control	7-15 mixed	Yes (ES = 1.54) Yes (ES = 1.09 Yes (ES = 1.08)	No differences in MRT in any task
Schachar et al., 2000	(1) SST	72 AD/HD 33 control	7-12 mixed	Yes (ES = 0.89)	Differences in MRT
Scheres, Oosterlaan & Sergeant, 2001	(1) SST	24 AD/HD 41 control	7-12 mixed	No	Differences in MRT not errors
Seidman et al., 1997a	(1) Stroop (2) Auditory CPT (3) Cancellation test	43 AD/HD 36 control	6-17 girls	No No No	Differences in MRT, not accuracy, when comorbidities controlled for
Seidman et al., 2000	(1) Stroop (1) Auditory CPT (2) Cancellation test	40 AD/HD 118 control	6-17 mixed	Yes (ES = 0.74) No No	No differences in interference score
Semrud-Clikeman	(1) Stroop	10 AD/HD 118 control	6-17 mixed	Yes (ES = 1.46)	No difference in interference score
Slusarek et al., 2001	(1) SST	33 AD/HD 33 control	6-14 mixed	Yes (ES = 0.66)	Large incentives eliminate group differences
Solanto et al., 2001	(1) SST (2) Choice delay task	56 AD/HD 29 control	7-10	Yes (ES = 1.40) Yes (ES = 0.88)	
Van Leeuwen et al., 1998	(1) CPTax	11 AD/HD 9 control	9-12 boys	Yes (no ES calculated)	No RT differences, only hits and false alarms
Wiers, Gunning & Sergeant, 1998	(1) Door opening task	26 AD/HD 34 control	7-11 boys	Yes (ES = 1.25)	No differences in perseveration
Williams et al., 2000	(1) Rapid visual information processing (CANTAB)	10 AD/HD 10 control	6 mixed	No	

Note: ES = effect size (mean exp – mean control) / SD control

2.5.2.2. Working memory

According to Barkley, WM deficits are the inevitable consequence of core inhibitory deficits in AD/HD. Inhibition is seen to impact upon WM in two ways: Firstly, the lack of inhibitory control leads to distraction with task-irrelevant information and subsequent problems in accessing and activating task-relevant information (Stoltzfus, Hasher & Zacks, 1996) and secondly, deficient inhibitory control will impact upon controlled/intentional processing under conditions of conflict or interference and is therefore an executive problem (Engle, 1996). This review will examine the extent to which recent research supports the notion of WM deficits in AD/HD generally, and considers whether observed deficits are general or domain-specific, context dependent and unique to AD/HD.

Of the studies under review and reported in Table 2.2., 46% found WM deficits in at least one aspect of WM. Such deficits appeared to persist even when information about the task was given (Cornoldi *et al.*, 1999 Experiment 3) and only improved when strategic support was given (Cornoldi *et al.*, 1999 Experiment 2). These findings suggest a deficit in the executive component in AD/HD rather than a factual or knowledge-based difficulty, which concurs with Karatekin's (2000) findings. If attentional difficulties manifest themselves as memory deficits it is unsurprising that two studies that investigated medicated vs. non-medicated AD/HD performance found WM 'deficits' reversible with medication (Barnett *et al.*, 2001; Kempton *et al.*, 1999). Kempton *et al.* (1999) found no evidence for spatial recognition deficits in AD/HD but found spatial WM deficits which were sensitive to medication (again implying the deficit pertains to executive control)

Table 2.2. Review of WM studies

AUTHORS	TASKS	SAMPLE SIZE	SAMPLE AGE/GENDER	SIGNIFICANT GROUP EFFECTS	OTHER FINDINGS
Adams & Snowling, 2001	(1) Digit span (2) Counting span	21 AD/HD 21 control	8-11 mixed	No No	
Barnett et al., 2001	(1) Spatial WM (2) Spatial span (CANTAB)	27 AD/HD 26 control	6-12 mixed	Yes (ES = 1.51) Yes (ES = 1.06)	Deficits not seen in medicated AD/HD group
Chang et al., 1999	(1) Paired Associate Learning	197 AD/HD 22 control	7.5-13.5 mixed	Yes (No ES)	No differences between AD/HD sub-types
Cohen et al., 2000	(1) Verbal (2) Visual-spatial (3) Counting span	105 AD/HD 61 clinical control	7-14 mixed	No No No	
Cornoldi et al., 1999	(1) Strategic memory test	28 AD/HD 28 control	11-14 mixed	Yes (ES = 8.12)	Differences eliminated with strategic help
Karatekin & Asarnow, 1998	(1) Spatial WM Dot test (2) Verbal WM Digit span	31 AD/HD 27 control	9-20	Yes (ES = 0.55) No (Trend)	Deficits in delayed, not immediate recall Deficits also seen in schizophrenic group
Kempton et al., 1999	(1) Spatial WM (2) Spatial span (CANTAB)	15 AD/HD 15 controls	6-12 mixed	Yes (ES = 1.72) Yes (ES = 1.20)	Deficits not seen in medicated AD/HD group
Kuntsi, Oosterlaan & Stevenson, 2001	(1) Sentence span (2) Digit span (3) Delayed response	51 AD/HD 119 control	7-11 mixed	Yes (ES = 0.50) No Yes (ES = 0.42)	Differences not significant when IQ controlled for
Mahone et al., 2001	(1) California verbal learning (2) Letter fluency (3) Word fluency (4) Figural fluency	21 AD/HD 28 control	6-16 mixed	Yes (ES = 1.38) No No No	Deficits also found in Tourettes Syndrome group
Norrelgen, Lacerda & Forssberg, 1999	(1) Phonological WM	9 AD/HD 19 control	8-15 boys	No	
Oades, 2000	(1) CPTa v. CPTax	14 AD/HD 14 control	7-14 mixed	Yes	
Oie et al., 1999	Information not available				
Perugini et al., 2000	(1) K-ABC hand movement (2) Digit span	21 AD/HD 22 control	6-12 mixed	No No (Trend)	
Pineda, Ardila & Rosselli, 1999	(1) Delayed verbal (2) Delayed visual recall (3) Cued recall (4) Digit span	62 AD/HD 62 control	7-12 boys	No No No No	Differences only for number of trials
Seidman et al., 1997a	(1) Wide range assessment of memory and learning	43 AD/HD 36 control	6-17 girls	No	
Seidman et al., 2000	(1) Wider range achievement of memory and learning	40 AD/HD 118 control	6-17 mixed	Yes (ES = 0.52)	No differences in retention, only learning
Wiers, Gunning & Sergeant, 1998	(1) Self-ordered pointing (2) Digit span	28 AD/HD 34 control	7-11 boys	Yes (ES = 0.75) Yes (ES = 0.89)	
Williams et al., 2000	(1) Spatial WM (2) Spatial recognition (3) Spatial span	10 AD/HD 10 controls	6-12 mixed	No No Yes (ES = 1.29)	

Note: ES = effect size (mean exp – mean control) / SD control

Overall it would appear that there are deficits in strategic WM in AD/HD, but there is a marked lack of consistency in findings even where similar tasks are used. This suggests deficits are context-dependent. Pineda, Ardila and Rosselli (1999) argue against a memory deficit based on the fact that AD/HD children need more trials to retain the information therefore the problem is one of encoding rather than storage or retrieval. Even if the initial learning, rather than retention and recall, underpin WM deficits in AD/HD it is noted that deficits in spatial and verbal WM are also observed in other childhood disorders such as Schizophrenia (Karatekin & Asarnow, 1998) and Tourettes Syndrome (Mahone *et al.*, 2001). WM deficits are not unique to AD/HD, are not common to all AD/HD subtypes (Chang *et al.*, 1999), and may well reflect underlying attentional/learning deficits .

2.5.2.3. Planning

According to Barkley, planning deficits arise from core inhibitory deficits in AD/HD which impact on problem-solving abilities because of disruption to internally represented information. This review examines the extent to which recent research has supported the notion of planning deficits in AD/HD, and considers whether observed deficits are context-dependent and unique to AD/HD.

Not all problem solving involves planning (e.g., trial-and-error) but where a purposeful sequence of actions is performed toward a particular goal, then planning may be said to be demonstrated (Pennington & Ozonoff, 1996). The classic planning task is the Tower of Hanoi (ToH) disc transfer task originally used to assess planning skills in brain damaged adults (Shallice, 1982). Using this task, which evaluates an individual's ability to plan an organised sequence of legal moves in order to transform the initial state into the goal state (i.e., duplicate the experimenter's configuration), AD/HD children are consistently found to exhibit deficits in this domain (Pennington & Ozonoff, 1996; Weyandt & Willis, 1994). Confirmatory evidence is also forthcoming from studies which have employed the Porteus Maze (PM) as a planning measure (Grodzinsky & Diamond, 1992) and planning components of the CANTAB (Kempton *et al.*, 1999). On these tasks AD/HD children's performance was sensitive to stimulant medication. A study employing the simplified disc transfer task Tower of London (ToL) also found deficits which were confirmed for each AD/HD subtype (Cornoldi *et al.*, 1999, Experiment 3) although this is disputed by Klorman *et al* (1999) who found planning deficits in the combined, not the inattentive, subtype. This of course is compatible with Barkley's model as he views the inattentive type as a qualitatively different type of disorder.

Of the papers under review, 75% showed deficits in AD/HD children using a range of measures. This suggests planning deficits are a common feature of AD/HD in school-age children. Some researchers attribute this in part to the association between planning and WM, to the extent that ToL is a good predictor of memory performance (Cornoldi *et al.*, 1999), but Shallice (1982) persuasively argues the case for viewing ToL as relatively free of WM. Importantly Culbertson and Zillmer (1998) demonstrated the independence of ToL and WM in AD/HD children. In this study ToL loaded heavily onto an executive planning/inhibition factor, but was distinct from memory and cognitive flexibility factors.

Table 2.3. Review of planning studies

AUTHORS	TASKS	SAMPLE SIZE	SAMPLE AGE/GENDER	SIGNIFICANT GROUP EFFECTS	OTHER FINDINGS
Clark, Prior & Kinsella, 2000	(1) Six elements task (2) Hayling sentence completion test	35 AD/HD 26 control	12-15 mixed	Yes (ES = 1.64) Yes (ES = 1.09)	Differences in errors
Cornoldi et al., 1999	(1) ToL	28 AD/HD 28 control	11-14 mixed	Yes (No ES)	
Houghton et al., 1999	(1) ToL	94 AD/HD 28 control	6-12 mixed	No	
Jensen et al., 2001	Information not available				
Kempton et al., 1999	(1) ToL (CANTAB)	15 AD/HD 15 controls	6-12 mixed	Yes (ES = 1.43)	Impairment not seen in medicated AD/HD group
Klorman et al., 1999	(1) ToH	207 AD/HD 28 control	7.5-13.5 mixed	Yes (No ES)	Deficit in combined, not inattentive, sub-type
Nigg et al., 1998	(1) Rey-Osterrieth complex figure (2) Porteus maze	42 AD/HD 71 control	6-12 boys	Yes (ES = 0.42) Yes (ES = 0.58)	Differences independent of RD
Oie et al., 1999	Information not available				
Perez-Alverez et al., 2001	Information not available				
Pineda, Ardila & Rosselli, 1999	(1) Rey-Osterrieth complex figure	62 AD/HD 62 controls	7-12 boys	Yes (ES = 0.37)	
Seidman et al., 1997a	(1) Rey-Osterrieth complex figure	43 AD/HD 36 control	6-17 girls	Yes (accuracy only)	Deficient organisation when comorbidities controlled for
Seidman et al., 2000	(1) Rey-Osterrieth complex figure	40 AD/HD 118 control	6-17 mixed	No	
Wiers, Gunning & Sergeant, 1998	(1) ToL	28 AD/HD 34 control	7-11 boys	No	Differences in latencies

Note: ES = effect size (mean exp – mean control) / SD control

2.5.2.4. Attentional flexibility

According to Barkley, AF deficits are underpinned by core inhibitory deficits in AD/HD which result in poor interference control and perseveration. This review examines the extent to which recent research has supported the notion of AF deficits in AD/HD generally, and considers whether observed deficits are context dependent and unique to AD/HD.

AF is widely considered to be the ability of an individual to make a cognitive 'shift' or 'switch' from one response set to a different one. The WCST originally developed by Grant and Berg (1948) and the Trail Making Task are widely used as a measures of abstract reasoning and flexibility of thought and action (Pennington & Ozonoff, 1996). Both require responding (sort cards or connect circles respectively) based on one rule which may be implicit or explicit, then the rule changes and a new response set must be established. Although the WCST has been used to assess inhibition based on omission and commission errors, the task involves a set-shift and perseverative errors are an index of this ability to set-shift. Barkley, Grodzinsky & DuPaul (1992) reviewed 13 studies that employed the WCST as a measure of AF. Eight of the 13 (61%) confirmed AD/HD deficits in this task, and of the five that did not, three were studies of adolescents. It would appear that older AD/HD children were less impaired than younger AD/HD children and this is consistent with developmental accounts which claim cognitive flexibility is a late-developing skill which has a protracted course. However, the fact remains that not all studies have shown deficits using this measure. Pennington & Ozonoff's review (1996) was less confident as confirmatory evidence for AD/HD deficits was only found in 40% of the studies, so the constant presence of such a deficit is not demonstrated.

Of the studies under review here, 62% find deficits in AD/HD children using a range of measures. Whilst this appears to be convincing it may be observed that results using the same measures are not very consistent. Where deficits are not consistently found we are alerted to the possibility that other variables, cognitive or motivational, may impact upon task performance. Importantly, two large-scale studies of school-age AD/HD children (N=115; N=130) which applied very rigorous selection criteria found no evidence of deficits on the WCST (Grodzinsky & Diamond, 1992; Weyandt &

Willis, 1994) which also raises the possibility that deficits are due to comorbid disorders.

Table 2.3. Review of AF studies

AUTHORS	TASKS	SAMPLE SIZE	SAMPLE AGE/GENDER	SIGNIFICANT GROUP EFFECTS	OTHER FINDINGS
Adams & Snowling, 2001	(1) Trail making (2) Visual search	21 AD/HD 21 controls	8-11 mixed	Yes (ES = 0.90) Yes (ES = 0.68)	Differences in errors , not speed, for all tasks
Bayliss & Roodenrys, 2000	(1) Brixton Spatial Anticipation	15 AD/HD 15 control	8-12 mixed	No	
Cepeda et al., 2000	(1) Task switching	16 AD/HD 16 control	6-12 mixed	Yes (No ES)	Task performance improved with medication
Houghton et al., 1999	(1) WCST (2) Trail Making	94 AD/HD 28 control	6-12 mixed	Yes (ES = 0.76) No	No differences in set and non-perseverative errors
Kempton et al., 1999	(1) Set shift (CANTAB)	15 AD/HD 15 control	6-12 mixed	Yes (ES = 1.42)	Impairment not seen in medicated children
Klorman et al., 1999	(1) WCST	207 AD/HD 28 control	7.5-13.5 mixed	No	No differences in non-perseverative errors.
Perchet et al., 2001	(1) Posner	24 AD/HD 13 control	6-11 mixed	Yes (No ES)	RT and errors
Perugini et al., 2000	(1) Trail making	21 AD/HD 22 control	6-12 boys	No	
Pineda, Ardila & Rosselli, 1999	(1) WCST	62 AD/HD 62 control	7-12 boys	Yes (ES = 0.81)	Differences in set and non-perseverative errors
Seidman et al., 1997a	(1) WCST	43 AD/HD 36 control	6-17 girls	No	No differences in set or non-perseverative errors
Seidman et al., 2000	(1) WCST	40 AD/HD 118 control	6-17 mixed	Yes (ES = 0.46)	No differences in set or non-perseverative errors
Semrud-Clikeman et al., 2000	(1) WCST	10 AD/HD 11 control	8-18 boys	No	Differences in set
Williams et al., 2000	(1) Set shift (CANTAB)	10 AD/HD 10 control	6 mixed	Yes (no ES)	No differences in errors, only pass/fail

Note: ES = effect size (mean exp – mean control) / SD control

Perhaps more than in any other domain, the tasks tapping AF are multifaceted. Whilst attention deficits are presumed to impact upon task performance across domains, a cognitive switch certainly involves inhibiting previously salient features which is a particular confound. This is reflected in the varied use of any given task, which may be defined as tapping attention, inhibition, impulsivity and/or set-shift. Pennington and Ozonoff (1996) point out that the WCST has a specificity and sensitivity problem; it frequently does not discriminate patients with frontal damage from those with diffuse damage, and 'frontal' patients often perform normally on the task. This is often the case when molar EF measures are used. Furthermore many tasks, including the WCST, involve the learning of a rule and many researchers believe AD/HD children use less efficient learning strategies than their non-AD/HD peers (Chang *et al.*, 1999; Frank, Seiden & Napolitano, 1996). In this case the difficulty may reside in the initial learning rather than the subsequent shift.

2.5.2.5. Summary of literature review

The picture that emerges is that deficits have been demonstrated in all EF domains, but it is questionable whether such deficits are unique to AD/HD, or whether they are always present. Inhibitory deficits have been shown across a range of tasks but are most constantly demonstrated in the SST and Go/No-Go tasks. Interestingly the various delay tasks are producing consistent results and this is of particular importance in the context of this thesis. WM deficits have also been shown across a range of measures. However, results are not conclusive as WM deficits may be characteristic of child psychopathology generally. Evidence for planning deficits is impressive, which may reflect the extensive use of variants of the disc transfer problem or the high degree of cohesion in the construct validity of the planning tasks. The evidence for AF deficits is possibly the most confusing as there is little consistency even using the same task.

Although it appears that AD/HD children differ from control children on a range of EF measures and do not differ on a range of non-EF measures, there are certain caveats: Gross measures of EF may mask specific deficits which are not tapped by broad neuropsychological tests; EF deficits may not be exclusive to AD/HD but may be a characteristic of child psychopathology in general; EF deficits appear to be less severe in older children. The difficulty is illustrated by Doyle *et al.* (2000) who find the discriminative ability of single EF tests to be very limited, and although impairments on multiple tests is predictive of diagnostic status, there was no difference between medicated and non-medicated AD/HD children, and normal scores were observed in some AD/HD children.

Overall, this assessment concurs with that of Sergeant, Geurts and Oosterlaan (2002) whose review of the specificity of executive dysfunction in AD/HD, CD, ODD and higher functioning autism (HFA) children concluded that (a) results from different studies are often inconsistent (b) inhibitory deficits have been demonstrated using the Stroop Task and SST but deficits are not specific to AD/HD (c) planning deficits found using the ToL task differentiate between clinical groups but not controls (d) cognitive flexibility deficits in AD/HD have not been conclusively demonstrated using the WCST and were not specific to AD/HD. Unfortunately the authors were unable to draw firm conclusions in respect of WM as the task selected (Self-ordered pointing) had not been sufficiently used .

2.5.3. The impact of symptom severity

Many studies have shown that the risk associated with AD/HD is not a function of symptom severity (Nigg *et al.*, 1998). Symptom severity does not therefore determine the outcome. Similar levels of symptom severity have been found in both clinic and non-clinic samples (Hudziac *et al.*, 1999) indicating that symptom severity does not drive referrals. Persistence of symptoms is also unrelated to symptom severity (August, Braswell & Thuras, 1998). Although symptom severity has not been extensively investigated with regard to specific areas of EF, studies have also confirmed deficits in working memory are unrelated to symptom severity (Barnett *et al.*, 2001). This supports the view that investigation of AD/HD across the range of symptom severity is valid.

2.5.4. The impact of comorbidity

The frequent co-occurrence of RD, CD and ODD in AD/HD children, and the noted lack of screening for comorbidities in experimental groups, leads us to question to what extent the observed executive deficits in AD/HD children can be accounted for by the comorbid condition. Furthermore it has been previously stated that the comorbid disorders may interact with and change the nature of AD/HD. This means it is necessary to consider both the relative contributions of each distinct disorder and the pattern of deficits in the combined disorders.

With the aim of investigating the independence of RD and AD/HD as discrete categories and the possible causal relationship, a recent longitudinal study which followed four groups (AD/HD, AD/HD+RD, RD, CONTROL) of children aged 7/8 years through 16/17 years found no evidence to support the notion of causal mechanisms. The presence of either disorder did not predict the emergence of the other and, where the comorbid condition existed at age 7/8, there was no evidence for its persistence over time (Chadwick *et al.*, 1999). Certainly it appears that AD/HD and RD are distinct from each other, but it is still possible to suggest that RD may contribute to executive dysfunction. To answer this question, Purvis and Tannock (2000) tested RD, AD/HD, AD/HD+RD children aged 7-11 years using measures of inhibitory control and phonological processing, which were selected on the basis of core deficits associated with AD/HD and RD respectively. The comorbid group displayed deficits of both single groups in an additive fashion which replicated their previous finding (Purvis & Tannock, 1997), but some inhibitory deficits were unexpectedly found in the RD group. While confirming the independence of the distinct disorders, this questions the notion that inhibition is unique to AD/HD and allows that comorbid RD may make some contribution to inhibitory dysfunction. A similar finding has been observed in another executive domain, WM, which was also unexpectedly associated to a greater extent with language impairment. This prompted the comment that WM may be the 'zone of overlap' between AD/HD and language impairment (Cohen *et al.*, 2000). The independence of AD/HD and RD is also supported by a large-scale study conducted by Klorman *et al.* (1999) employing the ToH and WCST. This study concluded that executive deficits were found in the AD/HD combined type which were not accounted for by comorbid RD although RD displayed high levels of rule breaking in the ToH. If rule breaking is analogous to impulsive responding the picture is consistent with viewing RD as distinct from AD/HD, and when both conditions are present the deficits of each will be additive (i.e., increased risk). However, it is unlikely that RD exacerbates the features of AD/HD when both disorders are present. This accords with Lazar and Frank (1998) who assert that executive dysfunction is equally, if not more, prevalent in children with learning difficulties (LD) and EF tasks cannot discriminate between AD/HD and LD.

The picture with regard to AD/HD and CD seems less clear. Pennington and Ozonoff (1996) state that executive deficits are consistently found in AD/HD but not CD. However, studies utilising the SST have found inhibitory deficits in CD and CD+AD/HD children (Oosterlaan, Logan & Sergeant, 1998). This is problematic for Barkley's model which assumes inhibitory deficits are unique to AD/HD but Schachar *et al.* (2000), who also used the SST to compare the performance of AD/HD (N=72), AD/HD + CD (N=47) and CD (N=13) children, found impaired inhibitory control in the AD/HD group alone, replicating the results of an earlier study (Shachar *et al.*, 1993). The notion of inhibition being uniquely associated with AD/HD is further supported by Chee *et al.* (1989 Experiment 1) who found that AD/HD children differed from CD children in terms of commission (impulsive) errors but not omission (attentional) errors on a CPT task. However, the fact that the AD/HD+CD group in the Schachar study did not show the expected inhibitory deficits led to the assertion that AD/HD + CD represents a phenocopy of CD rather than a variant of AD/HD. Certainly it would appear that what differentiates these groups is impulsivity rather than cognitive impairment. Unlike AD/HD + RD, which appears to be additive, AD/HD + CD appears to represent a qualitatively different pattern of impairment. Inhibitory deficits that characterise AD/HD are not always found in the combined type. It is certainly true that children with concomitant AD/HD + CD are more aggressive, present with a greater variety of behaviour problems, and are more at risk for persistent social problems than children with AD/HD or CD only (Toupin *et al.*, 2000; Dery *et al.*, 1999; Gresham *et al.*, 1998). It seems as though the combination of disorders result in more severe problems than an additive model would suggest. This effect may explain why cognitive deficits are found in CD children with comorbid AD/HD even after AD/HD is controlled for (Toupin *et al.*, 2000).

A study of executive performance in AD/HD boys with and without ODD found that the AD/HD+ODD group scored lower than the AD/HD only group on a range of EF tests. EF deficits were confirmed in both AD/HD and ODD boys, with the AD/HD+ODD group exhibiting greater impairment than the group with ODD alone (Speltz *et al.*, 1999). Klorman *et al.* (1999) found performance deficits on the ToH and WCST tasks for the combined type AD/HD group, and these deficits were independent of ODD. Clearly both ODD and AD/HD children display impairment of executive functioning, and impairment is greater where both conditions are present. ODD is often seen as a precursor of later-occurring CD (Biederman *et al*, 1996) and it is interesting to note that Jensen *et al.* (2001) found AD/HD children with comorbid externalising conditions are least likely to benefit from behavioural intervention and most likely to require medication compared to those with comorbid anxiety, who responded to both interventions.

From this it can be seen that EF deficits are not unique to AD/HD. There is evidence that deficits in several EF domains (i.e., planning and WM) exist in other disorders which commonly occur with AD/HD. It is reasonable to suppose these deficits, whether acting in an additive fashion or of a qualitatively different kind, make some contribution to the observed executive deficits that have been attributed to AD/HD. This may have led to an overestimation of the extent of such deficits in AD/HD where the effect of comorbid conditions has not been partialled out. Even the core deficit of impulsivity is not unique to AD/HD and this is consistent with evidence from a 2-year longitudinal study of 235 school children which finds that inhibitory control predicts a range of externalising behaviour problems as rated on the CBCL (Nigg *et al.*, 1999). Nevertheless, inhibition appears in many studies to be the single factor which best discriminates AD/HD from other disorders. Furthermore it is apparent that the relationship between inhibition and disorder is contingent upon the measure and the definition of inhibition which is applied. It is vital in any study to account for influences of a comorbid condition, not only because they may contribute to poor executive performance but also because comorbid conditions may share an underlying aetiology.

2.6. The role of context and motivation in AD/HD

It has been previously suggested that EF deficits are fundamental to AD/HD. It is fully accepted that such deficits exist and there is no challenge here as to the validity of this conclusion. What is questioned here is the extent to which this narrow focus denies the possibility of exploring other salient features. The developmental neuro-psychological paradigm has been criticised for ignoring the role of environmental factors. Karmiloff-Smith (1998) asserts that a developmental account of any childhood disorder must involve the contribution of the environment not just in terms of the context for performance but also the significance of the environment in shaping the course and outcome of cognitive development. This is analogous to the role of non-shared environment that mediates the behavioural and cognitive expression of a genotype. Behaviour genetic studies that have supported the notion of an AD/HD endophenotype have also identified a possible role for environmental factors in AD/HD (Kuntsi & Stevenson, 2001).

Barkley's model is firmly based on the assumption of a core inhibitory deficit and one of its strengths is that it clearly explains the relationship between disinhibition and other EF deficits. However, there is an increasing body of evidence supporting the notion of two distinct inhibitory components relating to cognitive and motivational functions. Physiological evidence suggests that executive control is associated with vagal modulation of respiratory driven, high frequency heart rate variability, and motivational control is associated with sympathetic modulation of the posturally-driven, low frequency heart rate variability (Mezzacappa *et al.*, 1998). Perhaps Barkley's model is half the story. It is possible to hypothesise that inhibitory mechanisms impact differentially upon cognitive and motivational functions, and plausible to consider the extent to which EF deficits (which Barkley views as the consequence of disinhibition) are impacted upon by motivation. The following sections consider the evidence from studies that implicate contextual and motivational factors in EF task performance.

2.6.1. The impact of goal representation

Bauer *et al.* (1999) assessed the planning skills of 2-year-old children using a construction task in which toys were built using an ordered sequence of moves. The children solved 8% of trials when one move was demonstrated. This rose to 15% when two moves were demonstrated and 41% when the goal-state configuration was demonstrated. In terms of development these findings are consistent with the notion of scaffolding (Vygotsky, 1978) as a means of promoting performance within a zone of proximal development, and in very young children the structure of the problem needs to be very well identified.

2.6.2. The impact of external distracters

Zentall *et al.* (1978) studied the impact of situational variables such as noise, colours and lights on AD/HD children's EF performance and found AD/HD performance on partially-solvable problems was enhanced when external stimulation was provided. Similarly Abikoff *et al.* (1990) found AD/HD children's performance on an arithmetic task improved when music was provided, with significantly fewer errors being made. The beneficial effect of external stimulation in terms of improving performance was thus demonstrated and AD/HD children were perceived by the authors as sensation-seekers who have a preference for external novel stimulation and an over-reliance on external cues. These external cues may serve a more specific function than generally increasing arousal and it is suggested that external cues may facilitate self-focus. This is demonstrated in studies where the use of mirrors in the environment has improved performance (Zentall, Hall & Lee, 1998). A recent study has shown that external stimulation also serves to decrease symptomatic behaviours. In this study AD/HD and control children were required to wait fifteen minutes before beginning a task, during which time there was either no stimulation, or a video played. The AD/HD children showed a significant reduction in symptomatic behaviours in the video condition relative to controls (Antrop *et al.*, 2000). The reduction in hyperactive behaviours may also contribute to improved task performance.

2.6.3. The impact of event rates and display times

The pace of any RT task incorporates two aspects of a design, firstly the time to the onset of a stimulus, called the stimulus onset achronicity (SOA), which determines the event rate, and secondly the time in which the stimulus is displayed, called the display time (DT). Studies that have investigated event rate typically employ measures of focused and sustained attention and attentional flexibility. In dichotic listening tasks where the SOA varied between 0.5 and 3.5 s, AD/HD children were found to have poor re-orientation which was most marked when delays were longer. In cueing studies the delay between cue and target was found to impact on AD/HD performance with errors committed only under long delay conditions. Van der Meere, Stemerdink and Gunning (1995) argue that presentation rates of events are crucial in AD/HD performance on RT tasks. This is confirmed in a study using CPT, where AD/HD performance was uniquely affected by event rate, where fast (1 s) and slow (4 s) SOAs produced lower hit rates and and longer SOAs resulted in more false alarms and longer RTs compared to controls (Chee *et al.*, 1989 Experiment 1). In this study there were no significant differences with DT variations of 0.2, 0.4, and 0.8 s for the AD/HD group but when a subgroup was identified which conformed to the more stringent ICD-9 criteria, longer DTs adversely affected RTs, hit rate and false alarms.

2.6.4. The impact of delay

The previous section has described the impact of SOA and DT. In functional terms DT constitutes a form of response delay. Simply put, the longer DT trials meant longer periods of time where the child is waiting to respond. The DTs of 0.2, 0.4, and 0.8 s did not appear to impact upon AD/HD children's performance but it may be that the times were too short to elicit an effect. The impact of longer response-delay times was investigated by Sonuga-Barke and Taylor (1992). In a RT task where SOA was held constant but a signal, in this case a geometric shape, appeared on screen for 1, 15, or 30 s, children were required to respond as quickly as possible *after* the shape had disappeared. In this experiment the period of waiting to respond was more clearly defined and AD/HD children, though slower in general than controls, were increasingly slow with increases in pre-response delay.

The impact of delay can also be demonstrated in studies which have attempted to manipulate the overall time-on-task. In such studies the overall trial length is equalised, so fast/impulsive responding does not reduce task duration. In a RT task employing the MFFT, nine pervasive AD/HD and nine control children (mean age = 9 years) were exposed to two conditions, firstly the standard MFFT and secondly the fixed length MFFT (45 s). The fixed length format resulted in longer mean latencies in the AD/HD group to the level of that observed in the control group (Sonuga-Barke, Houlberg & Hall, 1994). This demonstrates that premature responding, which has characterised AD/HD performance on this widely used task and is interpreted as disinhibition, is in fact sensitive to manipulations of overall delay. In a similar vein, when delays were imposed after errors on a standard MFFT task AD/HD children's mean latencies increased and fewer errors were made, which challenges the notion that response inhibition deficits are intrinsic to AD/HD (Sonuga-Barke *et al.*, 1996).

2.6.5. The impact of time-on-task

On measures of sustained attention, typically CPT, it is observed that performance over time deteriorates in a general fashion for all participants. As such performance deterioration over time is an inherent feature of CPT as effort and motivation are required to maintain performance over an extended period. The important issue here is that the performance of AD/HD children should decrease as a function of time proportionately more than that of normal controls. A number of studies have shown that AD/HD children's performance does not decline over time in this way. That is, AD/HD children's task efficiency is not reduced during the course of a task. Chee *et al.* (1989 Experiment 2) controlled for time-on-task in a CPT where event rate was manipulated by fixing the task duration at 16 s. The SOA effect on AD/HD performance found previously persisted in this condition with the exception of hit rate. Apparently the RT and false alarm rates are sensitive to event rates but hit rates are sensitive to task duration. This is counter-intuitive given the attentional problems associated with AD/HD. Further evidence comes from attentional studies where RT slopes reflect learning and increased automisation of attention processing (e.g., RTs increase without performance cost over the task duration). Again, the performance of AD/HD children was slower, more variable and less accurate than that of the control group, but their performance decrements did not deteriorate as a function of time-on-task. The gradients of the RT slopes of AD/HD and controls were not significantly different (van der Meere & Sergeant, 1988).

2.6.6. The impact of external control

Gomez and Sanson (1994) explored AD/HD performance on an attentional task under three conditions: alone, mother present and experimenter present. It was found that AD/HD children performed least well when alone and best when the experimenter was present. This highlights the importance of external control and suggests motivational factors contribute, at least in part, to poor performance. Further evidence can be found in experiments that compare self-paced and experimenter-paced tasks, the latter constituting external control. Sonuga-Barke, Taylor and Heptinstall (1992) conducted a recognition memory experiment in which exposure time to the to-be-remembered material was fixed by the experimenter at 30 s, or set by the participant. AD/HD children consistently selected shorter exposure times and performed less well on the memory test in the self-paced condition. However, when the exposure time was fixed by the experimenter, AD/HD children performed as well as controls. This indicates that visual memory deficits displayed by the AD/HD children may reflect their unwillingness to spend sufficient time attending to stimulus material. In this case the opportunity for efficient cognitive processing is reduced resulting in a performance deficit, but there is no evidence for specific cognitive deficits *per se*. Of course there is evidence for deficits in AD/HD performance which exist even under experimenter-paced tasks where available processing time is increased. Dalby *et al.* (1977) found AD/HD performance on a paired-associate learning task was poor even when presentation rates were slow. Similarly, in a RT task Sonuga-Barke, Houlberg and Hall (1994) found AD/HD children continued to exhibit performance deficits, making more errors than controls, even when the trial lengths were fixed at 45 s. In this condition, mean latencies of the AD/HD group were equivalent to those of the control group yet the extra processing time afforded the children clearly was not well used. This may be construed as evidence for processing deficits but it is also possible that these children did not use the available time to their advantage, and it becomes necessary to distinguish between presentation/display time and time spent attending. The salient point here lies in the fact that in the Sonuga-Barke (1992) memory experiment the children were repeatedly told to use all the time to attend to the stimuli. In the experimenter fixed condition AD/HD children subsequently outperformed controls in recognising attended stimuli and remembering their location, which suggests that motivational, not cognitive, aspects were important in determining performance.

2.6.7. The impact of reinforcers

Many researchers have attributed AD/HD behaviour to an insensitivity to reward and punishment (Barkley, 1989, Sagvolden *et al.*, 1992). With regard to the relative impact of reward and punishment, early studies using RT tasks suggested that reward, punishment and reward + punishment were all successful in improving task performance. However, reward without punishment also increased impulsive responding/task irrelevant behaviours (Firestone & Douglas, 1975). Results suggested that rewards increased the AD/HD child's level of arousal and resulted in an eagerness to respond. This, of course, was effective in improving task performance on a RT task, but premature responding, together with increased task-irrelevant behaviours, distractibility and erroneous responses, would presumably impair performance on other cognitive tasks. The important question here is whether *targeted* behaviour is affected by reinforcement, and specifically whether impulsive failures can be improved with reinforcement. Studies utilising the Go/No-go task have found that inhibition failures (i.e., commission errors) are reduced when response costs (i.e., punishments) are introduced, and reduced further when both reward and response costs are introduced (Iaboni, Douglas & Baker, 1995). Solanto (1990) has also demonstrated that both reward and response cost improve AD/HD performance on a delayed response task. In this study a DLR task was used and children had to wait 6 s before responding. In the first condition correct responses earned a coin, in the second condition incorrect (premature) responses resulted in the subtraction of a coin from earnings. Impulsive responding by both AD/HD and control children was significantly reduced in both conditions. Taken together these results suggest that AD/HD children are not insensitive to reinforcement.

Even without the introduction of punishment, it appears that increasing the magnitude of the reward also eliminates inhibitory failures; Slusarek *et al.* (2001) found inhibition failures on the SST, a task that most consistently demonstrates inhibition failures in AD/HD children, were reduced when the credits were increased from one to five. Evidence indicates that reinforcement is most effective when it is frequent and continuous (Sagvolden *et al.*, 1993), as erratic or inconsistent reinforcement actually impairs AD/HD performance (Douglas & Parry, 1983).

2.6.8. Commentary

There are facets of AD/HD that the EDF hypothesis cannot readily account for, in particular the context dependent nature of the EF deficits. It has been argued that an inherent feature of classification is the collapsing of causal structures and a masking of aetiological origins (Mirowsky & Ross, 1989) and this raises the possibility that there may be specific AD/HD characteristics which implicate other causal mechanisms. The attempt to explain the impact of external variables has generated a range of theories that offer different perspectives to the EDF model, three of which will be discussed in the following section.

2.7. Models that implicate motivational factors

In seeking to explain these motivational aspects of AD/HD, several theories have proposed alternative explanations for AD/HD. The first two focus on arousal mechanisms and the third on delay.

2.7.1. The stimulation-seeking model

The notion that AD/HD children appear to be hyper-aroused in normal environments has been espoused by Strauss & Lehtinen (1947) and Cruikshank *et al.* (1961), who recommended that these children should be taught in an isolated environment. However, the finding that AD/HD children actually benefit from external distracters has led to the formulation of the Optimal-stimulation theory (Zentall & Zentall, 1983; Zentall & Meyer, 1987). This hypothesis states that organisms have an optimal level of stimulation, which is biologically determined. When the optimal level of stimulation is not present in the environment, activity can serve as a homeostatic regulator. AD/HD children are presumed to have a higher than normal stimulation threshold, and therefore seek higher levels of stimulation in their environment. This is demonstrated by the fact that AD/HD children are easily distracted and spend proportionately more time off-task than normal children, which is thought to reflect the search for additional stimulation. The model predicts that, because AD/HD children are under-aroused, they will benefit from increased sensory stimulation. This is supported by studies which demonstrate the impact of external distracters on AD/HD performance (see section 2.6.2.). This external focus runs counter to self-focusing and the model further predicts that specific environmental aids that facilitate self-awareness and introspection have a greater positive impact on performance. This explains why mirrors in the environment enhance AD/HD children's performance (Hall & Zentall, 1998; Zentall, Hall & Lee, 1998).

The theory is supported to some extent by the evidence for the beneficial effect of stimulant medication. However, the neurobiological basis for the model is not clear. Although arousal is not defined in any qualitative or quantitative way in terms of neurology, Zahn, Rappoport and Thompson (1980) reported that increases in gross motor activity in both AD/HD and normal children correspond with increases in physiological measures of arousal. This relationship underpins studies in which activity levels are thought to reflect arousal levels. There are also questions raised regarding the precise nature of self-stimulation. Do AD/HD children seek certain types of stimuli, or do they seek to increase the amount of stimulus inputs? One cannot be sure why, for instance, off-task behaviour constitutes a search for stimulation when additional, erroneous on-task activity may serve the same purpose.

Despite the lack of a clearly defined process that may result in under-arousal in AD/HD, it is true that arousal is associated with the frontal cortex. Pribram and McGuinness (1975) maintain that the amygdala mediates between the cortical and sub-cortical structures associated with arousal. Two reciprocal systems are hypothesised to modulate arousal, one that is associated with the dorsolateral frontal cortex, and the other associated with the orbitofrontal cortex. These systems serve to facilitate and inhibit arousal respectively.

2.7.2. The poor state regulation model

The finding that event rates and cue-stimulus delays are critical in AD/HD performance, coupled with indications that this may be linked to poor motor timing/preparation, has led to the formulation of the cognitive-energetic theory (van der Meere, 1996). This theory derives from an information processing perspective and distinguishes between process (discrete and short term events which mediate stimulus and response) and state (modulating process). The theory is based on Sanders (1983) model which proposes three distinct but related energetic systems - arousal, activation and effort. The arousal and activation systems are concerned with sensory activity and motor readiness respectively. The effort system modulates the operations of these two systems and will compensate in non-optimal conditions. If the level of preparedness of these arousal and activation mechanisms is insufficient to meet the task demands, the effort system will 'kick in' and optimise the performance of arousal and activation. It is hypothesised that in AD/HD sub-optimal activation/effort states result in slow motor preparation and execution, which manifests itself in slow, inaccurate responding. It has been previously mentioned that slow, inaccurate responding has been identified as characteristic of AD/HD performance on signal detection tasks, which was contrary to the traditional view of AD/HD children as fast, inaccurate responders. The model can be viewed as related to the EDF model as it attempts to explain a process by which an executive deficit (in state regulation) may result in AD/HD behaviours.

The neurological basis for the presumed deficit in AD/HD is the proposal that the function of the activation mechanism is performed by the basal ganglia and in particular the corpus striatum (Pribram & McGuinness, 1975). These areas of the brain are associated with motor control. AD/HD behaviour can be linked to dysfunction of the frontostriatal system which is, in turn, linked to the dopamine system (van der Meere, 1996). In this way, neurochemical imbalances in specific brain areas associated with motor control are responsible for sub-optimal arousal which manifests itself as slow, inaccurate responding.

In this theory the effort mechanism is influenced by motivational factors. Simply put, where effort is required, the amount of effort expended will be determined by task and situational variables. The theory predicts that AD/HD children's performance will be poor in both fast and slow trials, and would improve in medium trials which constitute optimal stimulus rates. This is supported by evidence from van der Meere, Stemmerdink and Gunning (1995) who found AD/HD children respond quickly and inaccurately where presentation rates are fast (1 s) and respond slowly and inaccurately when presentation rates are slow (8 s). A logical extension of this argument is that those task and situational variables that can reasonably be expected to impact positively upon motivation (e.g., incentives, feedback, task novelty and presence of an experimenter) will enhance AD/HD performance. Conversely, those variables that impact negatively on motivation (e.g., time-on-task, repetitive/boring tasks, task difficulty and absence of the experimenter) will result in poor performance. The evidence presented in section 2.6 offers only partial support for this model as there is little evidence to suggest AD/HD children's performance on CPT worsens as a function of time-on-task.

2.7.3. The delay aversion model

In order to account for some of these findings Sonuga-Barke developed a set of hypotheses that offer a radical departure from the dominant EDF model. The DA hypothesis states that AD/HD children are motivated to escape or avoid delay. The apparent impulsive (premature and error-prone) responding associated with AD/HD performance is recast as the child's attempt to reduce time-on-task. Simply put, the AD/HD child plays by different rules and achieves their objective of delay reduction at the expense of optimum performance. In this model DA replaces disinhibition as the central or core feature; As such a presumed dysfunction, the requirement of disorder, is displaced with a functional account of behaviours associated with AD/HD, and AD/HD is characterised as a motivational style.

The model attempts to link evidence from a range of sources: A hypofunctioning dopamine system (Sagvolden & Sergeant, 1998) is associated with a shorter reinforcement gradient (Sagvolden *et al.*, 1998) which results in an apparent intolerance of delayed reward and punishment. The behaviour of very young children who are naturally impulsive is therefore harder to shape and a history of failure (unrewarded and unsuccessful waiting) results in delay aversion acquired through conditioning. DA is therefore the primary impairment and the primary adaptation –

acting to avoid delay – underpins the symptom triad. In this way the mechanism and process are identified but, importantly, the role of the home and school environment is also considered integral to the process. Inconsistent parenting impacts upon the conditioning process when rewards are inconsistent or ineffective and is itself affected by the symptomatic behaviour of the child creating a feedback loop. The school environment similarly impacts upon the process by creating demands that reinforce aversion to delay although this is less interactive as the inflexible environment would not adapt itself to the child.

The model determines that impulsivity is the manifestation of DA in situations of choice and explains the disorganised and inattentive behaviour observed in AD/HD as a manifestation of DA in situations of no choice. Under conditions where delay cannot be manipulated or avoided, the experience of delay will be minimised by attending to non-temporal, peripheral aspects of the environment (Sonuga-Barke, Taylor & Heptinstall, 1992). In this way the over-reliance on external cues and the beneficial impact of non-temporal stimuli in the environment can be understood simply as a means to reduce the perception of time passing. It is worth noting that the aforementioned Antrop *et al.* (2000) study where AD/HD behaviours were reduced when a video played during a delay period was congruent with both the stimulation-seeking and DA hypotheses. This raises an interesting question regarding the AD/HD sub-types which could reflect situation specificity or the individual's personal learning history rather than different forms of AD/HD, which would accord with the assumption of phenotypic symptomatology with individual differences in expression.

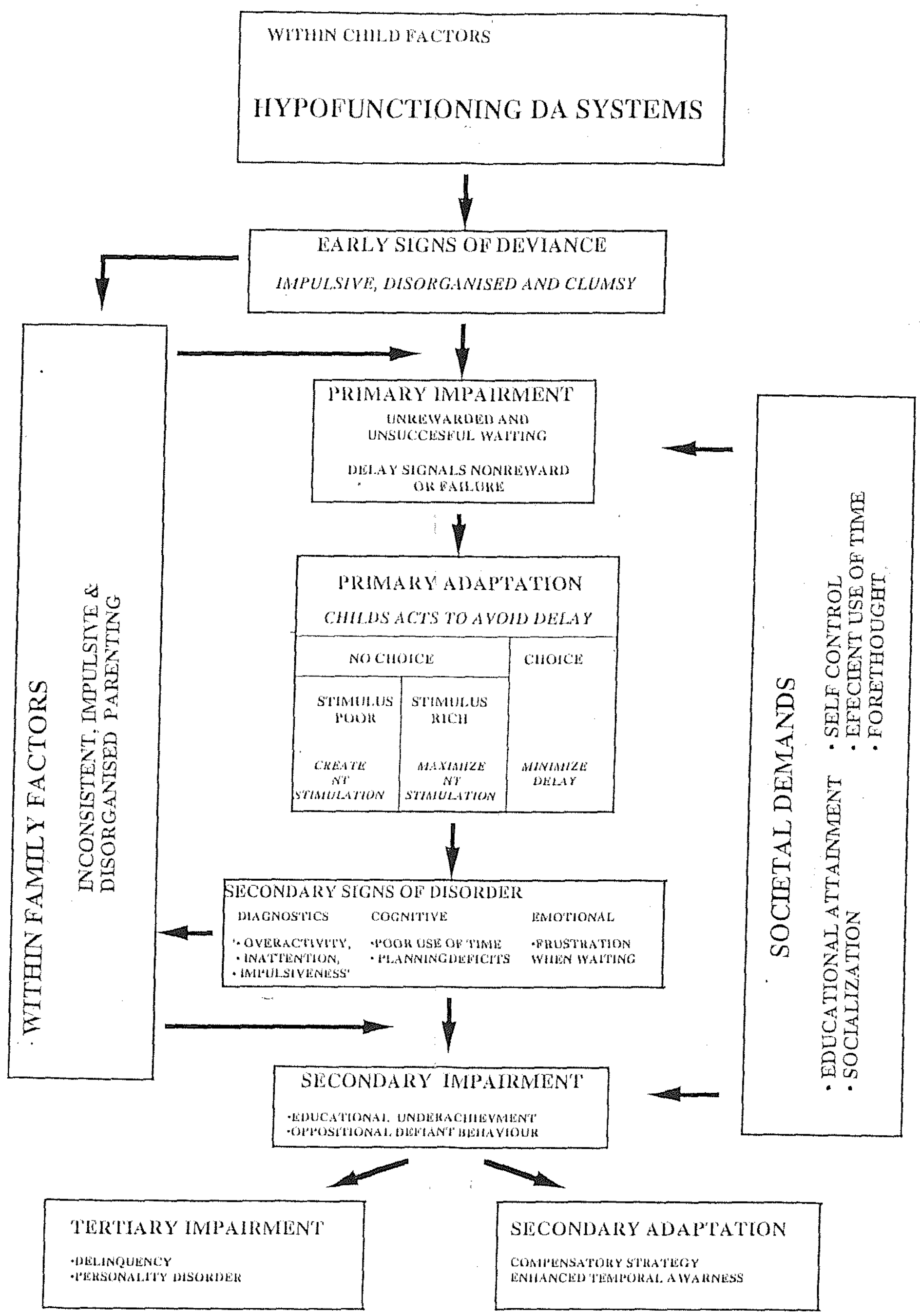

Figure 2.2. A motivational model of AD/HD. Sonuga-Barke (1997). Paper presented at a meeting of the Centre for Research in Child Development (CRPD), Southampton University, October 1998. Reprinted with permission from the author.

It is of particular interest that the model does not view AD/HD in a totally negative light. The impact of the environment can be positive, and sensitive parenting could ameliorate the difficulties in terms of secondary impairment. This would explain why poor outcomes are not an inevitable consequence of AD/HD. Furthermore the model includes as a secondary adaptation the positive developmental consequences of the motivational style, namely enhanced temporal awareness and strategies which lessen the impact of the symptoms.

The model is supported by a series of experiments conducted by Sonuga-Barke and colleagues described in the previous section, which demonstrate that AD/HD children (a) withold responses if doing so reduces overall delay, (b) increase response latencies to avoid post-response delay, (c) choose immediate rewards only when overall delay can be reduced, and (d) improve performance on external-paced tasks relative to self-paced tasks. These manipulations of delay have established that delay aversion is a characteristic of AD/HD. Generally AD/HD children's performance is similar to that of controls when delay cannot be reduced or avoided, and differs under conditions in which temporal features of the task may be self regulated. The notion that AD/HD children *can't* wait is challenged by this evidence which suggests AD/HD children *won't* wait.

2.8. The relationship between delay aversion and executive dysfunction

The evidence which supports the existence of EF deficits in AD/HD is considerable and, most importantly, these deficits have been shown to exist under optimal conditions (Sonuga-Barke, Houlberg & Hall, 1994). However, there is an increasing body of evidence that demonstrates the importance of delay factors in AD/HD performance. Clearly EF deficits and delay aversion are both characteristics of the disorder and have been independently associated with AD/HD. The question remains as to how these two characteristics relate to each other. This question can only be answered in a developmental context. There are three possible ways in which this relationship may be conceptualised: First, that early-occurring EF deficits result in DA; second, that early-occurring DA results in EF deficits; third, that EF deficits and DA are independent contributors in the disorder. The processes which may characterise these relationships have been ingeniously described in a recent paper by Sonuga-Barke, Spicer and Koojimans (submitted) using an ecological framework.

The ecological paradigm holds that patterns of cognitive growth during development are determined by proximal processes operating within developmental niches. The child's development is dependent upon (a) the exposure to developmentally significant experiences and (b) the regulation of the children's' engagement with their environment. The pattern of engagement with the environment is to some extent determined by the child whose behavioural and cognitive characteristics will modify the developmental niche by moving from one setting to another (niche picking) or re-organising proximal processes within existing settings (niche building). It is argued that, in the case of AD/HD, children modify the developmental niche in a way that reduces the effectiveness of proximal processes to promote development by constraining engagement in educationally significant activities (Sonuga-Barke, Spicer & Koojimans, submitted). Simply put, AD/HD children's impulsive style will create learning parameters which may result in developmental skills deficits. This allows that executive deficits may be the developmental consequence of AD/HD behavioural style. A special feature of this account is the possibility of adaptive as well as maladaptive functions. The adaptive capacity of AD/HD children has been observed on the neuropsychological level (Schweitzer *et al.*, 2000), where increased activity in the occipital region during a memory task is suggestive of internal speech regulation, and the behavioural level (Borger & van der Meere, 2000; Beaumont, 1998; Alberts & van der Meere, 1992), where AD/HD children accurately timed the stimulus interval so the impact of off-task behaviour was minimised. This evidence, together with the finding that AD/HD deficits in a reaction-time task were minimised in the niche-consistent condition (Sonuga-Barke, Spicer & Koojimans, submitted) adds weight to this account and certainly highlights the conditional nature of AD/HD cognitive deficits.

Motivational factors may impact upon executive performance in many ways. Firstly, it has been said that delay affords the opportunity in which to allow cognitive functions to occur. In this case the lack of processing time will result in performance deficits and it is the efficiency of the cognitive processing which is degraded. Secondly, the avoidance of any delay period creates a motivational style which means the goals of the impulsive child are different to those of other children (e.g., they are prepared to trade accuracy for speed). These are ways in which performance on EF tasks may be compromised, but they do not presume an executive deficit. However, it is also established here that performance deficits may result in skill deficits as the behavioural style of the impulsive child may impede the development of executive skills.

2.9. Chapter summary

The emergence of the dominant theory of AD/HD from the medical model and served by the neuropsychological paradigm has led to the widespread acceptance of AD/HD as an EF disorder. A large body of evidence from studies employing neuropsychological measures has maintained this assumption although studies employing developmental measures have to some extent encouraged us to question whether tests of gross impairment are ignoring other salient features of the disorder. In seeking to explore motivational aspects of AD/HD, the DA hypothesis proposed by Sonuga-Barke (1997) represents a radical departure from this model. Not only does this theory challenge the assumption of disinhibition by recasting apparent impulsive behaviour in terms of delay-reduction strategy, it also suggests ways in which EF deficits may occur as a result of the AD/HD child's motivational style.

The evidence presented here suggests that both EF deficits and DA are characteristics of the disorder that are independently associated with AD/HD, and the pressing question therefore is how these characteristics relate to each other. In considering the relationship between executive dysfunction and delay aversion it is important to take a developmental perspective. It can be said that the key to understanding this relationship lies in plotting the developmental course of both, and the following chapter will consider what is currently known about preschool development, and in particular the developmental course of domain-specific functions.

CHAPTER THREE: EXECUTIVE FUNCTION AND DELAY AVERSION IN THE PRESCHOOL YEARS

3.1. Introduction

This chapter aims to explore EF and DA in the preschool period. It will outline how these constructs have been conceptualised and measured and consequently what is known of normal development during this period. The following section reviews normal EF development and, where possible, considers the impact of AD/HD, although it should be noted that comparison studies within this age range typically refer to 'hard to manage' children or those with externalising disorders. In contrast, there has been little research on DA and AD/HD in the preschool period. Because of this we are informed by a large body of research that has focused on self-control/impulsivity using measures where delay is inherent in the task. This research has traditionally focused on the preschool age group.

3.2. Conceptualisation and definition of executive functions

Research on EF has been guided by what Pennington and Ozonoff (1996) call the 'frontal metaphor'. It has been stated in the previous chapter that EFs are viewed as higher level cognitive processes whose functions are under control of the prefrontal cortices which are the 'thinking workshop'. This domain is distinct from other cognitive domains (e.g., sensation, perception) but may overlap with many (e.g., language). Neurological studies on brain damaged adults have clearly linked the frontal lobes to higher cognition, and it is widely accepted that brain damage in this region impairs an individual's ability to process and synthesise information at a more complex level, although it does not necessarily impair IQ. This paradox is explained by the notion that the frontal areas are important for fluid intelligence rather than crystallised intelligence which underpins IQ (Duncan, 1995). As fluid intelligence is associated with goal-directed and problem solving behaviour (usually in a novel context) and crystalline intelligence is associated with the maintenance of accumulated information, it may be surmised that the frontal lobes may be even more important in early development than in later life.

EF has been defined as '*....the ability to maintain an appropriate problem-solving set for attainment of a future goal. This set can involve one or more of the following: (a) an intention to inhibit a response or defer it to a later more appropriate time, (b) a strategic plan of action sequences, and (c) a mental representation of the task, including the relevant stimulus information encoded in memory and the desired future goal-state*' (Welsh & Pennington, 1988, pp. 201). EF has been typically been measured using standard neuropsychological tests such as the WCST. Simply put, they are those tasks in which brain-damaged patients do badly. Cognitive psychology has also generated a range of measures of inhibition, WM, planning, set-shifting, interference control and integration across space and time, predicated on the assumption that cognition is what occurs between perception and response execution (Pennington & Ozonoff, 1996).

Measurement of preschool EF presupposes that children as young as 3 years display EF skills and that such functions can be measured. Early studies suggested that this might not be the case. For example, Golden (1981) and Kirk and Kelly (1986) claimed that the prefrontal areas were nonfunctional until preadolescence, and attained adult levels by age 10/12 years. However there is now a growing body of evidence which suggests rudimentary prefrontal skills are evident in school-age children (Anderson, Anderson & Lajoie, 1996; Krikorian *et al.*, 1994; Welsh & Pennington, 1988; DeLoache & Brown, 1984). Recent research has indicated that rudimentary executive skills are amenable to measurement, not only in preschool children, but also infants. The possibility of such early-occurring executive skills is underpinned by developmental neuropsychological studies that demonstrate maturation of prefrontal regions during the first year of life (Welsh, Pennington & Groisser, 1991; Diamond & Goldman-Rakic, 1985). Furthermore, Passler, Isaac and Hynd (1985) found evidence of multi-stage development of the frontal lobes consistent with multi-stage development of executive skills in children. The evidence for early EF in each domain will be considered.

3.2.1. Inhibition

Inhibition has been measured using developmental tests such as the MFFT and classic neuropsychological tests such as the WCST. These tasks are considered measures of inhibition because they require an inhibition of a previous response pattern. The measured variable is therefore the number of perseverative responses. A review of studies using the WCST found the task does not discriminate between AD/HD and normal adolescent children, possibly because maturation renders the subtle impairment less detectable on measures of gross damage (Barkley, Grodzinsky & DuPaul, 1992). These tests have been applied to school-age children and it is thought that adult levels of performance are achieved by age 10 (Welsh, Pennington &

Groisser, 1991). Similar results were found using the SST where inhibitory skills apparently emerged at age 7/8 and quickly reached adult levels of competence (Carver, Livesay & Charles, 2001; Schachar & Logan, 1990), therefore inhibition is considered one of the later emerging skills. Despite this, Diamond's (1985; 1988; 1991) work on both primate and human infants clearly demonstrates the precursors to inhibitory control and confirmed the prefrontal mediation of human performance quite early in development. Kopp (1982) suggests the developmental course of self-regulation of behaviour begins with responsivity to warnings (9-12 months) and external regulation of behaviour (24 months) progressing to self-directed overt-speech regulation (36 months) and covert-speech regulation (42 months onwards). This developmental pattern is observed by Winsler *et al.* (2000) who also show hard-to-manage children use more spontaneous private speech during problem-solving tasks which reflects their difficulty in speech-action co-ordination.

Using modified versions of the WCST, impulse control and self-monitoring skills have been demonstrated by 2-year-olds (Kopp, 1982) but it is questionable whether this is a reasonable classification. Although inhibition is inherent in any task where salient, if not prepotent, erroneous response alternatives are given (Welsh, Pennington & Groisser, 1991) the measure clearly involves reflection and the testing of new hypotheses and this suggests the measures are more likely to reflect cognitive flexibility than impulsivity. This is problematic but Espy (1997) developed a new task called the Shape School that purported to assess inhibition and cognitive flexibility separately. This task was presented in a story book format. The story began by showing colourful shaped figures in a playground and the child was told that the names of the figures were the same as their colour (i.e., red, blue or yellow). The story continued by showing the figures lined up for lunch and in the control condition the child was asked to name the figures in the line as quickly as possible. In the inhibit condition the figures had a happy or sad face according to whether they were ready for lunch or not, and the child was asked to name only those who were ready for lunch and not name the others. In the switch condition faces were neutral but figures in hats were added and these figures were named after their shape, not colour. The child was again asked to name all figures (i.e., colour for hatless figures, shape for hatted figures). The final condition re-introduced the happy/sad face and the child was asked to name (colour or shape) figures with happy faces and not those with sad faces, so involving both inhibit and switch. Using this task Espy found significant development of inhibition skills between 3 and 4 years whereas cognitive flexibility showed significant development between 4 and 5 years (Espy, 1997). From this perspective we may interpret performance on molar EF tasks as indicating inhibitory skills in very young children even when the measure also potentially taps cognitive flexibility.

Espy and colleagues have also found continuous development of inhibition skills on the AB reversal task for children aged between 2 and 5 years which, despite being conceptually similar to 'switch' tasks used to measure cognitive flexibility, load onto different factors which may be attributed to the reduced WM demands of the former (Espy *et al.*, 2001; Espy, Kaufman & McDiarmid, 1999). Rapid development of inhibition between age 4 and 5 has also been observed by Livesey and Morgan (1991) using the Go/No-go task frequently applied to school-age children.

Hughes (1998a) developed a new task called the Detour reaching box for the purpose of measuring inhibition in preschoolers and also adopted the classic neuropsychological measure Luria's handgame. The former required the child to retrieve a marble from an apparatus using two different routes (action sequences) each of which were signalled by a different coloured light and was similar to the card sort tasks, and the latter was a reversal task that required the child to mirror a hand action of the experimenter, then reverse that action. Using these measures it was found that preschool children as young as 3 years 6 months demonstrated inhibitory skills (Hughes, 1998a). In a comparison study of hard-to-manage children and control children of preschool age it was observed that in the experimental group 63.8% and 51.4% reached criterion on Luria's Handgame and Detour reaching box respectively compared to 83.8% and 78.9% of control children (Hughes, White & Dunn, 1998) thus confirming an inhibitory deficit in those children with high hyperactivity ratings. An interesting twist to this association is exposed in a later study which found performance on the detour reaching box task predictive of antisocial behaviour in both experimental (AD/HD + CD) and control groups. This highlights the inter-relationship between social and cognitive development, and the importance of motivation and compliance in task execution (Hughes *et al.*, 2000). Again, the question arises as to the adequacy of the classification. Both measures involved the inhibition of a prepotent response but neither involves the possibility of early responding or waiting to respond. At best it may be said that the tests only tap one aspect of inhibition, at worst they may also be too reliant upon cognitive flexibility. Several tasks which do measure premature and erroneous responding (so-called measures of impulsivity; MFFT, CPT and Chip sorting) were used in Mariani and Barkley's (1997) comparison study. This study failed to find significant group differences between AD/HD and control preschoolers on measures of impulsivity although task performance was consistently poorer in AD/HD children who also displayed significantly more task-irrelevant behaviours. This indicates that whether deficits are found or not depends upon the type of inhibition being assessed. Despite this many studies have determined that inhibition can be reliably measured in the preschool years (Campbell *et al.*, 1994) and prospective studies have shown this early rating of behavioural inhibition has stability over time and predictive value in terms of symptomatic behaviours (Mesman, Bongers & Koot, 2001; Hughes *et al.*, 2000; Winsler *et al.*, 2000; Campbell, 1994).

3.2.2. Working memory

Welsh, Pennington & Groisser (1991) found recognition memory was one of the earliest skills to emerge, being evident in 3-year-olds and reaching adult levels by age 4. If one considers the way young children begin reading, which is usually by recognising a whole word, the early development of these skills obviously underpins reading ability. The relationship between spatial WM and age was investigated by Espy and colleagues (Espy *et al.*, 2001; Espy, Kaufman & McDiarmid, 1999) using the AB and Delayed Alternation tasks. These tasks required the child to wait before retrieving an object they saw the experimenter previously hide in one of two locations, therefore imposing a WM load equivalent to the waiting period. In these studies, WM skills were demonstrated in children aged between 2 and 5 years, which steadily improved with age. This indicated greater skill efficiency rather than basic skill acquisition, but a ceiling effect was observed for the older children.

WM deficits have been found in AD/HD preschool children aged between 4 and 6 years. Mariani and Barkley (1997) compared the performance of AD/HD boys and normal controls on several measures of WM, including spatial and number recall tests. Deficits in the AD/HD group were significant for the spatial (ES = .77) and number (ES = .71) recall but not for verbal WM. The finding of spatial WM deficits is supported in a further study which required children to recreate a picture puzzle. This study reported that hard-to-manage children performed less well then normal peers (Winsler *et al.*, 2000). The WM task used by Hughes, White and Dunn (1998) to compare hard-to-manage and control preschoolers was similar to the number recall task in that items were verbally presented and increased in number over trials. Even though recall was cued in this case (i.e., the sequence was recreated using pictures) no group differences emerged.

3.2.3. Planning

The planning ability of 9- to-18-month-old infants has been demonstrated in several experiments which also showed strategic learning over trials and strategy monitoring in the 13- to-18-month-old infants (Chen, Polley-Sanchez & Campbell, 1997; Willatts, 1984; Willatts & Fabricius, 1993; Willatts & Rosie, 1989). In each study the task involved the infants getting an out-of-reach toy via a two or three stage process, so the goal and obstacles were observable and concrete throughout and the goal path existed though it was barred by obstacles. In contrast the three-disc ToH requires that a goal path be created and this challenging task has been used to assess planning skills in 3-to-5-year-olds. Under these conditions evidence has been adduced for limited single-goal planning in preschool children (Welsh, Pennington & Groisser, 1991;

Espy *et al.*, 2001) and similar results were found using a shopping trip planning task (Hudson & Fuvish, 1991). Each study found rudimentary skills in 3-year-olds, and report significant improvements between 3 and 4 years of age, with Espy and colleagues reporting further improvements between 4 and 5 years. Hudson and Fuvish suggested that younger children's performance deteriorates when task difficulty increases because they lack plan monitoring skills as opposed to plan formulation/plan execution skills and to some extent this is commensurate with Swanson's (1996) finding that cognitive load best predicts age-related performance in working memory tasks. The increased demand on WM is clearly an important variable in complex executive tasks. Using construction planning tasks where toys are assembled using a planned sequence of moves, Bauer *et al.* (1999) found evidence for planning in children as young as 2 years with 8% of trials successfully completed with minimal external support.

Although planning is admittedly poor in 3-year-olds it appears that planning emerges in the latter part of the second year but performance is contingent upon the amount of external support and the representation of the goal-state. By age 4, children are less reliant on these external variables and show evidence of a range of planning execution and monitoring skills. Indeed, Welsh, Pennington and Groisser (1991) suggest that planning emerges only slightly later than memory skills and adult-level performance on the three-disc ToH is achieved by age 6. Of course this does not imply that adult levels of planning skills are intact at this stage, merely that the cognitive challenge at this level of difficulty is met at this age. This principle is demonstrated on the more complex four-disk version, which shows continuing development into middle childhood.

Mariani and Barkley (1997) examined the planning ability of AD/HD children aged between 3 and 6 years using the classic neuropsychological test the Porteus Maze. In this study AD/HD children performed less well than their normal peers (ES = .69). Planning deficits in AD/HD children aged between 3 years 6 months and 4 years 6 months have also been confirmed using the ToL (Hughes, White & Dunn, 1998) where significantly fewer children reached criterion on the task compared to normal controls. However, group membership did not predict ToL performance when verbal ability and social background were taken into account. In this study the ToL was significantly more difficult than an inhibition task for both experimental and control groups which also suggests planning skills are not so well developed as inhibitory skills at this age. Hughes *et al.* (2000) have also found that performance on the ToL predicts antisocial behaviour in hard-to-manage preschool children but not their normal counterparts (mean age = 4 years 3 months).

3.2.4. Cognitive/attentional flexibility

The ability of young children to set shift is debated, with Diamond and Boyer (1989) suggesting preschool children have the cognitive skills and other researchers finding poor performance on the WCST (Chelune & Baer, 1986) and CANTAB Set Shift (Luciana & Nelson, 1998) both of which are adult neuropsychological tests. As was mentioned previously, Espy (1997) extended her EF task, the Shape School, to include a ‘switch’ or ‘shift’ as a further condition. Thus the measure could assess both inhibition and attentional flexibility, and these functions could be dissociated. In a developmental study the 'switch' condition was only applied to children older than 4 years of age as it was thought that the principle of shape as well as colour would be inappropriate for younger participants. The study showed switching skills were evident at age 4 and significantly improved between 4 and 5 years. This was confirmed in a later study utilising the modified card sort test (Schouten *et al.*, 2000) so it appears that 4-year-old children have difficulty with adult neuropsychological tests, especially shifting between two categories (as in the WCST), but can demonstrate shifting when developmentally appropriate tasks are applied. In a later normative developmental study Espy and colleagues employed two simple reversal tasks (colour and spatial) to assess cognitive flexibility in even younger children aged between 2 and 5 years and found a stage-like development which suggested a protracted period of skill acquisition. However, the tasks were too difficult for many of the youngest children and therefore a less reliable measure for this age group (Espy *et al.*, 2001) although Hughes (1998a) successfully utilised used a simple pattern reproduction task and a modified card sort task with children as young as 3 years 6 months.

A comparison study of preschool AD/HD vs. control children, which employed the Color Form test similar to the adult Trail Making task, found AD/HD children made more errors than controls (ES = .42) but this was not significant (Mariani & Barkley, 1997). Winsler *et al.* (2000) also confirmed deficits on a trail-making task (ES = .28) and a task derived from the MFFT (ES = .45) for hard-to-manage preschool children but there was no test of significance reported. A further study found hard-to-manage preschoolers were significantly more likely than controls to fail on two AF measures: a pattern reproduction task and a modified card sort test (Hughes, White & Dunn, 1998). From this we may infer that AD/HD children have difficulties on AF tasks but these tasks do not necessarily differentiate between normal and experimental groups. Given that cognitive flexibility skills are immature at this age, deficits on complex switching tasks may reflect other difficulties in task execution, such as inhibition and attentional problems.

3.3. Adapting EF measures for preschool children

The measurement of EF must involve challenge and adaptive capacity, making the familiar, comfortable or conventional inappropriate. Measures should include some, but not necessarily all, of the following core characteristics: a delayed response requirement, internal representation of schema and action plan, inhibition of inappropriate responses, effortful and flexible strategies, and consistency (Denckla, 1994). Considering the protracted course of maturation of the frontal system and the range of identifiable executive processes, it is possible that different processes may emerge and develop at different stages of maturation, and that early-developing skills may be different in form to the goal-directed behavior observed in adults. If so, investigation should focus on children's performance in age-appropriate tests, rather than considering what they cannot yet achieve judged by adult standards. Adapting neuropsychological tests that are based on adult populations for use on children may not be valid given the diversity of outcomes from early brain damage.

Over and above the requirements of construct and content validity, it is important that childhood EF measures should, if they are to be developmentally appropriate, be attractive to children (to ensure motivation), quick to administer (to reduce attentional demands beyond the abilities of the younger children), and include a range of difficulty levels (to challenge all children across the sampled age range). Tests must also avoid the obvious confound of limited linguistic skills. Many researchers have developed new tasks, or have successfully adapted adult tasks, to create developmentally appropriate EF tests. In particular, Hughes (1998a; 1998b) and Kochanska (1996) modified children's games that tap inhibition, WM and planning skills, finding the measures to be appropriate for children as young as 3 years 6 months. The three tasks were adopted for use in this study and are fully described in the method section of the following chapter.

3.4. Delay in the preschool years

There is a dearth of studies which utilise delay measures in relation to preschool AD/HD. Because of this we are informed by those studies which have investigated self-control/impulsivity using measures where delay is inherent in the task.

3.4.1. Conceptualisation and definition of self-control

From the radical behaviourist approach self-control is conceptualised as the ability to make choices based on longer term consequences. The temporal dimension is essential because, without it, choice simply reflects preferences. In this way, situations involving self-control are conceptualised as those involving mutually exclusive paths to rewards of differing magnitude occurring at different times (Logue, 1988; Rachlin, 1974). Operant psychologists have operationally defined self-control as choosing a larger, delayed reinforcer (hereafter referred to as the larger, later reward – LL) over a smaller, less delayed reinforcer (hereafter referred to as the sooner, smaller reward – SS), such that total access to reinforcers are maximised (see Logue & Chavarro, 1992). It is assumed that self-control is exhibited when the LL choice is made, and the choice of the SS reward is impulsive.

Not all behaviourists agree that self-control must involve a choice between two rewards. Another situation involves a choice between responding and not responding based on immediate and delayed consequences (Baum, 1994). Operant psychologists have also used schedules of reinforcement to assess the effect of reinforcement and temporal sensitivity on multiple response behaviour. In a fixed interval (FI) schedule the minimum time between reinforcers is fixed. In a variable interval (VI) schedule the time between reinforcers is averaged around a particular value. When two or more reinforcement schedules are available simultaneously (i.e., concurrently) the subject can distribute responses accordingly. A differential reinforcement of low rate responding (DRL) schedule, where subjects are reinforced for waiting before making responses, is the most direct measure of witholding responses.

Self control has been conceptualised by personality theorists as a triumph of mind over body, reason over passion and cognition over motivation. As such it is defined as the ability of an individual to defer gratification, or wait for a reward (Mischel, 1981) rather than the choice between two rewards. Self-control is operationalised as the ability to wait and impulsivity as not waiting. This, of course, could equally apply to the choices made in a SS/LL task and this experimental paradigm has been extensively employed as a delay-of-gratification task (DoG) by Mischel and colleagues (see Mischel, 1966). Unlike the behaviourist paradigm, in which self-control must necessarily involve a choice between reinforcers of differing magnitudes delivered at different times, the DoG tasks are those which also manipulate the pre-reward delay, but the focus is not on the physical properties of the reinforcer (e.g., magnitude). Such tasks may be considered analogous to the SS/LL choice as they involve reinforcer amount (perceived or actual) and reinforcer delay, but they do not always involve reinforcer options, so self-control is not a direct function of the current physical values of the reinforcer (Logue, 1988). In this way, DoG tasks may also take a delayed-reponse format where a child is simply asked to wait before responding (i.e., retrieving a snack; playing with a toy, etc.). Strictly speaking in this case the delay is pre-response rather than pre-reward (i.e., delay between response and reinforcement) although both involve delay of gratification. In this sense the delayed-response tasks are more analogous to the DRL tasks that reinforce waiting behaviour.

3.4.2. Self-control in humans and animals

Using the SS/LL paradigm, studies have shown that non-human animals (e.g., pigeons) are consistently impulsive (Logue *et al.*, 1988; Logue, Smith & Rachlin, 1985). Using schedules of reinforcement it has been found that delayed reinforcers are less effective at controlling behaviour than immediate reinforcers. This is explained in the behaviour-economic literature as temporal discounting (Mazur, 1998). Simply put, this means the longer you have to wait for a reward the less value that reward is worth to you. Discounting conforms to the quantitative Matching Law proposed by

Herrnstein (1961) in which choices are directly proportionate to reward size, and inversely proportionate to the amount of pre-reward delay.

Applying the SS/LL paradigm studies on adult humans has shown that, unlike animals, they consistently demonstrate self-control (Logue *et al.*, 1990). The self-control exhibited by humans is thought to reflect their higher developed language skill as humans produce their own verbally-based cues (e.g., they can count). This ability suggests humans would be sensitive to all temporal aspects of the task. For example, they would be sensitive to post-reward delay (PRD) as well as pre-reward delay, and will be able to reward maximise over the entire experimental period, not just per trial. This was the prediction of the quantitative Molar Maximisation model, which was supported in studies that incorporated a PRD. Data from these studies demonstrated that pigeons are sensitive only to pre-reward delay while human adults were sensitive to both pre-reward and post-reward delays (e.g., their choice resulted in maximum rewards taking account of overall delay)(see Logue, 1988).

3.4.3. Self-control in preschool children

Because the capacity of human adults for self-control was attributed to their highly developed language skills it was appropriate to investigate preschool children whose language skills were not so highly developed. Logue and Chavarro (1992) utilised the SS/LL paradigm to assess impulsiveness in children aged between 3 years 4 months and 4 years 9 months. In this study, children chose between 1 sticker available immediately (SS) and 3 stickers available after 30 s (LL). On average children chose the SS reward more often than the LL reward, and this preference for SS rewards was more pronounced in boys than girls. This was interpreted as demonstrating the natural impulsiveness of preschool children who, unlike adults, were unable to wait for the delayed reward. This was consistent with the notion of language development underpinning the development of self-control, and is further supported by studies that find greater self-control in school-age children relative to preschool children (Miller, Galanter & Pribram, 1978; Sarafino *et al.*, 1982).

Using the DoG paradigm, it has been demonstrated that the transition to greater self-control occurs at around age 5, commensurate with increased use of delay tactics such as distracting oneself (Mischel, Shoda & Rodriguez, 1989). Prior to age 5, children show a preference for attending to 'real rewards' rather than symbolic representations while trying to wait for them, which makes waiting more difficult (Mischel & Mischel, 1983). Metcalfe and Mischel (1999) propose that self-control is the interplay between the 'hot' (amygdala based, emotional) system and the 'cool' (hippocampus based, cognitive) system; the 'hot' system develops earlier than the 'cool' system and it is the mastery of the 'cool' system that promotes self-control in older children. The developmental association between the use of delay strategies and delay of gratification has also been shown in a follow-up study where children's ability to defer gratification at age 5 has been associated with use of distraction strategies during separation from the mother at age 18 months (Sethi *et al.*, 2000). Furthermore, the ability to defer gratification at age 4 has been associated with greater social, academic and reasoning competencies 10 years later (Mischel, Shoda & Rodriguez, 1989).

However, individual differences in self-control may be observed at any given age, and Mischel and colleagues also examined the conditions under which self-control is most likely. In these experiments, children's preferences for two different rewards (snacks) was established, then the experimenter left the room after telling the child that if (s)he waits until the experimenter returns (s)he will receive the preferred reward, but if (s)he calls the experimenter early (s)he will receive the less-preferred reward. Self-control was measured as the time children were prepared to wait rather than the choice itself. Results consistently showed children were more likely to wait for the preferred reward, were less likely to wait when the waiting periods increased, and were less likely to wait if the reward options were physically present (Mischel, Ebbesen & Zeiss, 1972; Mischel & Ebbesen, 1970). The surprising finding in these studies is the length of time the preschool child will wait under optimal conditions. Authors have noted waiting times of between 13 and 15 minutes are not unusual for preschoolers when rewards are absent and distractions are provided (Peake, Hebl & Mischel, 2002) but waiting times fall to below one minute when rewards are present and no distraction is provided. Therefore self-control is not just an ability, but is critically dependent upon specific conditions of the delay period.

The relationship between age and self-control has been investigated by Sonuga-Barke, Lea and Webley (1989), who tested 16 girls aged between 4 and 12 years using the SS/LL paradigm. In this study subjects were tested over five sessions; in every session the pre-reward delay for the SS choice was constant at 10 s, but the pre-reward delay for the LL choice increased over sessions from 20 s to 50 s. Because a time limit of 15 minutes was imposed per session, the potential earnings from consistently choosing the LL reward *decreased* as pre-reward delay increased. In this way choosing the LL reward consistently would be the optimal response until the pre-reward delay for the LL choice exceeded 40 s when the SS choice would now be optimal. Results showed 4-year-olds either chose the SS reward or were indifferent, the 6- and 9-year-olds consistently chose the LL reward (even when doing so was counter to reward maximising). The 12-year-olds were sensitive to global reward rate, switching from LL to SS choices when the pre-reward delay for the LL increased. The authors concluded that this demonstrates a two-stage development of self control where younger children (4-9 years) respond to reward size and learn *how* to wait for a large reward and older children (9-12 years) respond to reward rate learning *when* to wait for the large reward (Sonuga-Barke, Lea & Webley, 1989).

3.4.4. Self-control and AD/HD

From studies that have utilised the SS/LL paradigm to compare AD/HD performance to that of controls, it has been found that AD/HD children consistently choose SS rewards, being apparently unable to wait for the LL reward (Schweitzer & Sulzer-Azaroff, 1995). This preference for immediacy has been interpreted as insensitivity to reward and impulsive responding (Barkley, 1989). However, Sonuga-Barke (1989) pointed out that preference for the SS choice would also be consistent with a delay reduction strategy as choosing the SS reward would also reduce time-on-task. To test these hypotheses Sonuga-Barke, Taylor and Heptinstall (1992) used the choice paradigm but incorporated two conditions: the first condition involved only pre-reward delays, the second imposed a PRD after the SS choice equivalent to the pre-reward delay of the LL choice. The imposition of the PRD was important in that it allowed the dissociation between impulsive responding (making SS choices) and delay reduction strategies (making SS choices only when doing so reduces overall delay). Using this format, delay reduction was only possible in the NoPRD condition; in the PRD condition the trial lengths were equalised and children would be subjected to the same overall delay irrespective of choices made. In this study AD/HD children generally chose the SS reward when there was no PRD, and switched to the LL reward when a PRD was imposed. Also, AD/HD children actually showed a greater preference than controls for the LL reward in the PRD condition. This demonstrated that AD/HD children are not impulsive and are sensitive to overall delay in the same way that adults are.

Although this result was consistent with a delay reduction hypothesis, it could be equally well explained by reward maximising; consistent with the molar maximising model, choosing the SS rewards increased the rate of reward when there was no PRD delay, and switching to the LL reward in the PRD condition would also serve reward maximising as the rate of reward was constant regardless of choices made. Studies on adults have consistently shown reward maximising strategies typify their performance on this task (King & Logue 1987; Logue *et al.*, 1990). To test these hypotheses a further experiment was conducted which assessed AD/HD and control children's performance under time- and trials- constraint conditions (Sonuga-Barke, Lea & Webley, 1989). To demonstrate adaptive responding (i.e., maximise rewards) under the 20 min time constraint it was necessary to switch from LL to the SS reward as the pre-reward delay for LL choices increased, whereas under a 25 trial constraint it was always better to choose the LL reward. Results showed in the time constraint condition most children chose the SS reward, but in the trials-constraint condition only controls demonstrated reward maximising, with AD/HD children adopting a delay reduction strategy at the expense of maximising rewards. Sonuga-Barke and colleagues concluded that AD/HD children were delay averse rather than impulsive or reward maximisers.

A threat to this conclusion comes from Tripp and Alsop (2001) who found the AD/HD child's preference for SS rewards persisted even when a PRD was imposed to equalise trial lengths so the rate of reward was held constant (e.g., a delay of 3.5 s was imposed after the immediate reward which was equivalent to the 3.5 s wait to the delayed reward). Tripp and Alsop claim it is pre-reward delay rather than overall delay that is salient to the AD/HD child and conclude that preference for SS rewards characterises AD/HD performance rather than sensitivity to delay. This poses a difficulty for the delay aversion hypothesis but the delay periods were perhaps not long enough to elicit delay-averse behaviour. Also in this study the choice was made in the context of a signal detection task. As it is known that signal detection tasks are heavily reliant on attentional capacities, this modification to control for reward rate means the task is no longer analogous with that used in the Sonuga-Barke, Lea and Webley (1989) study.

Using a delayed-response task (DRT), Sonuga-Barke and Taylor (1992) also found AD/HD school children sensitive to pre-response delay. This sensitivity to a delay before responding has also been noted in infants in studies using tasks that require inhibition of previously learned response. The AB task, where infants watch a toy being hidden in one of two locations and retrieve the toy after an imposed delay of up to 10 s, is similar to the delayed-response tasks in that both require witholding responses until a signal. However, the DRT does not usually involve a switch, which makes it a more direct measure of delay aversion. Diamond (1988) used the AB task and found that infants generally perseverate when the location is switched to B, but on A trials errors were rare when there is no delay. For children aged 7-9 months delays of 2 to 5 s elicit B errors and longer delays elicit A errors (Diamond, 1988) and these errors are attributed to disinhibition as they persist in a 'seen' condition where the toy is visible, so performance was not WM dependent. The AB switch is conceptually similar to the WCST, which also involves a switch and inhibition of a previous response, so it may be presumed that the imposition of delay would similarly affect performance on this task.

An alternative source of information concerning AD/HD and delay comes from studies which have used an animal model of AD/HD, the spontaneously hypertensive rat (SHR). Sagvolden *et al.* (1992) employed single FI-60s or FI-120s schedules and found the SHR had a higher overall response rates compared to control rats, and higher response rates in the 60 s compared to the 120 s schedule. This was seen to model the behaviour of AD/HD children whose preference for immediacy is well documented, and was supported by the fact that SHR performance was found sensitive to methylphenidate.

A delayed response requirement is most clearly assessed in direct reinforcement of low rate responding (DRL) schedules. Such tasks tap the ability to wait before responding by forcing subjects to space responses for a minimum length of time before reinforcers are available. Utilising conjunctive VI-120s and DRL-16s schedules, where the VI schedule maintained a steady rate of responding but the DRL schedule required a minimum of 16 s between two responses, Sagvolden and Berger (1992) found SHRs made a higher number of responses overall and exhibited timing deficiencies, frequently making responses with IRTs below the 16 s DRL requirement. This is thought to model AD/HD hyperactive and impulsive behaviours. As well as the increased number of responses, the pattern of responding was also different. An increase in short IRT responses (i.e., below 2 s) represented a change in response style from the high-but-constant pattern to a break-and-run pattern (i.e., long pauses followed by a 'burst' of rapid responses).

This animal model was subsequently applied to AD/HD boys aged between 7 and 12 years (Sagvolden *et al.,* 1998) using a multiple reinforcement schedule in which a FI-30s schedule was alternated with a signalled 120 s extinction schedule where no reinforcers were delivered. Results were congruent with animal studies in that AD/HD children had a higher overall response rate and increased responding in the period immediately preceding the reinforcer. Also the style of responding changed over trials from the typical scalloped pattern of responding to the break-and-run pattern. This is thought to model the bursts of activity which characterise AD/HD behaviour. In addition, the AD/HD children continued responding in the extinction phase which was attributed to their inattention to the signal, and explains the perseverance in AD/HD responding. This evidence has created the basis upon which it is claimed that AD/HD is a reinforcement deficit disorder (Sagvolden, 1996) in which an altered reinforcement mechanism results in a shorter, steeper reinforcement gradient.

The reduced effectiveness of the delayed reinforcer certainly offers an insight into the impact of delay and temporal sensitivity, however it may also be said that DA can explain the reduced efficiency of reinforcers. Solanto (1990) found positive reinforcement and negative reinforcement in the form of response-cost does not differentially affect AD/HD and normal children aged between 4 years 6 months and 11 years on a simple delay task which required children to withold responses for 6 s. Although the AD/HD children were generally less efficient this was not statistically significant. This was interpreted as a challenge to the reinforcement hypothesis and it is probable that the delay itself accounted for the lack of efficiency in the AD/HD group who simply made more early responses consistent with delay reduction. As such this experimental paradigm is a useful method for investigating delay, perhaps especially in younger children given the evidence that preschool children are found to be relatively insensitive to reward size and reward rate, yet their behaviour is impacted upon by pre-reward delay (Sonuga-Barke, Lea & Webley, 1989).

3.5. Measuring delay aversion in preschool children

Unlike EF measures that are well documented in the child development literature, the concept of delay aversion is relatively new. When considering delay tasks suitable for use with preschoolers the methodological issues discussed in section 3.3. are to some extent equally salient here. However, the extensive application of operant tasks to assess delay brings with it particular advantages. In particular operant tasks avoid the confound of limited language skills and are usually quick and easy to administer. The literature shows the laws which govern behaviour apply equally to children as adults (Mazur, 1998). Operant tasks involve reinforcement, delay and a response requirement. In this sense there are some practical considerations when examining different experimental paradigms.

More than any other tasks, DoG tasks have been successfully used with young children as measures of delay aversion. These tasks may involve a choice (i.e., the SS/LL paradigm) in which case delay aversion is reflected by choices that minimise overall delay. The application of the task as a measure of delay aversion represents a departure from the traditional operant interpretation of choices. Choices are not interpreted in a unidimensional way as either choice may reflect a delay reduction strategy depending upon the task parameters (e.g., the size and rate of reward, the extent of the pre-and post-reward delays, trial or time constraints). Evidence from studies employing such tasks suggests preschool children may not be effective at processing rate information (Sonuga-Barke, Lea & Webley, 1989) so a time constraint format may be inappropriate. In a trials constraint format a reward ratio of 2:1 is sufficient to elicit differences between AD/HD and control children.

DoG tasks do not always involve choice and many delay tasks involve waiting to respond in which case delay aversion is demonstrated by shorter waiting times. These tasks are especially suitable for use with preschool children as, unlike the SS/LL choice paradigm, task performance does not rely upon cognitive skills (assessment of relative reward size and rates) which may be undeveloped in the very young preschoolers. One potential problem is that delayed responding often involves inhibition, and younger children are naturally impulsive. Unlike the choice paradigm which dissociates impulsivity and delay reduction using the PRD format, interpretation can be ambiguous. Therefore it would be important to consider how such tasks correlate with other measures of delay aversion and inhibition measures as well as task performance *per se.* A second consideration is that such tasks may demonstrate a ceiling effect in older preschoolers whose ability to wait for attractive rewards is well established.

Schedules of reinforcement also assess the effect of reinforcement and temporal sensitivity. Such studies have shown that response rate increases when rewards are more frequent (Bradshaw, Szabadi & Bevan, 1976). This response behaviour conforms to Herrnstein's matching law and the model is remarkably robust across species and for children and adults. A simple alternating VI schedule which alternates a dense and less dense reward schedule has demonstrated delay aversion and discriminated between AD/HD and control children of school age (Sagvolden *et al.,* 1998). Two issues arise when applying this to preschool children. First, the maximum rate of response is lower for younger children than older children because motor skills are less developed. Second, there is the possibility that reward satiation will occur soonest in the younger children.

The CPT has potential use as a delay task though not necessarily in its traditional signal-detection form. Sonuga-Barke (1998) has posited that the witholding of a response is qualitatively different from early/fast responding and this implies that a non-target stimulus is not appropriate as a variable in CPT. In this case the repeated presentation of a visual stimulus to which participants positively respond in all trials is considered sufficient to elicit impulsive responding and event rates may be manipulated to assess responding under different delay conditions. Evidence suggests that event rates differentially impact on AD/HD performance in CPT resulting in less accuracy when event rate is slow (Chee *et al.*, 1989). The fact that children's performance on CPT denigrates as a function of time-on-task (Corkum & Siegel, 1993; van der Meere & Sergeant, 1988) indicates it is a good measure of motivation. Also, one may expect boredom, fatigue and distractibility to be pronounced in very young children relative to older children and the task should be developmentally sensitive.

However, there are several problems with CPT when applied to AD/HD children. Although many studies report AD/HD deficits based on increased omission/commission errors (Swaab-Barneveld *et al.*, 2000; Horn *et al.*, 1989; Shapiro, 1986; Sykes, Douglas & Morgenstern, 1973) others find no significant differences (Schachar *et al.*, 1988; van der Meere & Sergeant, 1988). Furthermore, AD/HD children's performance does not degrade as a function of time-on-task relative to controls (Corkum & Siegel, 1993) and one review found a third of AD/HD children score in the normal range on this task (Trommer *et al.*, 1988). Swanson *et al.* (1990) conclude that decades of research using this task have not unequivocally proven deficits in AD/HD children. Finally, Corkum and Siegel (1993) find the CPT task performance sensitive to situational and external variables which affect perceptual sensitivity and response behaviour respectively. As testing will take place in multiple settings in which external distracters will be difficult to control, it is unlikely that CPT would be suitable in this context.

3.6. Chapter summary

There is a consensus regarding the definition of EF as being those higher-order cognitive skills associated with prefrontal areas of the brain. So far it appears that executive functions have different developmental trajectories. That is, the emergence, developmental course and attainment of adult competencies occur at different times for different skills. EF is variously measured using broad neuropsychological tests and developmental tasks that purport to measure a specifically defined aspect of EF. The latter measures have been applied to preschool children and provide evidence for rudimentary EF skills in these years or even a precursor to later-emerging skills. These skills can be discriminated from each other, and from non-executive functions, in middle childhood although it has not been established whether this trend is apparent in the preschool years. Where EF tasks have been applied to AD/HD preschool children, evidence suggests EF deficits in preschool children are similar to those found in school-age children. Three tasks previously used in the preschool population have been selected for inclusion in the test battery for this study, each representing a specific EF domain (inhibition, WM and planning). These measures will be described in the method section of the following chapter.

A case has been made for the development of delay tasks based upon measures of self-control. Despite conceptualising self-control in different ways, both personality and behaviour theorists have adopted a similar experimental paradigm (SS/LL) which allows the manipulation of delay, both pre-and post-reward. Operant psychologists have also contributed much to our understanding of delay using different schedules of reinforcement. Using these measures, it has been established that self-control is poor in preschool children compared to older children. The transition toward greater self-control happens around age 5, possibly allied to improvements in language skills at this time. Where the tasks have been used to investigate AD/HD, evidence suggests AD/HD children are more delay averse than control children even at this young age. Three delay measures based on these operant tasks will be used in this study, and are described in the method section of the following chapter.

The stated aim of this research is to investigate the relationship between EF, delay aversion and AD/HD. Before this is possible, it is necessary to assess the task battery and explore the patterns of association and developmental change in the normal preschool population. To this end the following chapter introduces the first of two studies contained within this thesis.

CHAPTER FOUR: AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS AND DELAY AVERSION IN PRESCHOOL CHILDREN

4.1. Introduction

The aim of this study was to explore the performance of preschool children on a battery of EF and delay tasks, taking a developmental perspective. In the first instance it was vital to assess the new delay tasks to determine their validity and reliability in the preschool population. Secondly the relationship between tasks was examined to determine the structure of these functions at different ages. Finally, the role of age in the development of these functions was investigated. This was viewed as the necessary first step prior to exploring the role of AD/HD, which is the main aim of the thesis.

4.2. Research questions

The following questions were posed:

(i) Are the delay tasks good measures of delay aversion?

(ii) What are the patterns of association between task measures, and is this stable over time?

(iii) What is the structure of preschool EF and delay aversion?

(iv) What is the relationship between task performance and other child characteristics?

(v) What is the relationship between task performance and age?

4.3. Method

4.3.1. Participants

Sixty children from five city nurseries and preschools took part in the study, aged 3 (n = 20), 4 (n = 20) and 5 (n = 20) years. In each age group there were 12 girls and 8 boys who were recruited on the basis of age and tested within one month of their birthday. Children were given a cognitive assessment using a subset of the British Ability Scales version II (BAS II; Elliot, Smith & McCulloch, 1983) which included verbal comprehension, picture similarities, early number concepts, naming vocabulary and copying. The BAS II is a standardised measure of general cognitive ability with extensive normative data for children aged between 2 and 17 years. Scores on any individual task are standardised (T-scores) and summed to achieve a score for each of three domains: verbal, pictorial reasoning and spatial. The summed scores for each domain are added to give a total score which can then be converted to a percentile score. It is this score that indicates general cognitive ability, or GCA, which is commensurate with an IQ score. A subset of the full battery yields valid scores in terms of GCA.

4.3.2. Measures

The task battery consisted of three EF tasks and three delay tasks. Pictures of each task can be found in appendix iii (EF tasks) and appendix iv (delay tasks). The EF tasks have been successfully used by researchers to assess inhibition, WM and planning in the preschool population. Their reliability, validity and discriminative ability have been established in the preschool population. The delay measures come from the operant school. The first two (Effort vs. delay and Choice delay) have been developed for this study and involve the introduction of a PRD. This type of manipulation allows us to dissociate delay reduction behaviours (i.e., responses which reduce delay) and disinhibition (i.e., impulsive responses) and so to assess delay aversion. The third delay task (VI Schedule) has been used with school-age children and was adapted for preschoolers. This task involves two schedules of reinforcement which represented less delayed and more delayed rewards. This manipulation allows us to examine sensitivity to different delay conditions to assess delay aversion.

4.3.2.1. Inhibition task

The Puppet task (Kochanska, 1996) is based upon a task utilised by Reed, Pien and Rothbart (1984) as a behavioural inhibition task on the basis that it involves suppressing or initiating an activity to a signal. This is analogous to the Go/No-go tasks that have been widely used to measure inhibition in school-age children. It would be familiar to children as a variant of the childhood game 'Simon says' in which children only follow an instructions if they are preceded by the words 'Simon says…' but inhibit any response to a request that is not preceded by these words. In the Kochanska (1996) study two hand puppets, a bear and a dragon, were used. The experimenter instructed the child to perform the movement requested by the bear and inhibit the action requested by the dragon. On each trial the child could score between 0-3 with higher scores reflecting successful inhibition or successful execution of an action. Over six trials for each puppet, the mean score for the activity (bear) and inhibitory (dragon) trials was calculated. The preschoolers' mean score for the bear trials was 2.68 (SD = 0.63) and dragon trials was 2.03 (SD = 1.17) indicating that it was harder for preschoolers to inhibit than to positively respond.

In the present study this task was modified slightly. The puppets chosen were a policeman and a princess. These were deemed less scary for the younger children as both figures evoke positive images, yet each commanded authority; a preschool child is typically used to obeying their mother figure and is expected to familiar with the role of a policeman. In order to eliminate the possible confound of one being perceived as more authoritative than the other, and therefore more readily obeyed, the action puppet (i.e., the one whose requests should be followed) was counterbalanced across subjects.

4.3.2.2. Working memory task

The WM task used in a series of studies by Claire Hughes and colleagues was developed from a task used to assess WM deficits in children with brain lesions. The original task required children to use picture cards to recreate a sequence of items presented verbally by the experimenter. This task qualifies as a test of WM on two counts: firstly the serial order of each item varied between trials so success depends upon holding the most recent sequence on line whilst resisting interference from previous trials; secondly, it involves a physical search in a visual array for a picture match (Dennis *et al.*, 1991). Hughes (1998a) adapted this task to make it more attractive for younger children by substituting the picture cards with a child's story book that incorporated a panel of pictures which, when pressed, emitted a corresponding sound. With this 'Noisy book' the child could create an auditory sequence by pressing the pictures in the order in which they were verbally presented. Using this task, Claire Hughes and colleagues investigated antecedents of social impairment in behaviourally disturbed or 'hard to manage' preschool children

(Hughes, White & Dunn, 1998). The selection criteria for the experimental group involved a score of 8 or more on the parent-completed SDQ hyperactivity subscale. In this sense the children will be referred to here as hyperactive, but it is noted that 80% of these children also scored above the 90^{th} percentile on the subscale for conduct problems. The noisy book used in these studies was a red riding hood storybook containing a 3x3 array of nine pictures. The pictures were covered while the experimenter gave the to-be-recalled sequence verbally, which prevented the child from creating the sequence as it was spoken. The panel was then uncovered and the child recreated the sequence. Children were familiarised with the materials by naming the pictures and the experimenter used this terminology so failures were not due to identification. Four practice trials were allowed.

In a normative developmental study fifty children aged between 3 years 3 months and 4 years 7 months were tested using the Noisy book. Possible scores on this task were 1-3 and results showed a mean score of 1.88 (SD = 0.59). There was a significant main effect of age $p<.001$ and task scores were highly correlated with verbal ability when age was partialled out (Hughes, 1998a). The cohort were assessed again after a period of 13 months at which point 80% of children had started school. The percentage of children passing criterion rose from 12% to 78% over this period (Hughes, 1998b). In a comparison study (Hughes, White & Dunn, 1998) the performance of 40 AD/HD children (mean age = 4 years 4 months, SD = 4.7 months) was compared with that of matched controls. No group differences were found on the task although more control children (51.3%) reached criterion – in this case a score of 2 - than AD/HD children (32.5%).

In the present study further modifications were applied to make the task more challenging, as the task would be need to challenge the abilities of slightly older children up to 5 years. It was decided that the picture panel would remain covered for the duration of the task, so children not only had to recreate the sequence but also remember the positions of the pictures in the panel which were now only marked with blank squares. In this case the visuospatial as well as phonological components of WM would be engaged creating a more challenging test of WM. The noisy book chosen was 'Barney the dinosaur' with a vertical panel of nine pictures measuring 25mm x 25mm (dinosaur, rain, horse, crunchy leaves, bird, dog, wind, whistle, children laughing) that emitted a corresponding sound when pressed (e.g., the dog barked). The storyline was novel compared to the relatively well known story of red riding hood, so children could not use their prior knowledge of the storyline as a cue to the sequential position of each picture in the array. It was hoped that this modification would increase the discriminative properties of the task. During the practice trials where single-item lists were verbally presented, children were allowed to uncover the panel as many times as it was necessary to correctly locate 50% of the pictures. In this way poor performance would not be a result of a failure to initially identify the picture sequence.

4.3.2.3. Planning task

Hughes (1998b) introduced a planning task based on Shallice's (1982) disk-transfer task called the Tower of London (ToL), which has been extensively used to assess brain functioning in adults with frontal lesions. Shallice states that the task involves higher order cognitive skills such as focused and sustained attention, recognition and selection of goals, generation of plans and response feedback, but does not involve lower order skills such as short term memory, visuo-motor coordination and spatial processing. The original task utilised a pegboard and different sized disks that had to be moved from a start position to a goal-state in a prescribed number of moves. Hughes modified this task to make it more simple and attractive for younger children by substituting the different sized disks for same size but different coloured balls. The balls (80mm diameter) and pegs sizes (240mm, 120mm and 80mm) meant the small, middle-sized and large pegs fitted one, two and three balls respectively which reduced the number of possible moves. The balls were highly tactile (sponge) and the size of the balls meant children could comfortably hold only one in their hand, thus encouraging the child to observe the move-one-ball-at-a-time rule. Using this modified task, the experimenter created the goal state on one pegboard and the child was asked to move from the start position to the goal-state on their pegboard within a prescribed number of moves. The goal state remained in view for the duration of the trial. Practice trials consisted of three 1-move and three 2-move problems, and children were tested on 3-and-4-move problems.

Hughes, White & Dunn (1998) used this task to compare the performance of AD/HD and control children aged between 3 years 6 months and 4 years 6 months. Fewer AD/HD children (17.9%) reached criterion - correct solutions to two out of three 3-and-4-move problems - than controls (26.3%) and this group difference was confirmed as significant using χ^2 (Chi-square) analysis. In a longitudinal study (Hughes, 1998b) the task was introduced at Time 2 follow-up 13 months after Time 1, so data is only available for older children (mean age = 5 years, SD = 5 months). At this age, 82%, 64% and 44% of children passed criterion for 2, 3 and 4-move problems respectively.

The present study required no further modification to the task as developmental sensitivity and discriminative validity had been established.

4.3.2.4. Effort v Delay task (EvD)

Guided by the delay aversion hypothesis which states that children are motivated to reduce delay, and informed by the operant paradigm which shows children are sensitive to overall delay, the EvD Task was developed to represent a delay task which could be viewed as a true measure of motivation (e.g., performance would involve effort/motivation under different delay conditions). The measure was conceived as a computer-based task in which the child has a single response operandum (button-press) and is reinforced for working at it. In this sense it is essentially a standard operant procedure (de Villiers & Herrnstein, 1976) but two conditions were imposed. In the no-post-reward-delay (NoPRD) condition the children would be reinforced for working hard to reduce delay. In this sense the task is the opposite of the DRL which reinforces low rates of responding. The introduction of a PRD as a second condition meant working hard (i.e., making more button presses) would still be reinforced but would not reduce the overall delay. This task, quite simply, would measure how hard a child will work to reduce delay. It would be familiar to children as a variant of the 'Frogs-and-logs' children's board game in which children move pieces (frogs) across a board timing moves to coincide with logs moving along water channels.

Graphics showed a cartoon penguin character standing to the far left of the screen representing a shoreline, while icebergs travelled from the far right of the screen along the water channel. The penguin was programmed to jump onto the iceberg when it was level with the position of the penguin on the shore. The objective of the game was to gain rewards by operating a hand-held button-press control to make the penguin move along the shoreline to meet the iceberg. Rewards (1 sticker) were gained at the point of the jump so participants were reinforced for working the button-press. The pace of the trials was manipulated by incorporating two levels of speed. The iceberg was either fast (4.16 pixels/s) or slow (0.8 pixels/s) and this was randomly distributed over the 40 trials. There were two conditions, consisting of 20 trials each. The first condition incorporated no PRD (NoPRD) so the next trial began immediately after reinforcement. Working hard during these trials meant reducing the pre-reward delay and overall delay (i.e., overall time-on-task). The second condition incorporated a PRD (i.e., the trial was not over until the iceberg travelled to the far left of the screen regardless of the point at which the penguin jumped) so working hard during the trial reduced the pre-reward delay but increased the PRD. As the trial length was fixed in the PRD condition for fast (20 s) and slow (100 s) trials, responding did not reduce overall delay. In this way working harder in the No-PRD condition relative to the PRD condition would indicate delay aversion. The computer recorded the number of responses, rate of responding (IRTs) and erroneous responses (responses made during the PRD period). The table below describes the reward and delay contingencies in each condition.

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Table 4.1. Rewards gained and overall delay associated with working hard (i.e., button pressing)

	NoPRD	**PRD**
Pre-reward delay	Reduced	Reduced
Overall delay	Reduced	Fixed
Reward rate	Increased	Fixed
Rewards earned	20	20

Note: NoPRD = no post-reward delay condition; PRD = post reward delay condition

4.3.2.5. Choice delay task (ChD)

Based on the DoG tasks used by Mischel in which a choice is made between a SS and LL reward, the ChD Task was conceived as a computer-based task adopting the SS/LL paradigm, but incorporating a PRD condition in order to investigate the sensitivity of the preschool child to the imposition of a PRD. The task parameters were similar to those used in the trials constraint choice delay task used by used by Sonuga-Barke, Taylor and Heptinstall (1992) and Solanto *et al.* (2000). Rewards were 1 (SS) or 2 (LL) stickers as this 2:1 ratio was most effective in avoiding floor and ceiling effects and maximising group differences. Pre-reward delays in the aforementioned studies (2 s for SS choice and 30 s for LL choice) were adjusted to 3 s and 15 s respectively because the literature suggests younger children are even more impulsive than older children which implies a shorter delay would elicit delay averse characteristics. This also meant the overall testing time would be manageable for younger children whose ability to concentrate on a single task would be limited. Two blocks of 20 trials were presented with the conditions counterbalanced. The presentation was adapted for use with younger children by displaying teddies holding balloons (one balloon indicating the SS choice, two balloons indicating the LL choice) rather than squares labelled '1 point' or '2 points'. Also a touch screen was fitted over the monitor rather than using a computer keyboard so choices were made literal for children who may find it more difficult to understand the symbolic association on a keyboard.

The graphics showed two identical teddy bears, one of which appeared to be in the foreground and one of which appeared to be in the background. Depth cues were the paths on which the teddies stood. The foreground teddy held one balloon and the background teddy held two balloons. Teddies were chosen or activated by pressing their tummies. When either teddy was activated, the teddy 'walked' to the front of the screen and released the balloon(s), at which point the reward was delivered by the experimenter. In the NoPRD condition the trial was over when the balloon(s) were released. In this condition consistent LL choices would result in maximum rewards but consistent SS choices would reduce overall delay (i.e., overall time-on-task) and increase the reward rate. In the PRD condition graphics showed a balloon bin located at the rear, and after the balloon(s) were released the teddy walked back to pick up more balloons before returning to the original position. Thus the trial lengths were equalised at 23 s and the rate of reward was fixed. In this condition consistent LL choices would result in maximum rewards and neither choice would reduce overall delay as a smaller pre-reward delay meant a longer PRD. In this way, delay aversion is demonstrated by more SS choices in the NoPRD relative to the PRD condition, a preference for immediate reward would be demonstrated by SS choices in both conditions, and reward maximising demonstrated by LL choices in both conditions.

The percentage of SS and LL choices was recorded. The table below describes the reward contingencies in both conditions.

Table 4.2. Rewards earned and overall delay with consistent SS or LL choices

	SS choices		LL choices	
Condition	**Rewards earned over 20 trials**	**Overall delay (seconds)**	**Rewards earned over 20 trials**	**Overall delay (seconds)**
NoPRD	20	60	40	300
PRD	20	460	40	460

Note: SS = Sooner, smaller choices; LL = larger, later choices
Note: SS choices in the No-PRD condition increased the rate of reward by 5:1. The rate of reward was held constant in the PRD condition.

4.3.2.6. VI Schedule

To investigate the sensitivity of preschool children to different rates of reinforcement the VI schedule developed by Martin Hall at Southampton University was employed, which represented an experimenter-imposed delay task (i.e., the delay was externally controlled). This task was an alternating VI Schedule which alternated a dense and less-dense reward schedule. The schedules of reinforcement were generated using the Harvard Golden Loop system. Reinforcer means were 3 s for the dense schedule and 15 s for the less dense schedule. Actual reinforcement times were randomly distributed around these means with reinforcers delivered between 0.15 and 10.79 s in the dense schedule and between 0.75 and 53.95 s in the less-dense schedule. It has been mentioned that in a single schedule response rates increase with frequent rewards, and in this alternating schedule response rates will be a function of the reward rates in each condition.

Graphics showed a grey square in the middle of the screen over which a touchscreen was fitted to allow the square to be activated by on-screen pressing. The background colour was blue during the dense schedule and yellow during the less dense schedule. In this way the schedules of reinforcement were signalled. The reinforcers were cartoons which flashed on the screen. An increase in responding in the dense reward condition relative to the less dense condition would indicate delay aversion. The number of on-target and off-target screen presses, and the rate of responding (mean IRTs) were recorded.

4.3.3. Procedure

Participants were tested individually in a single test session lasting approximately 2 hours (including breaks). All children were first given the cognitive assessment described in section 3.4.1). Tasks were presented in a fixed order. In child development literature it is common to see tasks presented in order of difficulty, and the EF tasks were presented in the order of earlier/later skill development. The delay tasks were presented last and the progression from manual to computer games was intended to allow time for developing a relationship between experimenter and child, and capitalise on the enthusiasm children display for computer games. Frequent breaks mitigated the effect of boredom and fatigue that would otherwise create a systematic bias. Table 4.3.indicates the number and presentation order of tasks within the test battery.

Throughout testing, and particularly during the computer tasks, an attempt was made to keep instructions to a minimum. The impact of verbal shaping of behaviour is well documented and several studies have reported that minimal instructions result in greater sensitivity to contingencies in adults (Shimoff, Matthews & Catania, 1981). However, it is conceded that very young children may require the salient features of a task to be explicitly stated and their understanding checked. Therefore the instructions used in the current study were detailed. In the experimental tasks the delay period was emphasised in demonstration trials by the experimenter pointing out that this involves waiting. This strategy was deemed necessary as impulsive children may not attend to, or expose themselves to, all contingencies. The instructions and scoring criteria for the measures described in the previous section are presented here.

Table 4.3. Task battery

Order of presentation	Task	Delivery	Approximate time (mins)
EXECUTIVE MEASURES			
(1) Inhibition	Puppet	Manual	5
(2) WM	Noisy Book	Manual	10
(3) Planning	Tower of London	Manual	15
DELAY MEASURES			
(4) EvD	Penguin	Computer	15
(5) ChD	Teddies	Computer	15
(6) VI Schedule	Squares	Computer	20

Note: WM = working memory; EvD = Effort vs. delay; ChD = Choice delay; VI Schedule = variable interval schedule

4.3.3.1. Inhibition/Puppet Task (Kochanska, 1996).

The experimenter said '*Here are two puppets, Policeman Pete and Princess Pearl. In this game, if Princess Pearl asks you to do something, you must do it. Let's try.*

(demonstrate using a simple request). *If Policeman Pete asks you to do something you must not do it . Let's try.'* (demonstrate using the same request). This instruction was repeated using both puppets requesting different actions. Having established the correct responses, children were tested on 16 requests, half of which were inhibitory. For these eight inhibit trials responses were coded, and children scored 2 = fully inhibited, 1 = partially inhibited and 0 = no inhibition, giving a range of possible scores from 0-16 where higher scores indicate better inhibitory control. The operative puppet (i.e., the one used in the inhibit trials) was counterbalanced.

4.3.3.2. WM/Noisy Book Task (Hughes, 1998a).

The experimenter said '*Here are nine pictures. If you press them they make sounds. Can you press them and tell me what the sound is*?' Having established the child's naming of each sound these names were used throughout the test phase. '*I am going to cover up the pictures and ask you to press the ones I say* (demonstrate). *You will need to remember where they are, so let's look at them once more. Look carefully: the dinosaur, rain and horse are at the TOP, the crunchy leaves, bird and dog are in the MIDDLE and the wind, whistle and children laughing are at the BOTTOM.'* The child was invited to press and name the sounds again before the panel is covered. Once the panel was covered the experimenter said '*Can you press the* ---- ?' The three practice trials used single items and the child was allowed to uncover the panel if they could not recall its position. The test phase consisted of three 2-item trials, three 3-item trials and three 4-item trials presented in a fixed order. Each child attempted all three trials at a given level, and scored at that level if (s)he recalled the correct sequence on two of the three trials, but had to correctly recall on all three trials at a given level in order to progress to the next level.

Coding was 0 = one or less 2-item trials recalled; 1 = at least two of three 2-item trials recalled; 1 = at least two of three 3-item trials recalled; 3 = at least two of three 4-item trials recalled. The range of possible scores was 0-3, where higher scores indicate better performance.

4.3.3.3. Planning/ToL Task (Hughes, 1998b).

The experimenter said '*Here is a pegboard. It has a small, middle-sized and big peg. Here are three balls. Which is the red ball/green ball/blue ball?* (child points to each color ball) *Watch carefully; the small peg fits just one ball, the middle-sized peg fits two balls and the big peg fits all three balls* (demonstrate). *If you move ONE ball at a time you can make different patterns, see?* (demonstrate) *but the balls must stay on the pegs. Now I will show you a game. Here is my pegboard. If you start like this* (experimenter arranges balls in the start position on the child's pegboard) *and I make a different pattern on my board* (experimenter arranges balls in the goal state, but does not demonstrate the moves to this end point) *can you make yours look like mine?'* The practice phase consisted of two 1-move problems and two 2-move problems. This provided an opportunity to reiterate the two rules: move only one ball at a time and keep them on a peg. If a child could not resist moving more than one ball at a time, they were asked to keep one hand behind his or her back. During the practice trials each move was counted aloud and the number of moves agreed. '*Some patterns need more moves than others. If I make a pattern I will say how many moves'*. The test phase consisted of three 2-,3-,4- and 5-move problems, with the experimenter prompting in any of the following ways: either '*Don't worry, if you make a mistake you can go back to the beginning'* or '*Is yours exactly the same as mine?'* or '*You* *must put it on a peg, where are you going to put it to wait?'* Children were allowed two attempts at a problem if they recognised they had made an incorrect move. Each child was given all three problems at any given level, scored as achieving that level if (s)he correctly solved two of the three problems, but was required to solve all three problems to progress to the next level. Coding 0 = one or less 2-move problems; 1 = at least two 2-move problems; 2 = at least two 3-move problems; 4 = at least two 4-move problems, where higher scores indicate better performance.

4.3.3.4. EvD/Penguin Task

At the start of the programme the experimenter used the first trial to explain the task and demonstrate the hand-held button press. During the first trial the experimenter said '*Here is Penguin. He is standing by the water. Here comes an iceberg. Penguin wants to run and jump onto the iceberg but he can't move unless you help him by pressing the button* (demonstrate). *Every time you help Penguin jump on the iceberg I will give you a sticker'*. The button press was then handed to the child and the experimenter remained silent, prompting only to maintain on-task behaviour. Such prompts were '*Here it comes again'* or '*Look! Here's another one'*. The presentation of the conditions (NoPRD/PRD) was counterbalanced to avoid fatigue and boredom affecting one condition only. At the end of the first 20 trials, there was a break during which the experimenter said '*Penguin would like you to help him some more and see if you can win more stickers. This time something is different so let's see if you can tell me what is different.'* After the first trial in the second condition the experimenter confirmed that the child could identify the presence or absence of the PRD by saying '*Yes, this time you have to/don't have to wait until the iceberg travels all the way to* *the end of the screen'*. The computer recorded the number of button presses, IRTs and the rate of button presses made in each condition.

4.3.3.5. ChD/Teddies Task

At the start of the programme the experimenter used the first two trials to demonstrate the two options. During these trials the experimenter said '*This is a choosing game. Here are two teddies. This one is holding one balloon, if you choose him I will give you one sticker* (demonstrate) *This one is holding two balloons, if you choose him I will give you two stickers but you have to wait for him to walk all the way to the front before you get your stickers'* (demonstrate). The experimenter then asked the child to make their choice, saying '*Which teddy will you choose?'* The presentation of conditions (NoPRD/PRD) was counterbalanced and at the end of the first 20 trials there was a break and the experimenter said '*The teddies would like you to do some more choosing and win even more stickers but this time something is different. Let's see if you can tell me what is different.'* At the end of the first trial in the second condition the experimenter confirmed that the presence or absence of the PRD is understood by saying '*Yes, this time you have to wait/don't have to wait until the teddy goes to pick up another balloon'*. The computer recorded the number of SS and LL choices made in each condition.

4.3.3.6. VI Schedule/Squares task

At the beginning of the programme, the experimenter said '*Here is a square on the screen. If you press the square* (demonstrate) *you can find cartoons. Can you press the square and see how many cartoons you can find?'* The child was left to press the square at random but occasional prompts were given to maintain on-task behaviour. Such prompts were '*What is happening now?*' or '*Can you find another cartoon?*'. The conditions (dense/less dense reward) were signalled by the background colour change. The computer recorded the number of responses, IRTs and rate of responding in each condition.

4.4. Results

For the sake of clarity, data reduction is described in the appropriate results sub-section but the data treatment prior to analysis, statistical procedures that were applied and the strategy for analysis are described here.

4.4.1. Outliers and missing data

For all measures, outliers (+/- 2 SD) for each age group were replaced with the means for that age group. Where data were missing for the EvD/Penguin task (one case) and the ChD/Teddies task (two cases) it was replaced with the mean for the age group.

4.4.2. Statistical procedures

In this section a brief explanation of the statistical procedures used, and their underlying assumptions, has been informed by Green, Salkind and Akey (2000) and Howitt and Cramer (1997).

4.4.2.1. Univariate and multivariate analysis of variance

The univariate and multivariate procedures test for relationships between factor(s) (within- or between-subject variables) with single (i.e., ANOVA) or multiple (i.e., MANOVA) dependent variables. The F statistic evaluates whether the group means on the dependent variable differ significantly from each other. The assumptions are (1) normality (2) sphericity and (3) random sample. The first assumption pertains to the normal distribution of the dependent variables for each of the populations, and this is not only very difficult to achieve in general, but also unlikely in the present context. However, this assumption is robust to violation in large sample size (15+ cases per group) and is therefore assumed not to be an issue in the current study. The second assumption pertains to the variances and covariances being the same across levels of the factor. This assumption was tested using Box's M but it was noted that an occasional significant result may be due to the violation of its normality assumption. The third assumption pertains to a random sample where participant scores on any single variable are considered independent of each other and in a community sample it is considered that this assumption is met.

4.4.2.2. Correlational analysis

The Pearson Product Moment correlation procedure assesses the strength of the linear relationship between variables, but not its causal status. The r statistic is a correlation coefficient ranging from -1 to $+1$, indicating the strength of association where higher values (regardless of sign) indicate stronger associations and a zero indicates no association. The assumptions underlying this procedure are (1) bivariate normality, and (2) random sample. Examination of scatter plots was used to determine if the first assumption is met, and the second is assumed in a community sample. As a large number of correlations increase the possibility of Type I error (i.e., rejecting the null hypothesis when it is true) this was controlled for using a Bonferroni correction which divides the level of significance by the number of correlations, indicated on tables as alpha adjusted p.

4.4.2.3. Factor analysis

Principle Components Analysis identifies factors (domains in which measured variables 'cluster') and explains the variance in the measured variables. It therefore reduces the data as well as defining the factor structure. Factor analysis is more subjective in its interpretation than other statistical procedures and in the present study, the number of factors identified were achieved using a statistical criterion (in this case Eigen values greater than 1) and a rotation method (in this case Varimax), and scree plots were also examined to assist judgement of the best solution. The factor loading, or weight, is read as a correlation coefficient indicating the strength of association between the factor and each measured variable. The one assumption underlying this procedure is that measured variables are linearly related to the factor. Examination of scatter plots suggested that this assumption was upheld, and this was confirmed using curve fit analysis.

4.4.2.4. Multiple Regression

Multiple Regression assesses the relationship between a set of predictor variables and a criterion variable, and the direction implies causality. In a model summary, the r^2 statistic indicates the amount of variance explained by the combination of predictors; a t value indicates whether the proportion of variance explained is significant. Within the model, the B statistic is the unstandardised correlation coefficient and *Beta* is the standardised coefficient of association (as in a Pearson's correlation) which indicates the individual contributions of each predictor within the model. The assumptions underlying this procedure are (1) normality, and (2) random sample. The first assumption is robust to violation and, in large sample sizes, will yield valid results in terms of Type 1 error. The second assumption is deemed met in a community sample.

4.4.3. Analytic strategy

Analysis was carried out in three stages that addressed the research questions and logically progressed through stages of data reduction.

The first stage related to the research question concerning how well the tasks perform as measures of delay aversion (i.e., examine the impact of condition on participant responding). As the delay tasks employed repeated measures designs with all participants being exposed to two conditions, or levels of the dependent variable, a repeated-measures MANOVA was applied for these tasks. The dependent variables entered into the analyses were the number of button presses (EvD/Penguin), the number of LL choices (ChD/Teddies) and mean IRTs (VI Schedule/Squares). Where possible multivariate statistics have been calculated because multivariate analyses adjust the alpha level and so control for issues of multiple measurement. For each task the evidence for their effectiveness as measures of delay aversion rested on finding an effect of condition. As many variables were measured in each of these tasks, subsequent analyses were facilitated by the creation of a single index of delay for each delay task. The difference between the means for the dependent variable in each condition was considered appropriate. This was the first stage of data reduction.

The second stage related to the research questions concerning the associations between tasks and their structure. In all analyses the task scores for the EF tasks and the indices of delay for the delay tasks were used. In the first instance the reliability of all measures was assessed using intraclass correlations after the method suggested by McGraw and Wong (1996). Multivariate analyses were conducted to assess age differences in performance with task/index scores as the dependent variables. The stability of associations between tasks at different ages was examined using Pearson *r* correlations. A Bonferroni correction was applied to adjust for multiple correlations. The structure of the tasks was then assessed using factor analysis. As factor analysis was the second stage of data reduction, reducing the measured variables to a smaller number of factors, factor scores were subsequently used to assess the association between task factors and IQ.

The third stage related to the research question concerning age and task performance. Initially the evidence for preschool executive functioning was assessed by calculating the percentage of children reaching criterion on each EF task. The age-related changes for EF were then assessed using multivariate analysis with task/index scores as the dependent variables. Post-hoc comparisons (Sheffe) were applied to assess if differences were significant between the three age groups (3/4; 4/5; 3/5). The developmental trajectories were plotted and linear and quadratic functions were investigated using polynomial contrasts. As the data reduction in stage two yielded three factors, the associations between task factors at each age was then assessed using Pearson *r* correlation. Age related changes were assessed using multivariate analysis with task factors as the dependent variables. Again, the developmental trajectories for these factors were plotted and the linear and quadratic functions were assessed as before. After examining age-related changes in task performance it was of interest to examine the extent to which task factors are predicted by child characteristics. A multiple regression was conducted on each task factor using age, gender and IQ as predictors. These were entered simultaneously to assess the individual contributions of each factor.

4.4.4. Section I: Experimental analysis of delay tasks

In contrast to the EF tasks, the delay tasks are newly developed or, in the case of the VI Schedule/Squares task, have not been used with preschool children. This section addresses questions regarding the extent to which the new delay tasks function as measures of delay aversion. As they require a more detailed analysis they are presented separately with individual summaries.

4.4.4.1. EvD/Penguin Task

It is hypothesised that the imposition of a PRD will impact upon task performance where delay aversion is demonstrated by children making fewer responses in the PRD condition when responding does not reduce overall delay. A main effect of condition therefore would determine whether the task is a good measure of delay aversion. A main effect of age is expected as the task involves responding over an extended period during which fatigue and boredom will disproportionately affect the younger children. Figure 4.1. shows the mean number of responses for each age group in the PRD and NoPRD conditions, and for fast and slow trials in each condition.

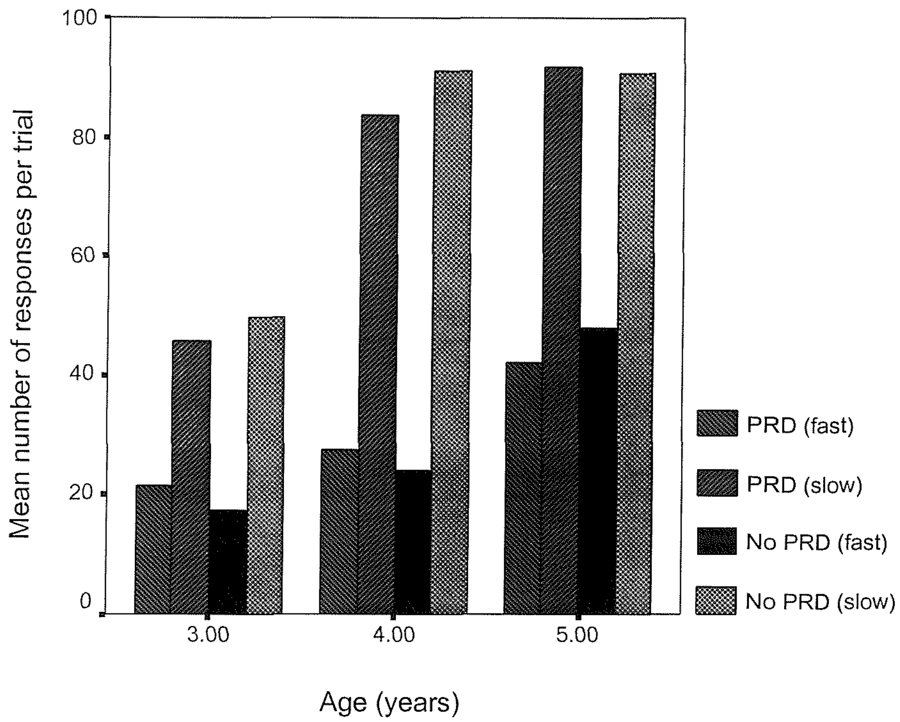

Figure 4.1. The effect of speed and post-reward delay on responding

A repeated-measures MANOVA was performed with the mean number of button presses as the dependent variable. The between-subjects factor was age and the within-subject factors were delay (NoPRD or PRD) and speed (fast and slow). MANOVA results indicate a main effect of age ($F(2,57) = 42.01$; $p = .001$) and a speed by age interaction ($F(2,57) = 3.92$; $p = .02$). Within-subject effects show an effect of speed ($F(1,57) = 86.03$; $p = .001$) but not delay ($F(1,57) = 1.30$; $p = .26$). No other interactions were significant at the $p<.05$ level. It seems the children are sensitive to speed, but not condition.

4.4.4.2. Commentary

The main effect of age confirms the developmental sensitivity of the task. This is consistent with the development of motor skills and older children make more button presses than younger children. The effect of speed was significant with children making more responses in the slow trials but this logically reflects the opportunity for responding, which is greater in the slower, longer trials. The effect of delay was not significant and it appears the children are not acting to reduce delay by working harder to reduce the overall trial length in the PRD condition. The task is therefore not working well as a measure of delay aversion.

4.4.4.3. ChD/Teddies Task

It is hypothesised that the imposition of a PRD will impact upon task performance where delay aversion is demonstrated by children making fewer LL choices in the NoPRD condition when making the alternative SS choice would reduce overall delay. A main effect of condition therefore would determine whether the task is a good measure of delay aversion. Based on the literature no main effect of age was expected. Figure 4.2 shows the mean percentage of LL choices in the PRD and NoPRD conditions for each age group.

To assess age group differences on task performance a repeated-measures MANOVA was conducted with the number of LL choices as the dependent variable. The between-subject factor was age and the within-subject factor was condition (PRD vs. NoPRD). Between subject effects showed no main effect of age ($F(2,57) = 1.68$; $p = .21$) and no significant interaction between age and condition ($F(2,57) = 2.94$; $p = .06$). Within-subject effects showed a significant effect of condition ($F(1,57) = 27.92$; $p = .001$) which indicated children were sensitive to the imposition of a PRD. To assess if this sensitivity to delay was significant at each age a paired-samples *t*-test was applied for each age group and results were significant for all age groups ($p < .05$).

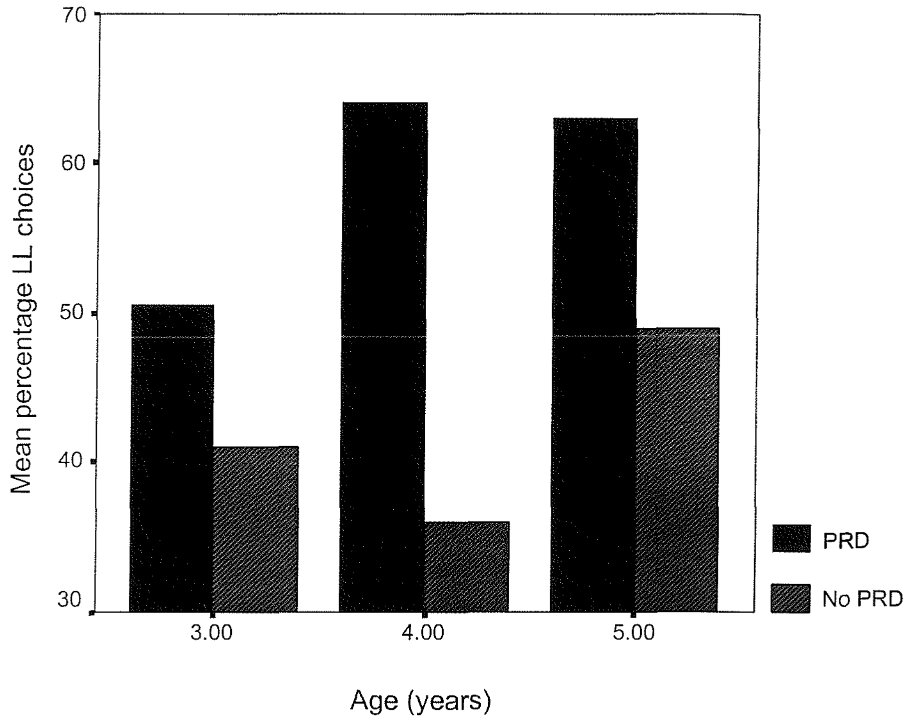

Figure 4.2. The effect of post-reward delay on LL choices

4.4.4.4. Commentary

The non-significant main effect of age indicated that the measure was not developmentally sensitive as children in different age groups responded in a similar way. This expected result is consistent with Logue and Chavarro (1992) who used a similar task and found age alone was not a significant predictor of performance for children aged between 3 years 6 months and 6 years 6 months.

It has been said that in a trials constraint format SS choices in both conditions demonstrates impulsivity, LL choices in both conditions demonstrates reward maximising and choosing the LL reward in the PRD condition but switching to SS choices in the NoPRD condition demonstrates delay aversion. The significant main effect of condition indicated children in all age groups were sensitive to the imposing of a PRD. Children generally choose the LL reward less in the NoPRD condition because making SS choices in this condition would reduce overall delay, and their delay aversion is demonstrated using this task.

It was observed that in the youngest group, the percentage of LL choices was at the 50% level in the PRD condition and did not rise above 65% in any age group. This accords with findings from school-age children (Sonuga-Barke, Taylor & Heptinstall, 1992) which showed that control children made a higher percentage of LL choices in the PRD condition, but this was still only 60%. Clearly young children are not reward maximisers even when delay reduction is no longer salient. It was observed during testing that children appeared to adopt a response pattern (e.g., alternating between choices in a regular fashion) irrespective of reward amount. This strategy was also observed by Logue and Chavarro (1992) who also found girls more indifferent than boys. This gender question could not be investigated here due to the small numbers of either sex within single age groups. Indifferent responding is unlikely to be attributable to the child's difficulty in discriminating contingencies as common sense would suggest that children, even as young as 3 years, understand that two stickers are more than one.

A further point of interest comes from the 4-year-old data, where means for LL choices in the NoPRD condition were the lowest of all groups. This corresponds with the Logue and Chavarro data, which also showed a drop in self-control (LL) choices in boys, but not girls, aged between 46 and 52 months. Whether or not this represents a developmental 'dip' cannot be answered here, but this replication highlights an interesting phenomenon.

It may be said that preschool children are typically ambivalent responders in this type of task. However, it is probable that their indifference is toward reward size as there is evidence that they are sensitive to pre-reward delay (e.g., are impulsive responders) and the overall delay (e.g., switch strategies when PRD is introduced). It would appear that this measure is a candidate for inclusion in a battery of tests designed to tap into delay aversion but modifications are indicated to increase the salience of the reward.

4.4.4.5. VI Schedule/Squares task

It is hypothesised that reward density will impact upon task performance where delay aversion is demonstrated by a higher response rate in the dense condition. A main effect of condition therefore would determine whether the task is a good measure of delay aversion. As with the EvD/Penguin Task, age effects are expected where older children can sustain responding over an extended period relative to younger children. Figure 4.3. shows the mean response rate for each condition.

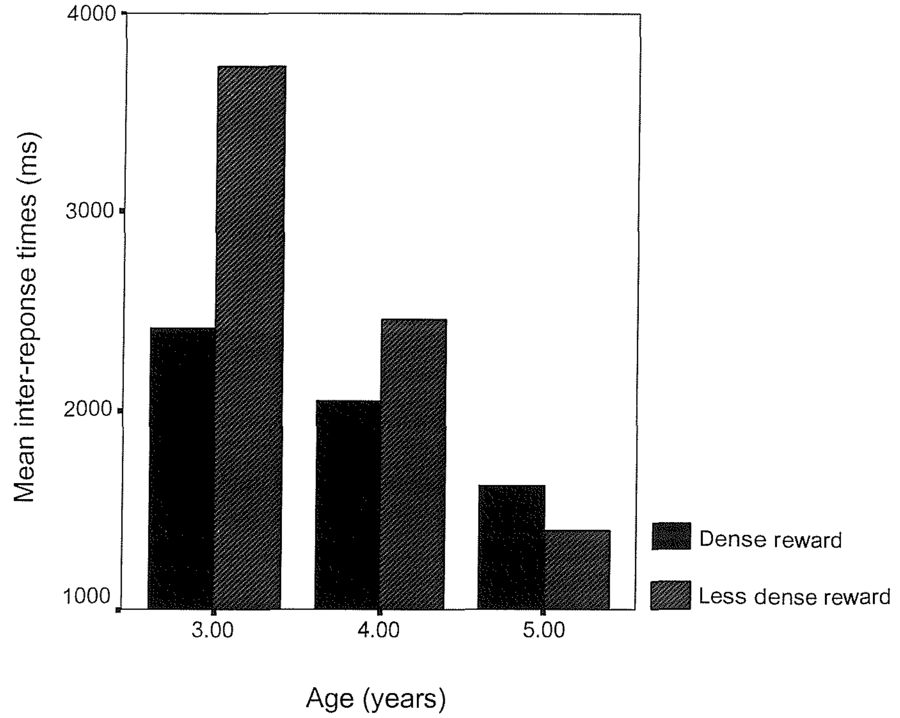

Figure 4.3. The effect of reinforcer density on response rate

A repeated-measures MANOVA was performed with mean IRTs as the dependent variable. The between-subjects factor was age and the within-subject factor was condition (dense/less dense schedules). Results showed a main effect of age ($F(2,57) = 11.38; p = .001$) and a significant interaction between age and condition ($F(2,57) = 11.00; p = .001$). This interaction effect is shown in Figure 4.3. where older children have higher overall response rates, but younger children (age 3 and 4 years) increase responding in the dense schedule relative to the less-dense schedule whilst the oldest children increase responding in the less-dense schedule. Within-subject effects showed a significant effect of condition ($F(1,57) = 13.89; p = .001$). To assess if the effect was significant at each age a paired-samples *t*-test was applied for each age group. Results were significant for the age 3 group (p = .00) but were non-significant at age 4 (p = .11) and age 5 (p = .20).

4.4.4.6. Commentary

The expected main effect of age confirmed the developmental sensitivity of the measure. Older children can respond at a higher rate, or sustain their performance over time. This would favour the increased stamina of the older child but it is conceivable that, due to fatigue, younger children could artificially inflate their interresponse times with long pauses in between bursts of responses.

The significant effect of condition indicated the children are sensitive to reward density. For the youngest children longer pauses between reinforcers resulted in significantly lower response rates. This pattern of responding was replicated in the age 4 group but did not approach significance. In the age 5 group this trend was reversed. This may be attributed to perseverance but the random variation in the two schedules, where the longer pauses in the dense schedule are temporally close to the shorter pauses in the less-dense schedule, suggests a more likely explanation lies in their sensitivity to a schedule which occasionally rewards a higher rate of responding.

Despite the apparent usefulness of this measure, two problems arose during testing. Firstly, many children became distressed when the less-dense schedule was introduced because they imagined they had broken the computer or done something wrong. Some children also found certain cartoons frightening. These problems resulted in extended test periods and undermined the aim of minimal verbal interaction. Secondly, technical difficulties arose from the use of the touchscreen that made interpretation of the data problematic. Where children did not make discrete presses but remained in contact with the screen and applied intermittent pressure it is possible multiple responses were recorded. Off-target (error) data was unsafe as off-target responses were occasionally reinforced (i.e., the cartoon appeared after off-target pressing) so could not be construed as an error. It was subsequently found that this problem was experienced by other researchers (Sagvolden's research group at Oslo University) whose solution was to replace the touchscreen with a keyboard response control. This was appropriate for the older children (6-13 years) who were the focus of research at Oslo university but was not considered appropriate for preschool children.

4.4.4.7. Creating an index of delay

To facilitate subsequent analyses, a single index of delay was computed for each of the delay tasks. For the EvD/Penguin and ChD/Teddies tasks the scores (mean button presses and LL reward choices respectively) from the NoPRD condition were subtracted from those scores in the PRD condition. In this way, positive scores indicated delay aversion (i.e., a sensitivity to the removal of the PRD). For the VI Schedule/Squares task, the mean IRT's in the dense condition were subtracted from those in the less dense condition. In this way, positive scores indicated delay aversion.

4.4.5. Section II: Analysis of executive function and delay aversion

This results section addresses questions regarding the nature and stability of associations between tasks. Analyses presented in this section were conducted using the task scores for the EF tasks and the index of delay (described above) for each of the delay tasks.

4.4.5.1. Reliability

As a preliminary step, the test-retest reliability of all measures was assessed. Twenty-five percent of participants (5 children from each age group) were tested twice, one month apart. Intraclass correlations were calculated using the method suggested by McGraw and Wong (1996).

For the EF tasks, all measures showed good levels of agreement: inhibition/puppet task ($r = .54$), WM/Noisy book task ($r = .83$) and planning/ToL task ($r = .79$). For the delay tasks, reliability was poor: EvD/Penguin task ($r = .20$), ChD/Teddies task ($r = .01$) and VI Schedule/Squares task ($r = .27$). This disappointing result poses difficulties, for without good reliability claims relating to the validity of the delay tasks are questionable. This will be addressed in the discussion section.

4.4.5.2. Descriptive statistics

The main analysis of age effects is presented in a later section, but for the sake of clarity the descriptive statistics are presented here. Table 4.4. describes the task performance for the sample. In general older children achieved higher scores than younger children on the EF tasks, which indicated the developmental sensitivity of the tasks. The age 4 children showed greater variability in scores as indicated by the higher standard deviations. Although the maximum possible score was achieved in the inhibition/puppet task at age 4 and 5, the mean scores indicated this was not a ceiling effect. The delay tasks do not appear to show any obvious age-related trend.

Table 4.4. Descriptive statistics

	Task	Min	Max	Mean	SD
Age 3 (n=20)	**Inhibition**	0	9	1.80	3.12
	WM	0	1	.40	.50
	Planning	0	1	.45	.51
	EvD	-33	40.50	4.13	16.50
	ChD	-50	20	-9.5	19.59
	VI Schedule	-2.15	4.15	1.23	1.53
	IQ	79	116	96.8	9.30
Age 4 (n=20)	**Inhibition**	0	16	11.95	4.11
	WM	0	2	.80	.62
	Planning	0	3	1.30	.73
	EvD	-12.80	29.40	6.01	12.45
	ChD	-100	.00	-28	28.4
	VI Schedule	-2.41	5.54	0.72	1.82
	IQ	75	132	107.28	14.48
Age 5 (n=20)	**Inhibition**	8	16	14.75	2.10
	WM	0	2	1.15	.49
	Planning	1	3	2.15	.67
	EvD	-56.70	51.60	-1.41	29.78
	ChD	-80	10	-14	26.64
	VI Schedule	-1.58	6.17	0.08	1.61
	IQ	88	123	104.75	10.39

Note: WM = working memory; EvD = effort vs. delay; ChD = choice delay; VI Schedule = variable interval schedule; IQ = intelligence quotient

A MANOVA was conducted to evaluate the relationship between age and task performance with task/index scores as the dependent variable. Results showed an overall main effect of age ($F(12,104) = 13.39; p = .001$). For individual EF tasks, there was a significant effect of age for inhibition/puppet ($F(2,59) = 89.72; p < .001$), WM/Noisy book ($F(2,59) = 9.70; p < .001$), and planning/ToL ($F(2,59) = 34.75; p < .001$). Post hoc Scheffe's revealed significant differences at each age for all measures ($p < .05$) with the exception of the WM/Noisy book task for age 3 vs. 4 years ($p = .07$) and age 4 vs. 5 years ($p = .13$). This confirmed the measures are developmentally sensitive with significant performance increments over time for inhibition/puppet and planning/ToL, and performance increments for WM/Noisy book which are significant between age 3 and 5. For the delay tasks, age effects were non-significant for EvD/Penguin task ($F(2,59) = .68; p = .51$) ChD/Teddies task ($F(2,59) = 2.94; p = .06$) and VI Schedule/Squares task ($F(2,59) = p = .10$).

4.4.5.3. Associations between executive function tasks

Previous research suggests that, by school age, EF domains are fractionated (i.e., are dissociated from each other). As we are unsure whether preschool EF skills are less differentiated than those found in older children it was necessary to consider associations between task scores at different ages. A correlational analysis was performed to determine the associations between EF tasks, which represent different EF domains, and the stability of the association over time.

The pattern of correlations shown in Table 4.5. describe a general trend where associations between tasks are stronger in older children. The pattern of association was similar at each age with the strongest correlation between planning/ToL and WM/Noisy book (significant at the $p<.05$ level at age 4 and 5, although non-significant using alpha adjusted p). Correlations between planning/ToL and inhibition/puppets were negative at age 3 and 4, and positive at age 5, but the association remained extremely weak. Correlations between WM/Noisy book and inhibition/puppets were similar in magnitude to those observed for planning/ToL and inhibition/puppets, but was negative for the age 4 group only.

Table 4.5. Associations between EF tasks at different ages

		Inhibition	WM	Planning
Age 3	**Inhibition**	--		
(n = 20)	**WM**	.09	--	
	Planning	-.04	.29	--
Age 4	**Inhibition**	--		
(n = 20)	**WM**	-.13	--	
	Planning	-.13	.49	--
Age 5	**Inhibition**	--		
(n = 20)	**WM**	.24	--	
	Planning	.24	.41	--

Note: WM = working memory

4.4.5.4. Associations between delay tasks

To assess the magnitude and stability of associations between the delay tasks, which are derived from different experimental paradigms, a correlational analysis was conducted to examine associations between the delay tasks at different ages.

The association between the EvD/Penguin and ChD/Teddies tasks was very poor but stable over time. The association between the ChD/Teddies and VI Schedule/Squares tasks appeared to show a general trend toward a positive relationship over time, but was otherwise weak. The association between the EvD/Penguin and VI Schedule/Squares tasks was generally negative, also poor, but the pattern of association was not consistent at age 4.

Table 4.6. Associations between delay tasks at different ages

		EvD	**ChD**	**VI Schedule**
Age 3	**EvD**	--		
(n = 20)	**ChD**	-.03	--	
	VI Schedule	-.04	-.28	--
Age 4	**EvD**	--		
(n = 20)	**ChD**	-.03	--	
	VI Schedule	.13	.02	--
Age 5	**EvD**	--		
(n = 20)	**ChD**	-.03	--	
	VI Schedule	-.27	.26	--

Note: EvD = effort vs. delay; ChD = choice delay; VI schedule = variable interval schedule

4.4.5.5. Associations between executive function and delay tasks

Having assessed the associations between tasks within specific domains, it was of interest to assess the associations across domains. A correlational analysis was conducted for all measures. As expected, there were no significant correlations between delay and EF tasks. This suggests the delay measures do not heavily rely on executive skills, and are tapping a fundamentally different capacity. For the

EvD/Penguin task, the general trend over time is toward greater associations with inhibition/puppet and planning/ToL tasks, together with a weaker association with WM/Noisy book task. For the ChD/Teddies task, there was a similar general trend over time toward stronger associations with inhibition/puppets and planning/ToL tasks, but a stronger positive association with WM/Noisy book task emerges for older children. The impact of WM for this delay task may reflect the older child's capacity to maintain temporal information which is an important determinant of choices made. For the VI Schedule/Squares task, associations with individual EF tasks appear to be of similar magnitude at different ages, and the strongest association is with the inhibition/puppet task. This suggests EF skill development in the preschool years does not impact upon performance characteristics in this task relative to the other delay tasks.

Table 4.7. Associations between EF and delay tasks at different ages

		Inhibition	WM	Planning
Age 3	**EvD**	.06	.16	.28
(n = 20)	**ChD**	-.06	-.30	-.03
	VI Schedule	.27	-.04	.04
Age 4	**EvD**	-.42	.23	.01
(n = 20)	**ChD**	-.16	.17	-.21
	VI Schedule	.15	.19	.02
Age 5	**EvD**	.23	-.02	.34
(n = 20)	**ChD**	-.13	.29	.24
	VI Schedule	.20	-.04	-.07

Note: EvD = effort vs. delay; ChD = choice delay; VI Schedule = variable interval schedule

4.4.5.6. Factor structure

The dimensionality of the six measures was analysed using principal component factor analysis. The criteria to determine the number of factor solutions was an Eigen value greater than 1. Consequently factors were rotated using a Varimax rotation procedure. For the sample, the rotated solution yielded three factors accounting for 36.85%, 17.99% and 17.03% of the variance respectively, with 71.87% of total variance explained.

Table 4.8. Factor solutions

Measures	Factor 1	Factor 2	Factor 3
Inhibition	**.81**	-.05	-.29
WM	**.80**	.06	.19
Planning	**.89**	.17	-.03
EvD	-.11	**.86**	.02
ChD	-.02	-.01	**.97**
VI Schedule	-.21	**-.55**	.07

Note: WM = working memory; EvD = effort vs. delay; ChD = choice delay; VI Schedule = variable interval schedule

Examining the factor loadings clearly showed that Factor 1 comprised of executive functions. Factor 2 comprised of two delay tasks, but the third delay task, ChD/Teddies, loaded onto a separate factor 3 which indicated that the measures are tapping different aspects of delay behaviour. These factors were therefore termed EFF, DEL(1) and DEL(2) respectively.

4.4.5.7. The relationship between task factors and IQ

To assess the impact of IQ on task factors, high- and low-IQ groups were created using a median split on the BAS II scores for the full sample. Table 4.9. displays the descriptive statistics for both IQ groups.

Table 4.9. Descriptive statistics for low- and high- IQ groups

IQ group		Min	Max	Mean	SD
Low (n = 29)	EFF	-1.65	2.14	-.19	1.00
	DEL(1)	-3.42	1.87	-.26	1.15
	DEL(2)	-2.34	1.25	-.03	.99
	IQ	75.00	101.00	93.69	6.86
High (n = 29)	EFF	-1.68	1.65	.13	.98
	DEL(1)	-1.13	2.27	.28	.78
	DEL(2)	-3.47	1.40	.09	.98
	IQ	102.00	132.00	111.90	9.05

Note: EFF = executive function factor; DEL(1) = first delay factor; DEL(2) = second delay factor

IQ group differences were assessed using MANOVA with factor scores as the dependent variables. Results showed no overall main effect of IQ (F(3,54) = 2.11; p = .11) but age effects were significant for DEL(1) (F(1,57) = 4.36; p = .04) but not for EFF (F(1,57) = 1.56; p = .22) or DEL(2) (F(1,57) = .25; p = .62). This result is unexpected as the relationship between IQ and EF is well established.

4.4.5.8. Commentary

The poor reliability results for the delay tasks are a threat to any claims made concerning their validity, despite the fact that children are found to be sensitive to the conditions. The reliability was calculated on the index scores and it was noted that reliability calculated on individual task variables were considerably better. Creating an index which represented the difference scores between conditions has inadvertently lowered the reliability. Another form of reliability comes from the block scores (first 10 trials vs. second 10 trials in each condition) which is split-half reliability. Block data was available for the EvD/Penguin and ChD/Teddies tasks and correlations for EvD/Penguin were moderate to good for fast games ($r = .82$) and for ChD/Teddies were moderate ($r = .54$). In particular the ChD/Teddies task yielded the lowest reliability values and this may be due in part to the indifferent performance noted in many studies. Quite simply children may adopt or invent different ways of 'playing the game' and this suggests reliability is best measured within, rather than between, sessions. Nevertheless there are indications that contingencies should be emphasised for greater impact (e.g., more enticing rewards offered, or delay periods exaggerated).

The data presented here extends our understanding of the structure of EF in the preschool years. The pattern of association between EF tasks at different ages shows planning and WM are significantly correlated, but neither correlate with inhibition. This is compatible with the EF factor structure outlined by Welsh, Pennington and Groisser (1991) who showed that, in older children, WM and planning loaded on to a different factor to inhibition. Thus, inhibition appears to be relatively independent function, but all three EF tasks load onto the same factor in this study. This may be explained as an artifact of the factorial procedure which finds statistical similarities that are not necessarily conceptual similarities. In the context of this study the EF measures simply share more in common with each other than with delay tasks. At this point we must acknowledge two issues which impact upon this conclusion. Measures of the components of EF are almost inevitably confounded and it could be argued that WM is inherent in any planning task and high correlations are to be expected. However, Shallice (1982) has suggested that WM is relatively unimportant in the ToL, that the task is relatively free of lower-order cognitive skills and therefore a relatively independent measure of planning. Additionally, the probability that domains may overlap is highlighted by Anderson, Anderson and Lajoie (1996) who found moderate correlations between the ToL and other EF tasks in children aged between 7 and 13 years. Because these other tests relied heavily on verbal skills (controlled word association test, Rey auditory-verbal learning test), it is suggested that linguistic development may be responsible for this finding. If so, dissociations observed in early development may be hidden in the process of subsequent maturation. The general trend toward greater associations between EF tasks with increasing age would appear to support this. The fact that a dissociation between inhibitory and other measures of EF can be demonstrated even as these skills are emerging supports the notion of domain specificity.

Delay aversion emerges as a construct independent of EF. Evidence for the structure of delay aversion comes from two sources. Firstly, the delay tasks are not significantly associated with EF tasks and, importantly, there is no significant correlation between any delay task and the inhibition/puppet task at any age. Secondly, the delay tasks load onto a different factor then EF tasks. Taken together these results suggest that EF, and in particular inhibition, do not underpin delay aversion. Inhibition is therefore not a common underlying mechanism, which weakens the case for the executive dysfunction hypothesis as an explanation for delay averse characteristics.

The fact that the delay tasks form two factors suggests they are measuring different types of delay aversion. As ChD/Teddies loads separately to EvD/Penguin and VI Schedule/Squares, the most obvious difference is that ChD/Teddies does not involve responding throughout the presentation of the stimulus. Once a choice is made there is no response requirement until the start of the next trial. In contrast the other measures rely on continuous responding. Because of this, off-task behaviour which is integral to delay-averse characteristics would impact upon EvD/Penguin and VI Schedule/Squares, but not affect ChD/Teddies task performance. The different performance requirements of the delay tasks may explain the differential pattern of association with EF tasks, and most especially the strengthening association between WM/Noisy book and ChD/Teddies over time as the temporal information must be held 'on-line' between each response.

4.4.6. Section III: Age and task performance

This section relates to the research questions regarding the relationship between age and task performance. A preliminary examination of EF performance was required in order to assess the extent of preschool EF skills and their developmental course. Therefore these analyses were based on the task scores. All subsequent analyses were conducted using the task factor scores reported in the previous results section.

4.4.6.1. Evidence for preschool executive functions

Given the uncertainty as to whether EF skills are evident in the preschool population, it was necessary to assess whether EF skills were demonstrated by the very young children in this study. Table 4.10. shows the percentage of children in each age group who achieved the minimum level of executive performance (indicating rudimentary executive functioning) on each of the three measures. The minimum level was defined as a minimum score of one achieved on any given measure. This indicated that two out of three problems at the first level of difficulty were successfully solved (WM/Noisy book and planning/ToL) and at least one correctly inhibited response was performed (inhibition/puppet).

Table 4.10. Percentage of children achieving minimum performance on EF measures at each age

	Age 3	**Age 4**	**Age 5**
Inhibition	30	90	100
WM	40	70	95
Planning	45	90	100

Note: WM = working memory

From the table it can be seen that, even in the youngest age group, between 30-45% of children achieved this level of performance on any given task, with the inhibition/puppet task being disproportionately difficult at this age. Again, the incremental scores for each age group suggested the tasks are developmentally sensitive.

4.4.6.2. Age-related changes in executive function performance

Patterns of association between EF tasks reported in the previous section indicated that EF skills are relatively independent of each other, despite the fact that they load onto the same factor. It was therefore of interest to examine the developmental course of each. Prior to assessing the age-related changes in EF task performance the individual scale scores for each EF task were standardised (Z-score). The mean Z-scores for each age group were plotted for each task and are shown in Figure 4.4. It should be noted that developmental trajectories usually come from longitudinal data. As this was cross-sectional data the 'developmental' trajectory is implied rather than actual.

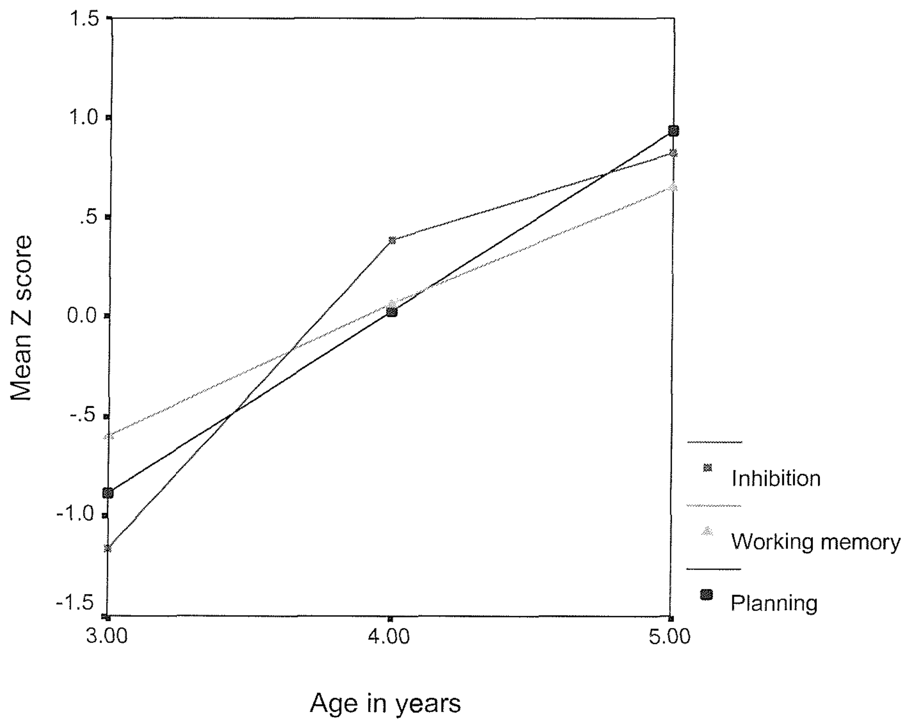

Figure 4.4. The developmental trajectories of individual executive functions

MANOVA was conducted to with age as the independent variable and the standardized task scores as the dependent variables. There was an overall main effect of age ($F(6,110) = 24.01$; $p < .001$). Age effects were significant for inhibition/puppet ($F(2,57) = 89.72$; $p = .001$) WM/Noisy book ($F(2,57) = 9.70$; $p = .001$) and planning/ToL ($F(2,57) = 34.75$; $p = .001$). The results were further analyzed using planned contrasts which revealed a significant linear trend for each measure ($p < .001$) and a significant quadratic trend was found for the inhibition/puppet task alone ($F = 17.40$; $p < .001$). This indicated that although performance generally increased with increased age, the developmental trajectory of inhibition was distinct and different WM and planning.

4.4.6.3. Age-related changes in task factors

Figure 4.5. plots the developmental course of the different factors. From this it can be clearly seen that EFF shows rapid, almost linear development where children's performance improves consistently over time. In contrast DEL(2), comprising mainly of the ChD/Teddies task, shows a reverse trend indicating children become generally less delay sensitive over time. DEL(1), comprising the EvD/Penguin and VI Schedule/Squares tasks, appears to be almost flat indicating no developmental trend in the nature of the delay aversion measured using these tasks.

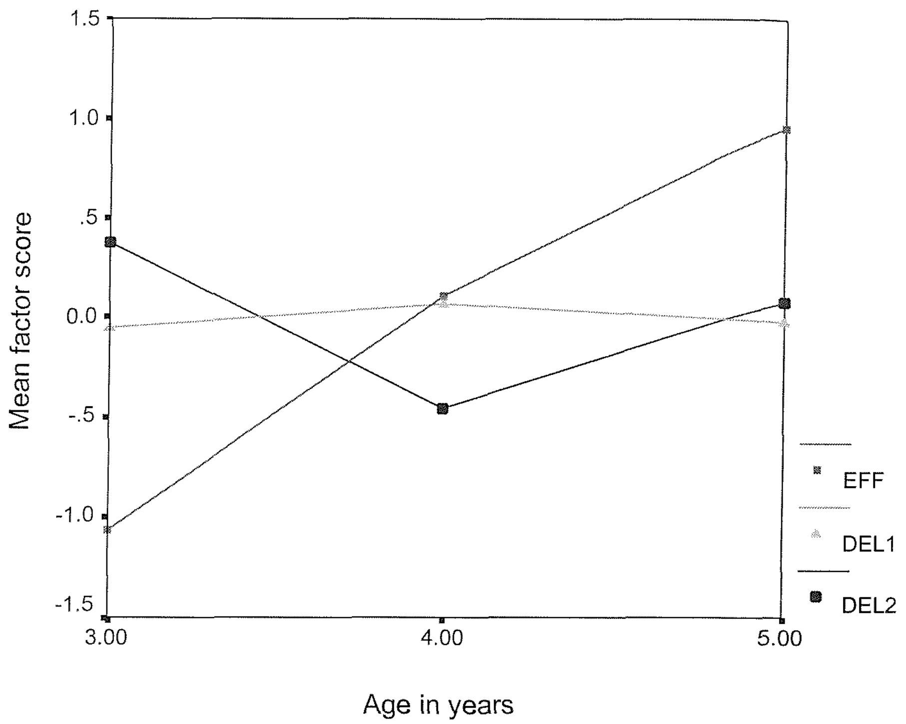

Figure 4.5. The developmental trajectories of executive and delay task factors

These observations were confirmed using MANOVA, with age as the independent variable and factor scores as the dependent variable. There was a significant overall effect of age ($F(6,110) = 18.29$; $p = .001$) Age effects were confirmed for EFF ($F(2,59) = 64.85$; $p = .001$) and post-hoc Sheffes revealed differences were significant between all age groups for this factor ($p = .001$). A significant effect of age was also found for the DEL(2) ($F(2,59) = 3.93$; $p = .02$) but post-hoc Sheffes revealed differences were significant between age 3 and 4 only ($p = .03$). The results for DEL(1) were non-significant ($F(2,59) = .08$; $p = .93$). Planned contrasts revealed a significant linear trend for EFF ($p = .001$) and a significant quadratic trend for DEL(2) ($p = .02$) alone. Results for DEL(1) were non-significant for either linear ($p = .91$) or quadratic trend ($p = .93$).

4.4.6.4. Explaining the independent contribution of predictors

The sample size did not allow independent analyses for girls and boys of the same age, yet gender remains an issue of some importance. To assess the extent to which gender and other child characteristics predicted task performance analysis was performed on task factors for the full sample. In each case the task factor score was entered into a multiple regression with the predictors (age, gender and IQ) entered simultaneously. The model was significant for EFF ($F(3,54) = 50.97$; $p <.001$) with 74% of the variance explained, but was not significant for both DEL(1) ($F(3,54) =$ 1.61; $p =$ ns), which explained only 8% of the variance, and DEL(2) ($F(3,54) = .96$; p = ns), which explained just 5% of the variance.

Table 4.11. The independent contribution of predictors

		B	Std.Error B	Beta	t	Significance
EFF	**Age**	.96	.09	.81	11.10	.00
	Gender	.03	.15	.01	.19	.85
	IQ	.01	.01	.14	1.93	.06
DEL(1)	**Age**	-.09	.16	-.07	-.54	.59
	Gender	-.34	.28	-.16	-1.21	.23
	IQ	.02	.01	.30	2.10	.04
DEL(2)	**Age**	-.11	.16	-.10	-.71	.48
	Gender	.39	.28	.19	1.38	.17
	IQ	-.01	.01	.08	-.57	.57

Note: EFF = executive function factor; DEL(1) = first delay factor; DEL(2) = second delay factor

For EFF age was a significant predictor but IQ also approaches significance as a predictor within the model. This concurs with many studies showing age-related increments for EF tasks, and those finding IQ predictive of EF performance. For DEL(1) and DEL(2) none of the predictors were significant except IQ which predicted DEL(1). As the model was non-significant for DEL(1), caution is advised when interpreting the meaningfulness of this predictor.

4.4.6.5. Commentary

The data presented here supports the notion that rudimentary EF skills evident in children as young as 3 years, and these skills are amenable to measurement using developmentally appropriate tasks. The fact that skill maturation varied by task provides further support for the fractionated model of EF. In particular, the trajectory for inhibition was significantly different to that for WM and planning. These functions appear to develop in a linear manner indicating improved skill efficiency, whereas inhibition appears to emerge in a stepwise fashion between 3 and 4 years of age indicating basic skill acquisition. Both the correlation patterns reported in the previous section and this developmental dissociation support Hughes' view that EF is fractionated. While it must be acknowledged that early fractionation may reflect stage-like development which may ultimately evolve into a unified construct, this pattern is consistent with that found in middle-childhood.

Although it has been established that EF and delay aversion are discrete and separate entities, it appears that the relationship between EFF and DEL(2) strengthens with increasing age. As EF components load to some degree on DEL(2), notably inhibition (-.29) and WM (.19), it is possible the stage-like development of inhibition contributes to this developmental trend. Of course there may be aspects of EF development that impact upon the delay aversion as measured by ChD/Teddies, and vice versa. Possible mechanisms by which this association may be forged have been discussed in a previous chapter (see Chapter Two). A more prosaic explanation may lie in the normal development non-executive cognitive skills such as language, which is known to underpin self-monitoring skills and may reasonably impact upon the development of both delay and inhibition skills.

The developmental course of EFF is linear with significant and consistent improvements with increasing age. In contrast, DEL(1) is relatively independent of age despite the fact that it comprises those delay tasks which have demonstrated age effects in a multivariate analysis. However, DEL(2) is age-related with older children displaying less delay aversion than younger children. The developmental course does not appear to be linear and it is interesting to speculate as to why this may be so. Based on findings using a similar task to the ChD/Teddies task which mainly forms DEL(2), Sonuga-Barke has posited that there is a two-stage development where young children learn how to wait and older children learn when to wait. It is conceivable that the dog-leg pattern of development reflects these two processes.

A significant proportion of EFF is predicted by age and IQ. In contrast, DEL(1) and DEL(2) are not predicted by age, IQ or gender. This implies that something other than these characteristics may be responsible for delay task performance. This is a promising base from which we may investigate the role of AD/HD.

4.5. Chapter Summary

The present study has suggested that both EF and delay aversion are independent functions. The developmental course of EF is generally linear with older children performing better than younger children, although different EF skills develop at different rates. In particular the patterns of association and developmental dissociation suggest that inhibition is distinct from other EF. Therefore it appears that the fractionated model of EF seen in older children is replicated in the preschool years. Delay aversion follows a different developmental course and does not appear related to age in the same way. Crucially, EF is predicted to a large extent by age and, to a lesser extent, IQ. These variables do not also predict delay aversion. This clearly raises the possibility that a characteristic other than those measured here may be important for delay aversion. This is the basis on which we may investigate the role of AD/HD. Before this is possible, modifications to the test battery are indicated to overcome the disappointing reliability of the delay tasks.

CHAPTER FIVE: METHODOLOGICAL ISSUES IN THE INVESTIGATION OF HYPERACTIVE PRESCHOOL CHILDREN

5.1. Introduction

This chapter aims to link the two studies contained within this thesis. The first study (Study One) reported in the previous hapter addressed EF and delay aversion in the preschool population. The suitability of the task battery and age-related performance was examined, thus forming the basis for a second study (Study Two) in which the relationship between AD/HD and task performance may be explored.

The use of a community sample in Study Two raises questions as to how the sample can be characterised in terms of hyperactive status. It is of critical importance that the reader is acquainted with the sampling method, the rating scales and behavioural measures that were used to ascertain hyperactive status, and the various ways in which they will be employed. Before introducing Study Two it is also necessary to describe and explain several changes to the test battery which include modifications to test measures indicated from the Study One, and the addition of new measures.

5.2. Sampling

A developmental perspective underpinned Study One and it was therefore helpful to select three age groups to reflect the rapid development of skills in the preschool years. In Study Two, which examines the relationship between hyperactivity and performance on EF and delay tasks, a decision was taken to restrict testing to two age groups (age 3 and 5 years) with larger numbers to increase statistical power. This was especially important when using a community sample approach as large sample sizes are required to yield the number of cases in the abnormal (hyperactive) range for statistical procedures to be viable and meaningful.

5.3. Sample selection

In the U.K. preschool children are not commonly diagnosed as AD/HD and it is therefore not possible to access a clinical population. It has been argued here that AD/HD type behaviours can be viewed as a continuum as they are extreme expressions of a generally occurring behaviour in the normal population (see section 1.6.2.). In this case a community sample would be valid as a means of exploring the relationship between hyperactivity, executive dysfunction and delay aversion. The present study employs a community-based sample of children with hyperactivity symptoms across the full range of severity. The rationale for this approach is:

a) There is uncertainty as to whether the diagnostic threshold applied to older children is appropriate for preschool children so it is sensible to initially examine associations across the full range of symptom severity
b) Exploring changes in the degree of associations between symptom severity and other characteristics informs us regarding the categorical or dimensional nature of hyperactivity
c) Genetic studies have shown the contribution of genetic and environmental factors is stable across all levels of symptom severity, which supports a dimensional approach

5.4. Measures of hyperactivity

Whilst there are many behavioural measures available, few are appropriate for preschool children. Of those that are available for preschool children, fewer still have versions which span the ages of the intended sample and this is extremely important as hyperactivity and attention scores would decrease for older children who are more proficient at regulating their behaviour and the age-appropriate versions must reflect this. As many rating scales are DSM referenced it is also important to use scales referenced from the latest version as differences between DSM-III and DSM-IV are meaningful in behavioural terms (Weiler *et al.*, 1999). The measures described below were chosen because they do meet these requirements.

5.4.1. The Strengths and Difficulties Questionnaire (SDQ)

The SDQ was developed by Goodman (1997) to assess a range of behavioural problems in children. There are different versions available for different age groups (preschool/school age) and different informants (teacher/parent/self) and the instruments have extensive normed data. The SDQ is a 25-item tick-box questionnaire where response options are 'not true', 'somewhat true' or 'certainly true'. The questions relate to five scales (five items per scale) which rate the child on conduct problems, hyperactivity, emotional problems, peer problems and a prosocial scale. For each scale the minimum score is 0 and the maximum score 10. A total difficulties score is calculated by summing scores on the first four scales (minimum score = 0, maximum score = 40). The cutoff scores, which may be slightly different on different versions, are chosen so that in a community sample, 80% of children are normal, 10% borderline and 10% abnormal.

In the present study the teacher-and parent-rated SDQ were employed. The parent SDQ scores were combined with the PPACS scores to create a parent hyperactivity rating and parent conduct rating. It is this rating that features in both dimensional (scale scores) and categorical (median split) analyses. Where the analysis indicated a clinical hyperactive group, the parent SDQ score was used as it was important to identify those children whose scores placed them in the abnormal or clinical range. In this way the meaningfulness of the score in relation to the general population was achieved. To distinguish between the highly active and clinically hyperactive groups, they will be referred to as hyperactive and AD/HD respectively.

5.4.2. The Preschool Parent Account of Childhood Symptoms (PPACS)

The Preschool Parent Account of Childhood Symptoms (PPACS) is a modified version of the PACS semi-structured clinical interview developed in the U.K. by Taylor *et al.* (1991) to assess hyperactive and conduct problems in school-age children. The PACS has a reputation as a valid clinical tool, supported by evidence that its hyperactivity ratings correlate highly with observed off-task and inattentive behaviour and its conduct ratings correlate with non-compliant behaviour (Gardner, Sonuga-Barke & Sayal, 1999). It discriminates between problems of clinical and non-clinical significance (Sonuga-Barke *et al.*, 2001) and correlates highly with other measures such as the SDQ (Goodman, 1997) and Behaviour Checklist (Gardner, Sonuga-Barke & Sayal, 1999; Richman, Stevenson & Graham, 1982). The modifications in the preschool version include dropping an item deemed to be inappropriate (lying) and changes to the coding of parental response in line with developmental expectations. The PPACS is reliable with inter-rater coefficients of between .92 and .98, and test-retest reliability over a 15 week period of .78 for the hyperactivity subscale and .62 for the conduct problems subscale (Sonuga-Barke *et al.,* 2001). Factor analytic studies support the distinction between the two subscales which are differentially predicted by intellectual and social disadvantage (Sonuga-Barke, Houlberg & Hall, 1994).

During the 1 – 2 hour interview a trained interviewer rates the behaviour which is reported by the parent, based on frequency and severity of symptoms across a range of situations over the previous 6 months. These ratings are based on criteria previously validated against clinical judgement and encompass the core symptoms of AD/HD and conduct disorder. Total hyperactivity and conduct ratings are derived from summing scores from 10 items per scale. A score above 17 indentifies the top 4% of highly active children in the normal population.

It has been mentioned in the previous sub-section that the PPACS scores were combined with the parent SDQ scores to create a parent hyperactivity rating. However, in the final analysis, which required identification of a clinical group, the PPACS was not used as it is not normed for the younger age group therefore we cannot with certainty make any claims regarding the clinical status. A standardised tool, in this case the SDQ, was used to identify a clinical AD/HD group.

5.5. Modifications to test measures

The results from the Study One informed decisions on the changes outlined here. The VI Schedule/Squares task has demonstrated many good qualities, showing children respond very differently in the two conditions. It appeared to work well as a delay task and has been useful in studies using older children. However, with the preschool children it was difficult to administer and technical difficulties with the touchscreen resulted in a less than confident interpretation of response behaviour. In the present context these problems were difficult to address and, taking this into account, a decision was taken to exclude it from the present study and introduce a more direct measure of delay. There will be no further mention of it here.

5.5.1. WM/Noisy book task

The WM/Noisy book task described in Study One was modified to reduce the number of picture items. Originally a nine-picture panel was used but scores suggested that this was too many as the older children's maximum score was 4. To reduce the possibility that remembering the spatial arrangement of nine pictures confounded the ability to correctly remember the smaller number of items from the verbally presented to-be-remembered list, three pictures in the panel were permanently covered and no longer referred to. The number of items in the verbally presented list remained the same, ensuring the task itself remained the same for each level of difficulty. To ensure the new version was not significantly different from the old, data from 5-year-old participants tested on the nine-picture version (n = 10) and the modified six-picture version (n = 10) was analysed using simple *t*-test which compared group means. Results showed no significant differences in the scores achieved using different versions of the task ($t = -1.14$; $p = .27$).

5.5.2. EvD/Penguin task

The results from Study One suggested the EvD/Penguin task was not working well as a measure of sensitivity to delay. As there were few indications as to why this was so, it was possible that the younger children may simply not be able to sustain a level of button-pressing over a sustained period to the extent that there were physical limitations on the amount they could reduce the delay-to-reward. For this reason a decision was taken to (a) reduce overall time-on-task by increasing the speed of the trials (i.e., the pace of the iceberg) to 10 s for fast trials and 20 s for slow trials, and (b) increase the effect of each button press (i.e., increase the penguin step size from 2 pixels to 5 pixels per button press) to reduce the effort needed to move the penguin. This modification allowed both time-to-reward and overall time-on-task to be more effectively regulated by the child.

5.5.3. ChD/Teddies task

Critical appraisal of the ChD/Teddies task suggested that on-screen activity during the PRD period was stimulating for the child. In the original programme the PRD period was defined by the teddy 'walking' back to a balloon bin to collect a balloon before the start of the next trial. Observations during testing indicated that the movement of the teddy at this time was interesting to the children. Occasionally children made comments like 'Look, the teddy is going to get a balloon' or speculated as to which balloon would be chosen. To ensure there was no stimulation for the child, and the delay period was more rigorously defined as a period during which no on-task behaviour was rewarded, the programme was modified and the PRD period was now characterised by the teddy 'freezing' on screen until the start of the next trial. In the

NoPRD condition rewards were 1 s (SS) or 17 s (LL). In the PRD condition the trial lengths were equalised at 18 s.

A second modification addressed the question of reward. The apparent ambivalent responding may reflect reward indifference. Given that evidence suggests preschoolers are sensitive to reward size (Sonuga-Barke, Lea & Webley, 1989) this indicated rewards should be made more attractive. As this task was presented as the second delay task, children had already won 40 stickers during the EvD Task (irrespective of performance) and winning yet more stickers was perhaps less attractive in which case the problem was reward satiation. Because evidence suggested the 2:1 reward ratio was sufficient to demonstrate sensitivity to conditions, the decision was taken not to increase rewards but to offer different/attractive rewards, and the stickers were substituted for sweets. The use of different rewards in this second-presented delay task serves to increase the attractiveness of the reward and reduce the probability of reward satiation which is known to particularly effect AD/HD children (Schweitzer & Sulzer-Azaroff, 1995).

5.6. Additions to the test battery

The decision to substitute the VI Schedule/Squares task for a more direct measure of delay resulted in a search for an age-appropriate and easy-to-administer delay task. There has also been increasing interest in the role of attentional flexibility (AF) in executive functions. Whilst many studies discuss the impact of the supervisory attentional system in EF task execution, some studies have introduced an attentional flexibility task as a measure of executive function in its own right. A decision was taken to include a measure of AF in the task battery.

5.6.1. Delayed response task (DRT)

The ChD/Teddies task employed in Study One is a DoG task based on the choice paradigm (SS/LL) but it has been mentioned previously that many DoG tasks have also assessed a child's ability to wait for a reward (i.e. withold responding until a signal from the experimenter). Such tasks do not involve choice and one version of this task involves the experimenter leaving the room after instructing the child not to touch the target object until (s)he returns. The dependent variable in this context is the time the child will wait before touching the 'forbidden' object. However, compliance is known to be affected by the presence or absence of the experimenter (van der Meere, 1996), and as non-compliance is a core symptom of conduct problems it may introduce a confound. In the present context it was deemed unwise to leave small children alone, and the use of elaborate recording equipment was not practical as testing occurred in multiple settings. The literature suggested a suitable alternative is the Cookie Delay task (Golden *et al.*, 1997). This task had the advantage of being widely used in the preschool population, was quick and easy to administer, and used readily available materials. It was included in the test battery and is described in detail in the method section of the following chapter as the Delayed Response Task (DRT), a term frequently used by researchers employing this type of paradigm.

5.6.2. Attentional flexibility task (AF)

AF tasks typically involve the switching of attention to different properties of materials during a problem-solving exercise, or shifting from one response set to another. The ability to shift or switch is the dependent variable in such tasks and this denotes cognitive flexibility. The switch or shift is therefore the critical feature of any AF task. A simple AF task involves pattern-replication where a fixed colour or shape pattern is reproduced by the child (Passler, Isaac & Hynd, 1985). A version used by Hughes, White & Dunn (1998) involved arranging coloured marbles in a perspex tube to create a repeat pattern which was then copied by the child. Unfortunately a ceiling effect was found for older preschool children (aged 4 years 9 months) and this indicated a more challenging task would be appropriate for this study. The classic AF task used with older children and adults is the WCST where cards with different symbols are sorted according to different sort principles which are not disclosed, but rather discovered by trial-and-error with feedback being given (right/wrong) until the sort principle is identified and the sorting of cards correctly executed. A preschool version asked the child to find out what a character liked rather than find a rule, and also signalled rule changes (Hughes, White & Dunn, 1998). However, this procedure is both lengthy and involves higher-level decision-making because the sort principle needs to be established. It was considered that for preschool children the process of decision-making was not appropriate and the focus should be on the ability to sort using specified principles, with AF established by switching attention between sorts based on different properties. The Weigl block sorting task satisfied these conditions and was chosen for inclusion in the test battery. It is described in detail in the method section of the following chapter.

5.7. Chapter Summary

This chapter creates the links between Study One and Study Two. Study One examined EF and delay aversion in normal preschool children and suggested that performance on delay tasks is not explained by IQ, gender or age. This confirmed the need to explore the role of behavioural characteristics such as hyperactivity, and created the basis upon which to do so. Study One informed the changes to the test battery, which are (a) the exclusion of the VI Schedule/Squares task, (b) the modification of the WM/Noisy book, ChD/Teddies and EvD/Penguin tasks, and (c) the inclusion of the AF/Blocks and DRT/Cookie tasks. Changes in selection and assessment are (a) a reduction in age groups from three to two, with a larger sample size, and (b) the addition of three behavioural measures: the parent-and teacher-completed SDQ and the PPACS semi-structured parent interview.

CHAPTER SIX: AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS, DELAY AVERSION AND AD/HD IN PRESCHOOL CHILDREN

6.1. Introduction

The present study is placed in the context of predictions made by two models of AD/HD therefore it is helpful at this stage to remind the reader of those predictions. The first, Barkley's EDF hypothesis, views AD/HD as a pathological disorder arising from a failure of the inhibition system. The second, Sonuga-Barke's DA hypothesis, views AD/HD as an adaptive response to delay aversion. The EDF model predicts AD/HD will be associated with EF deficits and the DA model predicts AD/HD will be associated with delay aversion. For each model the critical association (AD/HD-EF or AD/HD-Delay) should be evident at both ages as it is a core feature of the disorder. This association must therefore remain stable or strengthen over time. Providing this primary deficit is established both models allow that deficits predicted by the other may emerge as a developmental complication arising from the primary or core deficit. In this case a secondary deficit will emerge in the older children.

As the models assume different underlying processes, it is expected that delay and executive tasks will not be highly associated with each other, and will be differentially associated with cognitive variables, with IQ asserting a greater influence on executive performance. Each model predicts the tasks associated with it will be most effective in predicting AD/HD.

The EDF model characterises AD/HD as a discrete disorder of a categorical nature and therefore predicts that associations will be evident in the extreme, or clinical, range. The DA model takes a dimensional approach to symptomatology and allows for increased, but not necessarily significantly different, associations in the severe range.

6.2. Research questions

The aim of Study Two was to examine the relationship between AD/HD and EF and delay aversion. Specifically the questions posed are:

(i) Do the delay and EF tasks discriminate between hyperactive and control children?

(ii) Are patterns of association between task measures the same for males and females, and are they stable over time?

(iii) What is the structure of preschool EF and delay aversion?

(iv) What is the relationship between task performance and other child characteristics?

(v) Does the relationship between task performance and hyperactivity hold when other characteristics are controlled for?

6.3. Method

6.3.1. Participants

Participants were recruited via five Health Visitor (HV) teams, two nurseries and eleven primary/infant schools in Wiltshire, Hampshire and Dorset. Participating teams and institutions distributed consent forms and information packs to parents of children who were, or would become, aged between 3 years and 3 years 6 months (HV's and nurseries) and 5 years and 5 years 6 months (schools) at the time of testing. Parent consent was obtained for 185 children.

Fifteen 3-year-olds were not included in the study: of these, five could not be contacted, nine declined to take part when contacted, and one did not have English as a first language so was excluded. The Werry-Weiss-Peters activity scale (Routh, 1978), which measures behaviour problems and is routinely administered by health visitors as part of the 3-year-old health check, showed that of the 15 children who did not participate, five scored between 0-10, six scored between 11-20, and four scored 21 or more on this measure. This indicated that the group of children who were not tested was not a biased group but consisted of children who scored across the range of symptom severity.

Thirteen 5-year-olds were not included in the study. Each school had specified a number of days during which testing could conveniently take place and these children represented whose who could not be tested within that time frame. There was no information available on these children except that teachers confirmed that they were not deemed highly active, nor did they display any particular behaviour problems. The final sample consisted of 157 children, all of whom had English as a first language. Ethnicity was predominantly British (94%) with two Afro-caribbean, three middle-eastern, three Asian and two European children. Age, gender and IQ (British ability scales 11) information for the full sample is presented in the table below. It can be seen that the age 5 group had a higher mean IQ compared to the age 3 group. A simple *t*-test revealed this mean group difference was significant ($t(154) = -2.39$; $p = .02$).

Table 6.1. Characteristics of the sample

	Age (months)		**Gender**		**IQ**	
	Mean	SD	Male	Female	Mean	SD
Age 3 (n = 71)	39	1.68	35	36	104.20	12.26
Age 5 (n = 86)	63	2.58	43	43	109.00	12.63

Socio-economic status was ascertained for 73% of 3-year-olds and 56% of 5-year-olds, using the Standard Occupational Classification Volume 2 (2nd edition, 1995) which has seven categories based on the job title of the main provider within the family. From the table 6.2. it can be seen that children in both age groups were most likely to have parents who were skilled manual workers. However, the younger group included higher numbers of children whose parent was unemployed or professional, and lower numbers of children whose parents were partly-skilled manual workers compared to the older group. This may be due to the fact that two of the nurseries from which age 3 children were recruited are attached to a university and would serve both university staff and students. Given a normal distribution, the differences between observed and expected numbers in each category were statistically significant ($\chi^2 = 16.43$; $p = .01$).

Table 6.2. Socio-economic status of the sample

	0	1	2	3	4	5	6
Age 3 (n = 57)	15.7	19.6	13.7	5.9	35.3	3.9	5.9
Age 5 (n = 48)	8.3	4.2	22.9	10.4	33.3	20.8	0

Note: 0 = unemployed; 1 = professional; 2 = managerial and technical; 3 = skilled non-manual; 4 = skilled manual; 5 = partly skilled; 6 = unskilled.

6.3.2. Measures

The reader is referred to section 4.3.2. of this thesis for a description of three EF tasks (inhibition/puppet, WM/Noisy book and planning/ToL) and two delay tasks (EvD/Penguin and ChD/Teddies) used in both Study One and the present study. The two additions to the current test battery, one EF task and one delay task, are described below.

6.3.2.1. DRT/Cookie task

The Cookie Delay Task developed by Golden *et al.* (1977) is claimed to be a measure of impulsiveness predicated on the assumption that impulsive responding (not waiting for the signal to respond) indicated disinhibition. This simple task involves placing an edible treat under one of three upturned cups and asking the child to wait for a signal before retrieving the treat. Variations of the task have been used to measure impulsivity in children aged 2 and 3 years (Campbell *et al.*, 1982) using six trials with random delays of between 5 and 45 s, and to measure self-regulation in children aged 4 and 6 years (Campbell *et al.*, 1994) using eight trials with delays between 5 and 45 s. The former study scored both impulsive responding and correct responding (choosing the correct cup under which the cookie was hidden) and the latter scored impulsive responding alone, which was defined as a movement toward, or touching/eating the cookie before the signal was given. The authors reported good test-retest reliability for impulsive responding (.81) and good discriminant validity where hyperactive children made significantly more impulsive responses then controls. The measure was also found to have good predictive validity when used in a battery of impulsive tasks where 88% of children were correctly classified.

Analogous to the argument presented for the choice paradigm, this task is considered a delay task because the apparent 'impulsive' responding also reduces delay in tasks where there is no response cost (i.e., time added) following impulsive responses. In the present study the task was administered in the same way as reported by Campbell *et al.* (1982) but small sweets were used and only early/impulsive responding was scored.

6.3.2.2. AF/Block task

Sorting tasks assess the ability to shift concepts as well as use them and commonly utilise collections of objects that are sorted on different principles. Sorting tasks have been used for assessment of brain injured adult patients to assess concept formation and often the qualitative aspects of performance are of primary interest, so sorts are undirected by the experimenter and performance and verbal protocols are assessed. Weigl (1941) used 30 familiar objects which could be sorted on concrete (e.g., physical property) and more abstract (e.g., possible uses) principles. Weigl's test, Modified Version (De Renzi, Faglioni & Savoiardo, 1966) is appropriate for use with school children and utilises blocks which are four colours, three shapes, two sizes, two thicknesses, and four patterns which, together with a spontaneous sort, allow five concrete sorts, usually performed under time constraints. Results have shown poor task performance to be associated with left hemisphere lesions.

The materials used in the present study were similar to those described by De Renzi, but patterns on the blocks were substituted for attractive pictures and the number of blocks was reduced to 12 to make the task more manageable for the younger child. The 12 blocks may be sorted on the basis of colour (3 red, 3 blue, 3 green, 3 yellow), shape (4 circles, 4 squares, 4 triangles), size (6 large, 6 small), width (6 thick, 6 thin) and picture (3 dogs, 3 bees, 3 clocks, 3 trumpets). Because the focus was on set shift rather than concept formation, the sorts were directed by the experimenter, there was no time limit imposed, and sorting performance alone was assessed.

6.3.3. Procedure

Behavioural assessments were made after each child was tested so the experimenter was blind to the status of each child during testing. Parents of participants (usually mothers) were interviewed at home using the PPACS semi structured interview. At this time parents were also asked to complete the parent SDQ. The teacher SDQ's were mailed. Before testing, all participants were given a cognitive assessment using the BAS 11. All participants were tested in a single test session lasting approximately 2 hours (with breaks) with tasks presented in the same order. Ten 3-year-olds were tested in the nursery, the remainder were tested at home. All 5-year-olds were tested in school. Table 6.3. indicates the number and order of the test battery. The 'change' column in this table refers to changes to the test battery that was used in Study One.

Table 6.3. Test battery

MEASURE	TASK	DELIVERY	CHANGES
Inhibition	Puppet says..	Manual	Same
WM	Noisy book	Manual	Modified
DRT	Cookie delay	Manual	New addition
Planning	Tower of London	Manual	Same
AF	Block sorting	Manual	New addition
EvD	Penguin game	Computer	Modified
ChD	Teddies game	Computer	Modified

Note: WM = working memory; DRT = delayed response task; AF = attentional flexibility; EvD = effort vs. delay; ChD = choice delay

Those tasks which had already been used in Study One were administered using the same format and the same verbal protocol. It is therefore not necessary to describe the procedure for those tasks here. However, the AF/Blocks and DRT/Cookie tasks were added to the current test battery and are described here.

6.3.3.1. DRT/Cookie task

The experimenter placed three transparent plastic cups in front of the child and said '*In this game I am going to put a sweet under the cup. The sweet is yours, you can have the sweet and you may eat the sweet BUT in this game I want you to wait until I clap my hands like this (clap hand) BEFORE you can get the sweet. Let's try.'* The experimenter then used a single trial to demonstrate the procedure. If the child moved before the experimenter clapped, the rule was restated so the child understood that (s)he was not to make any movement toward the cup until the sound of the clap. Eight trials were given with delays of between 5 and 30 s. The order of the delays was randomised across trials and in each trial the experimenter's hands were raised at the midpoint (i.e., after 10 s if the delay was 20 s) ready to clap. The scoring was 0 = not inhibited, 1 = partially inhibited and 2 = fully inhibited, so the possible range of scores was 0 – 16 with a high score indicating lack of impulsivity.

6.3.3.2. AF/Blocks task

Twelve blocks were placed in front of the child. The experimenter discussed the properties of the blocks, pointing out that some were different colours, shapes, sizes, widths and pictures. During this familiarisation the experimenter checked that the child could identify colour, shape, size, width and picture. A shared understanding of naming was established (e.g., the use of the term fat/thin or high/low to indicate width, and the use of 'round ones' instead of circles if the younger children could not name the shape, etc.). The experimenter then said '*This is a sorting game. Do you know what sorting out means?*' The principle of sorting was demonstrated at this point using colour and shape, pointing out that these things 'go together because they are the same colour/shape'. The experimenter then proceeded '*So you see you can sort these blocks in different ways. I want to see if you can sort the blocks into colours/shapes/sizes/widths/pictures that go together.*' The child then sorted out the blocks according to the particular instruction. The child's response was scored a pass if they were correct, or a failure if they could not sort, if they made an error in the sort, or if they sorted on an incorrect characteristic (i.e., contrary to the instruction). Finally each child was told '*Now I want you to do something special. I want you to sort the blocks out in a new of different way. Not colour or shape or size or width or picture because you have tried that already. Can you find a new or different way to sort them* *out?'* If the child seemed unable to do this, or uncertain of what the instruction meant, the experimenter said *'Shall I show you my new or different way of sorting them out?'* A sort based on which of the picture items have legs (dogs and bees) and those that did not (clocks and trumpets) was demonstrated. Then the experimenter continued *'Now let's see if you can find your own new or different way of sorting them out. You mustn't do the same as I did, but try to find your own special way of sorting.'* This represented the final sort, the spontaneous sort. In this way a child could pass or fail a maximum of six sorts. The child scored 0 for a failed sort and 2 for each successful sort, giving a range of possible scores from 0-12 with higher scores indicating greater attentional flexibility.

6.4. Results

For the sake of clarity, data reduction is described within the appropriate section, but the treatment of outliers, statistical procedures and strategy for analysis is outlined below.

6.4.1. Outliers and missing data

When identifying outliers it was important to take hyperactivity scores into account because the link between AD/HD and test scores was of primary interest. Judging outliers from the full data set would result in the loss of critical data, so the sample was divided into quartiles (for each age group) on the basis of the parent hyperactivity rating (PHR, see section 6.4.4.3.). Task performance was then explored within each quartile and outliers (+/- 2 SD) were replaced with the mean for that quartile group. In the case of missing data for the ChD/Teddies (1 case) and EvD/Penguin (2 cases) the missing value was also replaced with the mean for the quartile group.

6.4.2. Statistical procedures

The reader is referred to section 4.4.2. of this thesis which outlines the statistical procedures common to both Study One and the present study. A discriminant function analysis was included in the present study and is outlined below.

6.4.2.1. Discriminant function analysis

Discriminant function analysis assesses how well a variable or variables discriminate between predetermined groups. The procedure identifies the function, based on linear combinations of the predictors which maximally separates the groups, and uses this function to predict group membership. The assumptions underlying this procedure are (1) Normality (2) Sphericity, and (3) Random sample. When multiple predictors were used a stepwise method of entry was applied to assess the independent contribution of each predictor while controlling for the effects of the other predictors.

6.4.3. Analytic strategy

The data was analysed in four stages which address the research questions in a logical sequence. The first section is concerned with the behaviour rating scales and interview. The performance of the behavioural measures in identifying hyperactive children was assessed using multivariate analysis with age and gender as the between-subject variables and hyperactivity ratings as the dependent variables. A Chi-square analysis was conducted to assess differences between observed and expected numbers of children identified as hyperactive in the sample. Associations between different measures were examined using Pearson *r* correlations. A single index of hyperactivity was created using combined data from the behavioural measures. A single index for conduct problems was derived in the same way. These were called PHR and PCR respectively. This was the first stage of data reduction and this single index was used in all subsequent analyses except the final analysis which used a clinical group.

The second section investigated the extent to which the modified delay tasks discriminate between AD/HD and control children. Group by condition interactions were examined using multivariate analyses using age, gender and PHR as between-subject variables and task scores as the dependent variables. To facilitate subsequent analyses a single index of delay was created for each measure following the method used in Study One. This was the second stage of data reduction.

The third section addressed the research questions regarding the associations between tasks. In the first instance intraclass correlations were conducted to assess the reliability of all measures. As the larger sample size allowed for exploration of associations between tasks at each age, and for males and females, Pearson *r* correlations were calculated using task/index scores for each sub-group. The factor structure was examined using task/index scores for both age groups. This was the third stage of data reduction as the measured variables were reduced to a smaller number of factors. The impact of IQ on task factors was then assessed using multivariate analysis with task factors as the dependent variables.

The fourth section addressed questions regarding the role of behavioural status in task performance. Using the PHR and PCR and factor scores, the associations between task factors and behavioural status were examined for each age group using Pearson *r* correlations. Then the independent contribution of child characteristics was assessed in a multiple regression analysis with IQ, gender, PHR and PCR as predictors. The linear and quadratic functions of task factors with hyperactivity was examined using curve fit analysis prior to examining differences in the extreme range of symptoms. For the final analyses a clinical group was identified using cutoffs from the parent SDQ. Differences between the clinical and control groups on task factors was assessed using multivariate analysis with clinical status as the independent variables and task factors as the dependent variables. Finally the sensitivity and specificity of tasks in predicting AD/HD and CD was assessed using discriminant function analysis.

6.4.4. Section I: Interview and behaviour rating scales

Tables 6.4. and 6.5. describe the sample in terms of scores for each subscale of the teacher- and parent-rated SDQ and the PPACS semi-structured clinical interview. To assess whether scale scores were statistically different for boys and girls at each age, a MANOVA was conducted with age and gender as the independent variables and scale scores as the dependent variables. Results showed an overall main effect of age ($F(11,123) = 2.34$; $p = .01$) and gender ($F(11,123) = 1.90$; $p = .04$) but no significant age by gender interaction ($F(11,123) = 1.20$; $p = .29$). Differences between age groups were confirmed for three subscales of the parent-rated SDQ only (total difficulties, conduct problems and prosocial scores all significant at the $p<.05$ level).

Table 6.4. Age 3 interview and rating scale scores

	Males					Females				
Subscale	N	Min	Max	M	SD	N	Min	Max	M	SD
TEACHER SDQ	28					29				
Total difficulties		1	22	9.68	5.81		0	15	6.72	3.70
Conduct		0	6	1.18	1.74		0	6	1.21	1.76
Activity		0	10	4.39	2.96		0	7	2.83	1.95
Emotional problems		0	8	1.43	1.87		0	5	1.17	1.31
Peer problems		0	8	2.68	2.09		0	5	1.52	1.24
Prosocial		1	10	5.93	2.39		1	10	7.55	2.26
PARENT SDQ	35					32				
Total difficulties		3	27	12.97	6.26		0	21	9.28	4.93
Conduct		0	8	3.63	2.40		0	7	2.41	1.90
Activity		0	10	5.06	2.90		0	9	3.41	2.47
Emotional problems		0	6	2.06	1.78		0	4	1.62	1.38
Peer problems		0	8	2.23	1.91		0	5	1.84	1.46
Prosocial		2	10	6.66	1.97		3	10	7.44	2.06
PPACS	35					35				
Total		14	44	29.17	7.72		11	45	23.77	7.26
Hyperactivity		5	24	14.46	5.11		4	26	11.74	5.99
Conduct problems		7	24	14.80	4.42		6	19	12.03	3.14

Note: Teacher SDQ = teacher completed strengths and difficulties questionnaire; Parent SDQ = parent completed strengths and difficulties questionnaire; PPACS = preschool parent account of child symptoms semi-structured interview

Table 6.5. Age 5 interview and rating scale scores

	Males					Females				
Subscale	**N**	**Min**	**Max**	**M**	**SD**	**N**	**Min**	**Max**	**M**	**SD**
TEACHER SDQ	42					42				
Total difficulties		0	32	10.45	7.71		0	21	6.12	5.39
Conduct		0	8	2.12	2.49		0	3	0.74	0.99
Activity		0	10	4.86	3.24		0	10	2.81	3.28
Emotional problems		0	8	1.43	1.74		0	6	1.09	1.60
Peer problems		0	9	2.05	2.37		0	8	1.48	2.04
Prosocial		0	10	5.43	3.05		0	10	6.93	2.73
PARENT SDQ	42					42				
Total difficulties		0	21	8.81	5.83		0	20	7.57	4.83
Conduct		0	7	1.93	1.74		0	8	1.69	1.90
Activity		0	9	3.59	2.70		0	8	3.05	2.66
Emotional problems		0	7	1.64	1.96		0	5	1.36	1.36
Peer problems		0	6	1.69	1.52		0	6	1.48	1.50
Prosocial		5	10	8.00	1.46		4	10	8.26	1.58
PPACS	43					43				
Total		11	42	22.30	7.15		7	31	18.30	6.27
Hyperactivity		4	22	10.46	4.46		2	19	9.00	4.24
Conduct problems		2	24	11.84	4.13		3	16	9.60	2.99

Note: Teacher SDQ = teacher completed strengths and difficulties questionnaire; Parent SDQ = parent completed strengths and difficulties questionnaire; PPACS = preschool parent account of child symptoms semi-structured interview

In general, younger children were rated by parents as less prosocial and displaying more conduct problems than older children. Gender differences were found to be significant at the $p<.05$ level for all subscales of the teacher-rated SDQ except emotional problems, and all subscales of the parent-rated SDQ except emotional and peer problems. In general, girls were rated by teachers and parents as less active, more prosocial, and having fewer conduct problems than boys.

6.4.4.1. Characterising the sample against population norms

The SDQ is designed so that, in a normal population, 10% fall in the abnormal range (Goodman, 1997). This means 10% of children in a normal sample would score above the cutoff (7+) on the activity subscale of the teacher- or parent-rated SDQ and would be deemed hyperactive. Research has suggested that the gender ratio for hyperactivity in a community sample could be as high as 5:1 with higher numbers of boys identified as hyperactive (Scahill *et al.*, 1999). The table below shows how the teacher- and parent-rated SDQ performed in the current sample. The PPACS was not included as a basis for characterising the sample as no normative data exists for preschool children.

Table 6.6. Percentage of children identified as hyperactive using the teacher- and parent-rated SDQ (actual numbers in parenthesis)

	Age 3				**Age 5**			
	N	**% male**	**% female**	**% sample**	**N**	**% male**	**% female**	**% sample**
Teacher SDQ	57	21.4 (6)	3.4 (1)	12.3	84	31.0 (13)	21.9 (9)	26.2
Parent SDQ	67	28.6 (10)	12.5 (4)	20.9	84	14.3 (6)	14.3 (6)	14.3

Note: SDQ = strengths and difficulties questionnaire

In general, more boys than girls were identified as hyperactive which is consistent with the literature. The teacher ratings identify higher numbers of children with AD/HD symptoms than expected, but this appears to be a common feature in community sampling with teacher reports identifying 15% (Weiler *et al.*, 1999) and 18% (Baumgaertel, Wolraich & Dietrich, 1995) in community samples. Parent reports also identified higher numbers than expected, especially in the younger group.

Given the expectation of 10% hyperactivity in a normal sample, a Chi-square analysis was conducted to assess if differences between observed and expected frequencies reached statistical significant. The results shown in table 6.7. confirm the numbers of hyperactive children identified were significantly higher than expected for teacher-rated children at age 5 and parent-rated children at age 3.

Table 6.7. Differences between observed and expected numbers of hyperactive children identified using the teacher- and parent-rated SDQ

	Age 3			**Age 5**		
	N	χ^2	**Sig.**	**N**	χ^2	**Sig**
Teacher SDQ	57	.19	.67	84	27.08	.00
Parent SDQ	67	7.82	.01	84	2.21	.14

Note: SDQ = strengths and difficulties questionnaire

6.4.4.2. Agreement between interview and behaviour rating scales

Research into ratings from different informants find poor agreement between teacher and parent reports (Mitsis *et al.*, 2000). It is of interest therefore to consider the extent to which different informants agree on their assessment of a child. The tables below show the correlations between the different parent and teacher measures of hyperactivity used on the current sample.

Table 6.8. Associations between hyperactivity scales of the behavioural measures at age 3

	Males			Females		
	TSDQ	**PSDQ**	**PPACS**	**TSDQ**	**PSDQ**	**PPACS**
TSDQ	--			--		
PSDQ	.32 (n=28)	--		.44 (n=27)	--	
PPACS	.42 (n=28)	.62* (n=35)	--	.31 (n=29)	.64* (n=35)	--

Note: TSDQ = teacher-rated strengths and difficulties questionnaire; PSDQ = parent-rated strengths and difficulties questionnaire; PPACS = preschool parental account of childhood symptoms
* $p < 0.02$ (alpha adjusted)

Table 6.9. Associations between hyperactivity scales of the behavioural measures at age 5

	Males			Females		
	TSDQ	**PSDQ**	**PPACS**	**TSDQ**	**PSDQ**	**PPACS**
TSDQ	--			--		
PSDQ	.63* (n=41)	--		.31 (n=41)	--	
PPACS	.41* (n=42)	.58* (n=42)	--	.32 (n=42)	.75* (n=42)	--

Note: TSDQ = teacher-rated strengths and difficulties questionnaire; PSDQ = parent-rated strengths and difficulties questionnaire; PPACS = preschool parental account of childhood symptoms
* $p < 0.02$ (alpha adjusted)

There was moderate agreement between the teacher and parent informed measures of hyperactivity. Not surprisingly the agreement between the two parent informed measures was in general greater. This reached statistical significance in all age groups for both males and females, despite the different modes of assessment.

6.4.4.3. Creating an index of hyperactivity

The literature alerts us to the importance of assessing hyperactivity across a range of contexts, preferably using multiple informants (Mitsis *et al.*, 2000). In the present context an index of pervasive hyperactivity was desirable and the initial intention was to combine hyperactive ratings across all measures. Unfortunately, although there was a degree of concordance between all three measures of hyperactivity, the teacher-completed SDQ was missing for fifteen 3-year-olds and five 5-year-olds and this would lead to reduced statistical power. As the agreement between the parent rated SDQ and the PPACS parent interview was greater, and data for both measures was available for 96.8% of the sample, it was decided that a combined rating for these two measures would provide the most powerful rating of hyperactivity with a loss of just 5 cases. This composite of parent-rated SDQ and PPACS provides some indication of pervasive hyperactivity because parents are asked to assess the child in a number of different environments (home, shop, etc.) during the PPACS interview. Standardised scores (Z-transformed) for the two measures were summed and divided by 2. This rating was termed Parent Hyperactivity Rating (PHR). In a similar way an index of conduct problems was derived using scores from the conduct subscales of the parent SDQ and PPACS. This rating was termed Parent Conduct Rating (PCR).

Having created new indices, it was of interest to assess how they were associated with the original subscale scores. A correlational analysis was performed on the PHR and

PCR and the teacher- and parent-rated SDQ conduct and activity subscales. The results for the age 3 and age 5 groups are displayed in tables 6.10. and 6.11. respectively.

Table 6.10. Associations between PHR, PCR and behaviour measures at age 3

	Males		**Females**	
	PHR	**PCR**	**PHR**	**PCR**
TSDQ con	.05	.26	.08	-.12
	(n=28)	(n=28)	(n=27)	(n=27)
TSDQ hyp	.43	-.19	.42	.06
	(n=28)	(n=28)	(n=27)	(n=27)
PSDQ con	.44	.88*	.60*	.88*
	(n=35)	(n=35)	(n=32)	(n=32)
PSDQ hyp	.90*	.36	.91*	.46
	(n=35	(n=35)	(n=32)	(n=32)
PPACS con	.25	.86*	.28	.83*
	(n=35)	(n=35)	(n=32)	(n=32)
PPACS hyp	.90*	.36	.90*	.49
	(n=35)	(n=35)	(n=32)	(n=32)

Note: PHR = parent hyperactivity rating; PCR = parent conduct rating; TSDQ = teacher-rated strengths and difficulties questionnaire; PSDQ = parent-rated strengths and difficulties questionnaire; PPACS = preschool parental account of childhood symptoms; con = conduct problem scale; hyp = hyperactivity scale
* $p < .004$ (alpha adjusted)

Table 6.11. Associations between PHR, PCR and behavioural measures at age 5

	Males		Females	
	PHR	**PCR**	**PHR**	**PCR**
TSDQ con	.38	.68*	.50*	.42
	(n=41)	(n=41)	(n=41)	(n-41)
TSDQ hyp	.59*	.50*	.34	.15
	(n=41)	(n=41)	(n=41)	(n=41)
PSDQ con	.43	.80*	.52*	.88*
	(n=42)	(n=42)	(n=42)	(n=42)
PSDQ hyp	.88*	.49*	.94*	.48*
	(n=42)	(n=42)	(n=42)	(n=42)
PPACS con	.39	.87*	.41	.81*
	(n=42)	(n=42)	(n=42)	(n=42)
PPACS hyp	.89*	.38	.94*	.57*
	(n=42)	(n=42)	(n=42)	(n=42)

Note: PHR = parent hyperactivity rating; PCR = parent conduct rating; TSDQ = teacher-rated strengths and difficulties questionnaire; PSDQ = parent-rated strengths and difficulties questionnaire; PPACS = preschool parental account of childhood symptoms; con = conduct problem scale; hyp = hyperactivity scale
* $p < .004$ (alpha adjusted)

The association between conduct and hyperactivity ratings on different measures is moderate, and the combining of parent ratings has slightly attenuated this association, though not dramatically. The association between conduct and hyperactivity was slightly stronger in females than males, which may reflect an attributional bias where the behaviour of hyperactive girls is seen as more intentional than boys, or may reflect a true difference where hyperactivity in girls is more closely allied to conduct problems. The associations across different subscales within the same domain (hyperactivity or conduct) has been strengthened. The pattern of association appeared to be similar for both sexes and stable across different ages, indicating that this association is not gender specific or developmental.

The pattern of association between PHR and PCR and IQ at different ages was examined using Pearson correlation. The tables below show that, with increasing age, the association between IQ and conduct problems weakens, whilst the association between conduct problems and hyperactivity strengthens.

Table 6.12. Associations between PHR, PCR and IQ at age 3

	Males			**Females**		
	PHR	**PCR**	**IQ**	**PHR**	**PCR**	**IQ**
PHR	--			--		
PCR	.40*	--		.52*	--	
IQ	-.30	-.17	--	-.24	-.28	--

Note: PHR = parent hyperactivity rating; PCR = parent conduct rating
* $p < .02$ (alpha adjusted)

Table 6.13. Associations between IQ and composite parent ratings at age 5

	Males			**Females**		
	PHR	**PCR**	**IQ**	**PHR**	**PCR**	**IQ**
PHR	--			--		
PCR	.48*	--		.56*	--	
IQ	-.26	-.21	--	-.16	-.07	--

Note: PHR = parent hyperactivity rating; PCR = parent conduct rating
* $p < .02$ (alpha adjusted)

It appeared that IQ has only a weak correlation with hyperactivity, and this association is stronger in the younger children. This may reflect the hyperactive child's' ability to develop strategies to compensate for their performance limitations, but could equally suggest the adaptation of brain functions in maturation.

6.4.4.4. Commentary

The sample can be characterised as an opportunity sample with scores across the range of symptom severity. Consistent with previous findings, more boys than girls are identified as hyperactive. The current sample has a higher rate of hyperactivity than one would expect to find in a normal sample and this is statistically significant in the age 3 group for parent-informed ratings, and in the age 5 group for teacher-informed ratings. This accords with evidence that in older children teachers identify higher numbers of AD/HD children than parents (Breton *et al.*, 1999). In the current sample, a possible explanation for this disparity may lie in the context-dependency of the interpretation of behaviour; for example, teachers of reception children may over-emphasise the hyperactive traits in a situation where children, perhaps for the first time, are required to sit still for long periods such as registration, and parents may erroneously attribute hyperactive traits in younger children whose behaviour may be frustrating but otherwise developmentally appropriate. Another explanation may lie in the two different approaches to gaining parental consent. Although both teachers and HVs involved in recruitment were aware of the research interest, the HVs had intimate contact with the parent and may have encouraged the parents of highly active children to participate. Teachers sent letters to parents and possibly parents of 'difficult' children were suspicious or reluctant to participate. This is borne out by anecdotal evidence as several teachers expressed regret that consent was not obtained for 'an interesting child' in their class. Nonetheless, the community sample here shows characteristics of an opportunity sample approach which has fortuitously resulted in a 'top heavy' distribution.

Using the composite ratings PHR and PCR, evidence suggested hyperactivity and conduct problems were more closely allied in girls than boys, and the association was stronger in the older age group. Given that girls in general (and in this sample) are rated as more prosocial and having fewer conduct problems, this association offers some support for the notion that girls are equally at risk for developing later externalising disorders, but are referred less because their behaviour is perceived as less problematic. IQ was more associated with hyperactivity than conduct problems, but the association is reasonably stable over time and remains moderate to low.

6.4.5. Section II: Experimental analysis of delay tasks

This section addresses research questions regarding the discriminant validity of the delay tasks. Results from Study One established that preschoolers are sensitive to the conditions and are to some extent delay averse. The question now is whether hyperactive preschoolers are more delay averse than their less hyperactive peers. For each task a group by condition interaction is the key finding.

In order to assess group by condition interactions on the two experimental tasks it was necessary to create hyperactive and control groups. Consistent with the assumption that hyperactive symptoms are a continuum, a median split on the PHR was performed to create hyperactive and control groups. This median split has two effects: Firstly, if group differences are found they are likely to underestimate the real effect (i.e., to be more diluted than if extreme cutoffs are applied). Secondly, the median split gives relatively even numbers in each group thus increasing the power to test for interactions.

6.4.5.1. EvD/Penguin task

The aim of this experiment was to determine whether the imposition of a PRD impacts differentially on hyperactive childrens' response rate when they are pressing a button to move toward a reward. The DA hypothesis predicts that hyperactive children will respond similarly to controls in the PRD condition where trial lengths are fixed and overall delay is not contingent upon the rate of responding. In the NoPRD condition hyperactive children will increase their response rate relative to controls as this will reduce overall delay.

Table 6.14. Hyperactive and control children's mean response rate (button presses per second)

	Age 3		**Age 5**	
Condition	**Control (n=34)**	**Hyperactive (n=33)**	**Control (n=42)**	**Hyperactive (n=42)**
PRD	2.86 (1.01)	3.06 (1.20)	4.24 (.81)	4.11 (1.11)
NoPRD	2.91 (1.02)	3.49 (1.50)	4.34 (.67)	4.19 (1.20)

Note: PRD = post-reward delay; NoPRD = no post-reward delay; Standard deviations in parenthesis.

Figure 6.1. describes a general trend where hyperactive children respond at a higher rate than controls in both conditions. Both groups appear sensitive to the imposition of a PRD as evidenced by a corresponding drop in response rate, and this sensitivity was pronounced for the hyperactive children relative to control children. This trend is in the direction predicted by the DA hypothesis.

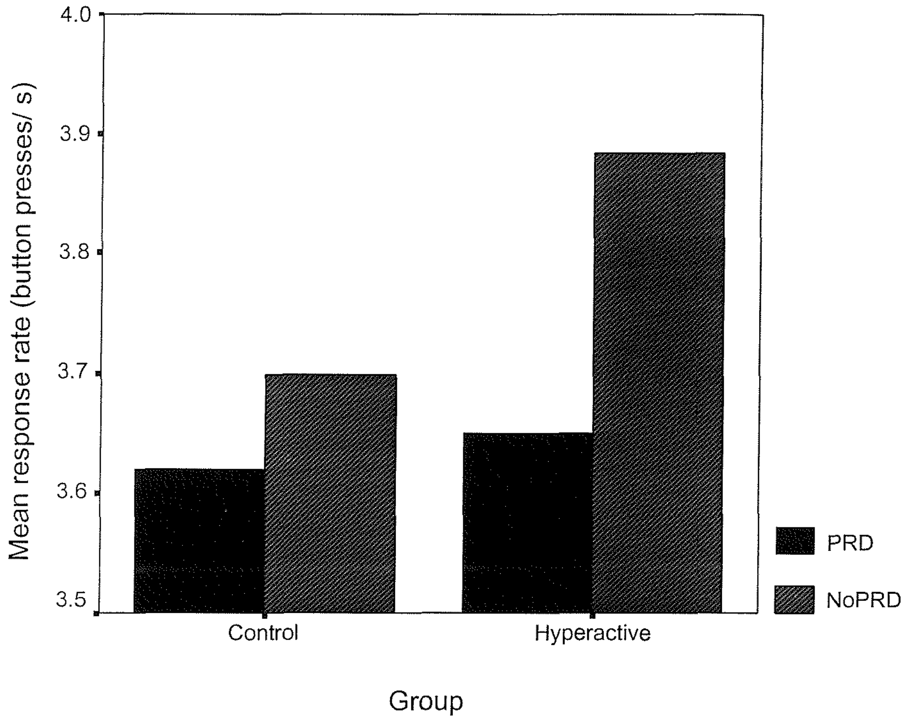

Figure 6.1. The effect of PRD on hyperactive and control children's response rate

To test if these observed differences reached statistical significance a repeated-measures MANOVA was conducted with mean response rate (button presses per second) as the dependent variable. The between-subject variables were age, gender and group. The within-subject variable was condition (PRD vs. NoPRD). Results showed an overall main effect of condition ($F(1,143) = 4.08$; $p = .04$), but no significant group by condition interaction ($F(1,143) = 1.17$; $p = .29$). No other interactions were significant.

Whilst it appeared hyperactive children were more sensitive than controls to the imposition of delay, this was not statistically significant. This suggested that, although the trend is in the direction predicted by the DA model, the task did not discriminate between hyperactive and control performance. Because of this, a decision was taken to omit the task from any subsequent analyses. The exclusion of this measure was supported by the test-retest reliability analysis which showed poor reliability in the PRD condition ($r = -.15$). There will be no further mention of the task here.

6.4.5.2. ChD/Teddies task

The aim of this experiment was to determine if the imposition of a PRD differentially affects hyperactive children's LL reward choices. The DA hypothesis predicts that hyperactive children will perform similarly to control children in the (PRD) condition where trial lengths are fixed and overall delay is not contingent upon choices made, but will choose the LL reward less frequently in the NoPRD condition where SS choices would reduce overall delay.

To investigate hyperactive and control group differences in task performance a repeated-measures MANOVA was conducted with the number of LL reward choices as the dependent variable. Between-subject variables were age, gender and group, and within-subject variable was condition (PRD vs. NoPRD).

Table 6.15. Hyperactive and control children's mean percentage of LL choices (SD in parenthesis)

	Age 3		Age 5	
Condition	**Control (n=34)**	**Hyperactive (n=33)**	**Control (n=42)**	**Hyperactive (n=42)**
PRD	64 (21)	55 (22)	54 (11)	58 (15)
NoPRD	56 (19)	36 (24)	50 (12)	49 (18)

Note: PRD = post-reward delay; NoPRD = no post-reward delay

Manova results showed an overall main effect of condition ($F(1,143) = 29.47$; $p = .001$). In general children chose the LL reward less often in the NoPRD condition. This replicated the results presented in Study One that suggested preschool children were sensitive to the conditions and the task worked well as a measure of delay. There was an overall main effect of group ($F(1,143) = 8.22$; $p = .001$) indicating differential performance between hyperactive and control children. Figure 6.2 shows hyperactive children chose the LL reward less frequently than control children, which is consistent with previous research which claims this to be 'impulsive' responding. There was no main effect of gender ($F(1,143) = .04$; p = ns) or age ($F(1,143) = .00$; p = ns) and no significant group by age by gender interaction ($F(1,143) = .52$; p = ns).

Crucially, a significant condition by group interaction was found ($F(1,143) = 4.52$; $p = .03$) and this confirmed the discriminant validity of the task by demonstrating the differential response to delay between hyperactive and control children. Figure 6.2 shows the hyperactive children made significantly fewer LL choices in the NoPRD condition. This means that, although hyperactive children chose the SS reward more often in general, they made significantly more SS choices in the NoPRD condition, when doing so reduces the overall delay. Although a significant interaction between condition and age ($F(1,143) = 3.86$; $p = .05$) confirmed that younger children were more delay averse than older children in general, a non-significant group by condition by age interaction ($F(1,143) = .52$; $p =$ ns) indicated the pattern of responding for hyperactive and control children was similar at age 3 and age 5.

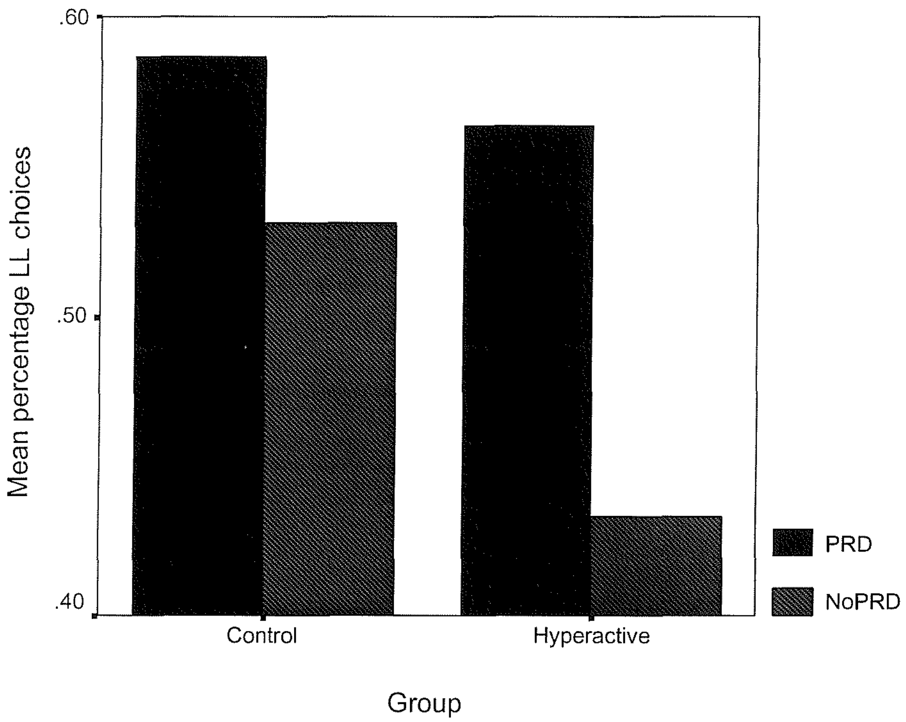

Figure 6.2. The effect of PRD on hyperactive and control children's LL choices

A significant condition by gender by group interaction was also found ($F(1,143) = 3.98$; $p = .05$) and Figure 6.3 shows this interaction. Overall hyperactive children displayed a greater degree of sensitivity to the imposition of a PRD but Figure 6.3. shows this sensitivity was marked for boys. A further ANOVA was conducted for boys and girls separately and results confirmed that on this task, delay aversion was demonstrated for boys ($F(1,73) = 7.75; p = .007$) but not girls ($F(1,70) = .01; p = .92$).

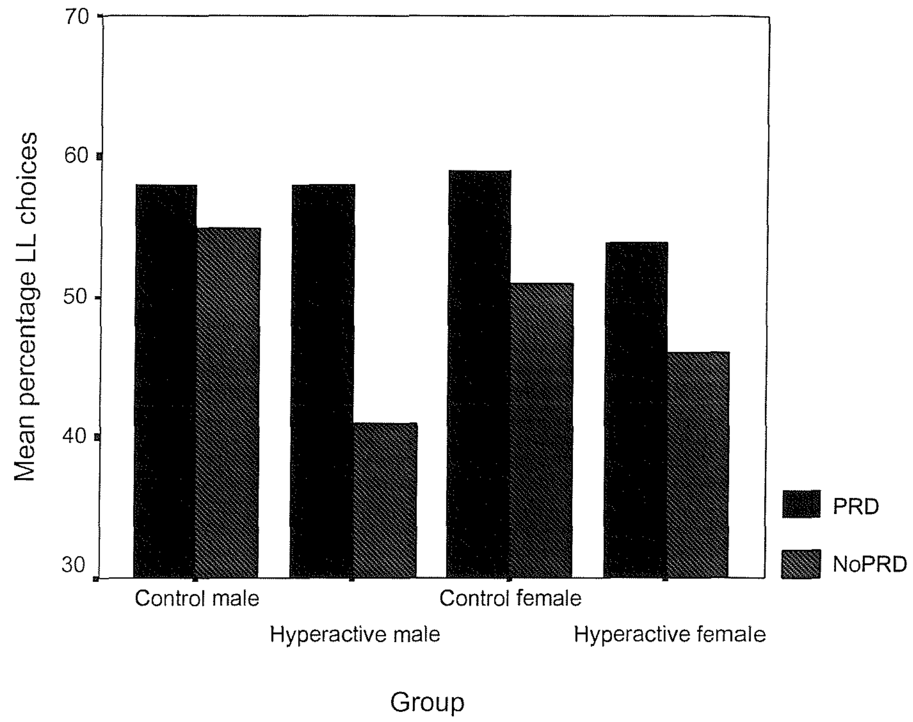

Figure 6.3. Gender differences in hyperactive and control children's LL choices

6.4.5.3. Creating an index of delay

To facilitate subsequent analysis, a single index of delay aversion was created to reduce the number of measured variables in the ChD/Teddies task. The number of LL choices in the NoPRD condition were subtracted from the number of LL choices in the PRD condition to create an index of delay where positive scores indicated delay aversion. This was termed the Delay Aversion Index (DAI).

6.6.2. Section III: Executive function and delay tasks

This section addresses the research questions concerning the associations between EF and delay tasks. As in Study One the analyses were conducted for each age group to assess stability of associations over time, but the larger sample size meant gender differences may also be analysed.

6.4.6.1. Reliability

Twenty percent of the sample (n = 30) were re-tested within one month on the manual tasks. Seventeen percent of the sample (n = 26) were re-tested within one month on the ChD/Teddies computer task. Intraclass correlations were calculated using task scores for the manual tasks and the DAI for the ChD/teddies task. The test-retest reliability for all measures, shown in Table 6.16, was found to be satisfactory with reliability for the ChD/teddies task showing a great improvement on that found in Study One. This indicates the introduction of more attractive rewards has improved reliability for this measure. The test-retest values for ChD/teddies are similar to those reported by Kuntsi *et al.* (2001) for a similar computer-based choice task ($r = .74$). The same authors reported reliability for a WM task ($r = .74$) which is also very similar to the value reported here for the WM/Noisy book task.

To assess inter-rater reliability two independent raters scored performance on manual tasks using video footage of the test session. Altogether 10% of the sample were rated (n = 15) and intraclass correlations were calculated. No inter-rater reliability was required for the computer-based tasks. Inter-rater reliability, as shown in Table 6.16, was found to be satisfactory for all measures despite the fact that scoring from the video was often made difficult by extraneous noise, which particularly affected the scoring of the auditory WM/Noisy book task.

Table 6.16. Test-retest and inter-rater reliability for EF and delay tasks

Task	Inter-rater r	Test-retest r
Inhibition	.97	.97
WM	.78	.75
Planning	.84	.86
AF	.98	.97
DRT	.94	.95
ChD	—	.63

Note: WM = working memory; AF = attentional flexibility; DRT = delayed response task; ChD = choice delay task

6.4.6.2. Descriptive statistics

The following tables displays scores for each EF and delay task, for each age group.

Table 6.17. Age 3 EF and delay task scores

	Male (n = 35)				**Female (n = 35)**			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Inhibition	0	16	3.34	5.62	0	16	7.0	6.44
WM	0	2	.63	.65	0	2	1.0	.59
Planning	0	2	.86	.73	0	3	1.31	.80
AF	0	8	2.03	2.09	0	10	3.60	2.65
DRT	0	6	8.03	6.74	0	16	10.89	5.18
ChD	-.47	.93	.17	.29	-.38	.59	.09	.23

Note: WM = working memory; AF = attentional flexibility; DRT = delayed response task; ChD = choice delay task

Table 6.18. Age 5 EF and delay task scores

	Male (n = 43)				**Female (n = 43)**			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Inhibition	14	16	15.53	.77	12	16	15.33	1.06
WM	1	3	2.02	.64	1	3	1.98	.51
Planning	2	4	2.98	.86	2	4	2.67	.75
AF	6	12	8.19	1.43	4	12	8.23	1.81
DRT	1	16	13.72	3.04	4	16	14.26	2.60
ChD	-.38	.54	.05	.17	-.22	.60	.07	.15

Note: WM = working memory; AF = attentional flexibility; DRT = delayed response task; ChD = choice delay task

A two-way MANOVA was conducted to assess age and gender differences in task scores with task/DAI scores as the dependent variables. Results showed no overall main effect of gender ($F(6,147) = 2.08$; p = ns) but a main effect of age ($F(6,147) = 76.42$; $p = .001$) and a significant age by gender interaction ($F(6,147) = 2.92$; $p = .01$). This interaction was significant at the $p<.05$ level for all EF tasks, but not the delay tasks. In general the older children performed better than younger children on EF tasks, but in the younger age group girls performed better than boys, an advantage not observed in older children.

6.4.6.3. Associations between executive and delay tasks

Having established the reliability and validity of the task battery the patterns of association between the task battery at different ages were examined. A Pearson *r* correlation analysis was conducted using task/DAI scores. As previous results have suggested gender differences in performance on EF tasks, this analysis was performed separately for males and females at each age.

Table 6.19. Associations between task measures at age 3

	Males (n = 35)						Females (n = 35)					
	Inhib	**WM**	**Plan**	**AF**	**CDT**	**ChD**	**Inhib**	**WM**	**Plan**	**AF**	**DRT**	**ChD**
Inhib	--						--					
WM	.32	--					.49*	--				
Plan	.43	.57*	--				.23	.43	--			
AF	.42	.51*	.44	--			.36	.30	.48	--		
DRT	.51*	.28	.32	.30	--		.36	.08	-.04	.29	--	
ChD	-.19	-.05	.12	.12	-.21	--	.09	-.00	-.11	-.00	-.04	--

Note: Inhib = inhibition; WM = working memory; Plan = planning; AF = attentional flexibility; DRT = delayed response task; ChD = choice delay
**p* <.003 (alpha adjusted)

Table 6.20. Associations between tasks measures at age 5

	Males (n = 43)						Females (n = 43)					
	Inhib	**WM**	**Plan**	**AF**	**DRT**	**ChD**	**Inhib**	**WM**	**Plan**	**AF**	**DRT**	**ChD**
Inhib	--						--					
WM	-.17	--					.19	--				
Plan	-.12	.31	--				-.01	-.02	--			
AF	.21	15	.31	--			.18	.37	.20	--		
DRT	23	11	.07	.24	--		.13	.04	-.05	-.21	--	
ChD	.37	-.12	-.11	.15	-.19	--	-.00	-.02	-.04	.13	-.38	--

Note: Inhib = inhibition; WM = working memory; Plan = planning; AF = attentional flexibility; DRT = delayed response task; ChD = choice delay
* $p < .003$ (alpha adjusted)

Overall the associative strengths between tasks appeared to diminish over time. Tasks were more closely allied in the younger age group, perhaps reflecting the less differentiated functions at this earlier age. The pattern for boys and girls was different with WM and inhibition being more closely allied in females than males. This converges with findings in other studies which show school-age AD/HD girls more sensitive to visuospatial WM tasks (Garcia-Sanchez *et al.*, 1997), which the authors suggest is due to greater attentional problems in AD/HD girls than boys.

6.4.6.4. Factor structure

The dimensionality of the six measures was analysed using principal component factor analysis. The manual task scores and the DAI for ChD/teddies task were entered into the analysis. For the age 3 group the rotated solution yielded two factors accounting for 44.5% and 20.2% of the variance respectively (64.7% of total variance explained). Examining the factor loadings it appeared that, for the age 3 group, Factor 1 comprised of executive tasks including inhibition and Factor 2 comprised the two delay tasks. Accordingly the factors were termed EFF/INH and DEL respectively.

Table 6.21. Factor solutions at age 3 (n = 70)

Tasks	Factor 1	Factor 2
Inhibition	**.68**	.39
WM	**.78**	.01
Planning	**.79**	-.08
AF	**.78**	.06
DRT	.48	**.57**
ChD	.16	**-.85**

Note: WM = working memory; AF = attentional flexibility; DRT = delayed response task; ChD – choice delay

For the age 5 group the rotated solution yielded three factors accounting for 24.1%, 21.2% and 20.1% of the variance respectively (65.4% of total variance explained). Examining the factor loadings it appeared that Factors 1, 2 and 3 comprised of executive tasks, delay tasks and inhibition loaded separately. The factors were termed EFF, DEL and INH respectively.

Table 6.22. Factor solutions at age 5 (n = 86)

Tasks	Factor 1	Factor 2	Factor 3
Inhibition	.02	.02	**.87**
WM	**.66**	.15	.05
Planning	**.71**	.04	-.23
AF	**.70**	-.18	.37
DRT	-.02	**.79**	.37
ChD	-.13	**-.78**	.34

Note: WM = working memory; AF = attentional flexibility; DRT = delayed response task; ChD – choice delay

These results indicated that the EF factor structure at age 3 is not the same as the EF factor at age 5. Interestingly, it appeared that executive functions at age 3 are more appropriately defined as executive functions *and* inhibition. At age 5 the inhibition factor is differentiated from executive functions and includes the inhibition task and the moderate loading of those tasks which imply an element of inhibition in the execution of set shift and delay of gratification. This appeared to question the assumption of the executive dysfunction model which asserts that inhibition underpins executive performance.

For both age groups, the DRT/Cookie task cross-loads (i.e., is associated with more than one factor) but the pattern for both ages is consistent with the notion that its association with executive factors at age 3 is carried on the inhibitory component which, when differentiated at age 5, results in a different cross-loading with the inhibition factor alone. This task inevitably draws on inhibitory capacities at the same time as indicating delay aversion. More generally it is clear that none of the measures can be considered as a pure measure of either delay aversion of executive functions.

6.4.6.5. The impact of IQ on task factors at different ages

Thus far the impact of IQ has been examined only for behaviour ratings. A median split on IQ scores was performed to create high IQ and low IQ groups. Table 6.23 shows the factor scores for high- and low- IQ males and females at age 3.

Table 6.23. Factor scores for low- and high-IQ groups at age 3

		Low IQ				**High IQ**			
		Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
Males	**EFF/INH**	-1.63	.62	-.64	.70	-1.74	1.97	-.03	1.17
	DEL	-2.58	.99	-.26	.91	-2.16	3.78	-.08	1.46
Females	**EFF/INH**	-1.28	1.49	-.02	.76	-.24	2.34	.86	.80
	DEL	-1.58	1.67	.12	1.01	-.87	.70	.17	.53

Note: EFF/INH = executive function factor including inhibition; DEL = delay factor

A two-way MANOVA was conducted with IQ and gender as the independent variables and factor scores as the dependent variables. Multivariate results showed a significant overall main effect of IQ ($F(2,63) = 6.79$; $p = .002$) and gender ($F(2,63) =$

7.62; $p = .001$). Univariate results showed a significant effect of IQ for EFF/INH ($F(1,64) = 12.76$; $p = .001$) but not DEL ($F(1,64) = 7.62$; $p = .52$). This indicated that, at age 3, IQ impacts upon EF performance but not delay.

Table 6.24. Factor scores for low- and high-IQ groups at age 5

		Low IQ				High IQ			
		Min	Max	Mean	SD	Min	Max	Mean	SD
Males	**EFF**	-1.88	2.02	-.11	1.02	-1.17	2.74	.36	1.05
	DEL	-4.51	1.36	-.13	1.26	-1.26	1.36	.02	.75
	INH	-.60	1.60	.39	.57	-2.46	1.12	-.43	1.13
Females	**EFF**	-2.54	1.37	-.36	1.02	-1.23	2.19	.18	.77
	DEL	-1.98	1.81	.03	1.00	-3.02	1.13	.09	.93
	INH	-2.77	1.48	-.19	1.16	-1.94	1.38	.20	.88

Note: EFF = executive function factor; DEL = delay factor; INH = inhibition factor

The age 5 data was subjected to a MANOVA as before. Multivariate results were not significant for IQ ($F(3,82) = 2.36$; $p = .08$), but there was a significant IQ by gender interaction ($F(3,82) = 2.83$; $p = .04$). Univariate results showed the IQ by gender interaction was significant for INH alone ($F(1,82) = 8.63$; $p = .004$). From the table of means it can be seen that high IQ results in lower inhibition scores for boys, but higher inhibition scores for girls.

6.4.6.6. Commentary

Of the two computer-based tasks designed to tap into delay aversion only one, the ChD/teddies task, was shown to be a valid measure of delay aversion in hyperactive children. Reliability for this task has considerably improved as a result of the modifications described in the previous chapter. This task discriminated between hyperactive and control performance for boys but not girls. Patterns of association between tasks showed associations got weaker with increasing age. This most likely reflects increasing fractionation of functions into specific domains. This notion is further supported by evidence for different factor structures at each age, indicating the separation of executive and inhibition components in the older age group. Within the factor structure it is also interesting to note that, in contrast to Study One, both delay tasks now load onto a single factor. This suggests the DRT/Cookie task, which is also based on the DoG paradigm and also requires a single response per trial, is similar to the ChD/teddies task in a way that the other delay tasks were not. It is also clear that despite the inevitable influence of inhibition in these types of delay task, both load independent of inhibition.

Using factor scores, IQ did not significantly impact upon delay aversion. IQ impacted upon the younger children's executive/inhibition performance but this is no longer significant when EF and inhibition are separate at age 5. IQ impacted upon inhibition differently for older boys and girls. Schachar and colleagues have found only small to moderate correlations between IQ and inhibition (-.15) in AD/HD boys using the SST (Schachar *et al.*, 1995).

6.4.7. Section IV: Hyperactivity and task performance

This section addresses the research questions concerning the relationship between AD/HD and EF and delay aversion. Analyses presented within this section will use the factor scores derived from the previous section.

6.4.7.1. Associations between task factors and behavioural status

The EDF model assumes hyperactivity will impact on the executive and inhibitory skills, and the DA model predicts hyperactivity will impact on delay performance. It has been hypothesised that the critical association (whether delay/hyperactivity or executive/hyperactivity) should exist at both ages, and remain stable, or increase over time. A Pearson *r* correlational analysis was performed for each age group, using task factor scores and the composite parent ratings PHR and PCR in order to examine the relationship between task performance and behaviour status at different ages. Table 6.25 shows correlation coefficients indicating strength of associations.

Table 6.25. Associations between task factors and behavioural status

	Task factors	PHR	PCR
Age 3	**EFF/INH**	-.22	-.15
	DEL	-.34*	-.30
Age 5	**EFF**	-.11	.09
	DEL	-.41*	-.24
	INH	-.24	-.10

Note: PHR = parent hyperactivity rating; PCR = parent conduct rating; EFF/INH = executive/inhibition factor; DEL = delay factor; EFF = executive factor; INH = inhibition factor
* $p < .01$ (alpha adjusted)

Whilst hyperactivity was consistently negatively associated with task performance in all domains, for both age groups the significant associations were between PHR and DEL. This supported the predictions of the DA model and did not support the predictions of the EDF model. PCR was not significantly associated with task performance in any domain or factor. The results suggested hyperactivity, not conduct problems, is associated with delay task performance.

6.4.7.2. Explaining the independent contribution of predictors

Having examined the association between hyperactivity and task performance, it was of interest to assess the extent to which hyperactivity, and other child characteristics, accounted for variation in task performance. A multiple regression analysis was performed for each task factor with IQ, gender, PCR and PHR scores as predictor variables. The predictor variables were entered simultaneously to assess the independent contribution of each predictor whilst controlling for the others.

At age 3, the model was significant for EFF/INH ($F(4,60) = 11.70$; $p = .001$) with 44% of the variance explained, and was significant for DEL ($F(4,60) = 2.76$; $p = .04$) with 16% of the variance explained. Table 6.26 shows the individual contribution of each predictor within each model.

Table 6.26. Child characteristics as predictors of task factors at age 3

Task Factor		B	St.Error B	Beta	T	Significance
EFF/INH	**IQ**	.04	.01	.56	5.11	.00
	Gender	.51	.21	.26	2.40	.02
	Conduct	.18	.12	.17	1.46	.15
	Hyperactivity	-.14	.12	-.13	-1.16	.25
DEL	**IQ**	-.01	.01	-.07	-.55	.58
	Gender	.22	.27	.11	.82	.41
	Conduct	-.18	.16	-.16	-1.15	.25
	Hyperactivity	-.32	.15	-.28	-2.08	.04

Note: EFF/INH = executive function and inhibition factor; DEL = delay factor

At age 5, the model was significant for EFF ($F(4,79) = 4.16$; $p = .004$) with 17% of the variance explained, and DEL ($F(4,79) = 4.16$; $p = .004$) also with 17% of the variance explained. The model was not significant for INH ($F(4,79) = 1.29$; p = ns) with just 6% of the variance explained. Table 6.27 shows the individual contributions of each predictor within each model.

Table 6.27. Child characteristics as predictors of task factors at age 5

Task Factor		B	St.Error B	Beta	T	Significance
EFF	**IQ**	.03	.01	.36	3.48	.00
	Gender	-.10	.21	-.05	-.50	.62
	Conduct	.25	.16	.19	1.55	.12
	Hyperactivity	-.14	.13	-.13	-1.09	.28
DEL	**IQ**	-.00	.01	-.02	-.16	.87
	Gender	.04	.21	.02	.18	.85
	Conduct	-.05	.16	-.04	-.34	.74
	Hyperactivity	-.43	.13	-.40	-3.27	.00
INH	**IQ**	-.00	.01	-.05	-.48	.63
	Gender	.03	.22	.01	.13	.89
	Conduct	.04	.17	.03	.24	.81
	Hyperactivity	-.29	.14	-.27	-2.07	.04

Note: EFF = executive function factor; DEL = delay factor; INH = inhibition factor

Results showed IQ was a significant predictor of EFF/INH at age 3 and EFF at age 5, but not DEL or INH. Conduct problems were not predictive of any task factor at any age. Hyperactivity was predictive of DEL at both ages, but not EFF or EFF/INH. Gender was not a significant predictor except for EFF at age 3 and it has already been established that girls gained better EF task scores than boys at this age.

6.4.7.3. Linear and quadratic associations

As mentioned earlier there is a major debate as to whether hyperactivity should be considered to be a continuum or a discrete category. The continuous approach predicts linear associations between hyperactivity and task performance, but other relationships may exist and this has implications with regard to associations which may be evident in the extreme range. A curve fit analysis was conducted for each task factor to test for linear and quadratic associations, using PHR as the criterion variable.

Table 6.28. Linearity of task factors with hyperactivity at age 3

	Linear		**Quadratic**	
Task factor	***F*(1,63)**	**Sig.**	***F*(2,62)**	**Sig.**
EFF/INH	3.18	.08	2.02	.14
DEL	8.13	.01	5.08	.01

Note: EFF/INH = executive function factor including inhibition; DEL = delay factor

At age 3, the linear and quadratic trends were significant for the delay factor. It was therefore important to consider whether the quadratic trend offers a significantly better fit than a linear one. The contribution of a quadratic fit over the linear fit was computed as a regression equation within the curve fit analysis. Results shown in Table 6.29 indicated that fitting a quadratic curve did not significantly change the associative strength over-and-above the fit achieved with a linear trend (i.e., does not significantly change the beta weight). This implied that, for the younger children, the association between task performance and hyperactivity is best characterised as a linear one.

Table 6.29. The additional contribution of a quadratic trend

Task factor		B	SE B	Beta	t	Sig
EFF/INH	Linear	-.20	.14	-.18	-1.38	.17
	Quadratic	-.13	.14	-.12	-.93	.35
DEL	Linear	-.45	.14	-.39	-3.17	.00
	Quadratic	.20	.14	.17	1.38	.17

Note: EFF/INH = executive function factor including inhibition; DEL = delay factor

At age 5, the linear trend was significant for both delay and inhibition task factors, and the quadratic trend significant for the delay factor.

Table 6.30. Linearity of task factors with hyperactivity at age 5

	Linear		**Quadratic**	
Task factor	***F*(1,82)**	**Sig.**	***F*(2,81)**	**Sig.**
EFF	1.04	.31	.96	.39
DEL	17.02	.00	20.01	.00
INH	5.02	.03	2.61	.08

Note: EFF = executive function factor; DEL = delay factor; INH = inhibition factor

As before, the additional contribution of fitting a quadratic curve was investigated. Results shown in table 6.31 indicated that the quadratic trend is significant for DEL, and examination of the curve plots confirmed the association is stronger between delay aversion and hyperactivity at the extreme ends of the range. If the true relationship between delay performance and hyperactivity is U-shaped, and associations are stronger in the extreme range for older children, we may be confident that the results so far which have employed a median split on the PHR are conservative with regard to delay performance.

Table 6.31. The additional contribution of a quadratic trend

Task factor		B	SE B	Beta	t	Sig
EFF	Linear	-.18	.13	-.16	-1.33	.19
	Quadratic	.13	.14	.11	.94	.35
DEL	Linear	-.24	.11	-.22	-2.17	.03
	Quadratic	-.50	.11	-.44	-4.38	.00
INH	Linear	-.23	.13	-.21	-1.78	.08
	Quadratic	-.07	.13	-.06	-.50	.62

Note: EFF = executive function factor; DEL = delay factor; INH = inhibition factor

6.4.7.4. Identifying a clinically hyperactive group

To investigate differences which are only evident in the clinical range, the sample was split to create a clinically hyperactive (AD/HD) group (those children scoring 7+ on the SDQ) and non-hyperactive (control) group (those children scoring below 7 on the SDQ). The parent SDQ was used as it is a normed instrument where a score of 7 and above on the hyperactivity subscale places children in the abnormal (clinical) range of symptom severity, which specifically defines the group in a way that cutoffs on the composite parent rating cannot. Descriptive statistics for the AD/HD and control groups identified using this cutoff are presented below.

Table 6.32. Factor scores for AD/HD and control children at age 3

	Control (n = 53)				AD/HD (n = 14)			
Factor	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
EFF/INH	-1.72	2.06	.01	.99	-1.39	.81	-.53	.80
DEL	-2.16	3.78	.12	1.01	-2.58	.70	-.45	.97

Note: EFF/INH = executive function factor including inhibition; DEL = delay factor

Table 6.33. Factor scores for AD/HD and control children at age 5

	Control (n = 72)				AD/HD (n = 12)			
Factor	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
EFF	-2.54	2.74	.06	.93	-1.84	2.19	-.18	1.31
DEL	-1.98	1.81	.18	.78	-4.51	.81	-.96	1.49
INH	-2.77	1.60	.04	.98	-2.46	.97	-.35	1.06

Note: EFF = executive function factor; DEL = delay factor; INH = inhibition factor

To ascertain if differences between AD/HD and control task performance were statistically significant, a MANOVA was conducted with factor scores entered as the dependent variables, and PHR as the independent variable. Univariate *F* results are presented in table 6.34. Results showed significant group differences for DEL at both ages, suggesting children with extreme symptoms exhibited greater delay aversion. Group differences in EFF/INH were approaching significance for age 3 children but this was not significant for EFF at age 5, confirming the associations become more linearly related in older children. Interestingly, differences in INH were not significant at age 5, which indicated that the inhibition factor previously shown to be predicted by hyperactive status in the multiple regression is not associated with this categorical approach.

Table 6.34. AD/HD and control group differences in task factor scores

Age 3			Age 5		
Task factor	$F(1,63)$	**Sig.**	**Task factor**	$F(1,82)$	**Sig.**
EFF/INH	3.38	.07	**EFF**	.62	.43
DEL	4.31	.04	**DEL**	16.00	.00
			INH	1.60	.21

Note: EFF/INH = executive function factor including inhibition; EFF = executive function factor; DEL = delay factor; INH = inhibition factor

6.4.7.5. The sensitivity and specificity of tasks in predicting hyperactivity

The diagnostic value of the tasks (i.e., the degree to which the tasks can successfully predict AD/HD status) was examined for each age group using discriminant function analysis. Task scores were entered using a stepwise method (using the best predictor first). Table 6.35 displays weightings for each task which indicates the magnitude of the correlation between each task and the function derived for each age group.

Table 6.35. Table of weightings for each function

Age 3		Age 5	
Task	**Weighting**	**Task**	**Weighting**
DRT	1.0	**DRT**	1.0
Inhibition	.43	**ChD**	-.22
AF	.26	**Inhibition**	.16
WM	.18	**WM**	.02
ChD	-.16	**Planning**	-.02
Planning	.13	**AF**	-.01

Note: DRT = delayed response task; AF = attentional flexibility; WM = working memory; ChD = choice delay

Based on the respective functions, sensitivity indicates how well the tasks performed in terms of correctly rejecting non-AD/HD cases; it was calculated as the number of true positives/(false negatives + true positives). Specificity indicates how well the measures correctly identified genuine cases; it was calculated as the number of true negatives/(true negatives + false positives). Table 6.36 reports sensitivity and specificity for the test battery.

Table 6.36. Task battery as a predictor of AD/HD group membership

	Wilks Λ	**Significance**	**% Sensitivity**	**% Specificity**	**% correctly identified**
Age 3	.86	.00	71.4	77.4	76.1
Age 5	.79	.00	50.0	86.1	81.0

From the weights given in Table 6.35 it can be seen that the DRT/Cookie task was the strongest predictor of group membership for both age groups. Using the stepwise procedure, the inclusion of other tasks does not significantly increase the predictive power (i.e., no significant change in the Wilks' Lambda). This suggested that, within the task battery, no further benefit was achieved by considering the contribution of other tasks. However, this does not imply that the other tasks were not good predictors *per se*, but rather that they did not add any value in the task battery. It was of interest therefore to examine the extent to which individual tasks can predict group membership, and the discriminant function analysis was applied to each task individually.

Table 6.37. Individual tasks as predictors of AD/HD group membership at age 3

Tasks	Wilks' Λ	Significance	% Sensitivity	% Specificity	% Correct
Inhibition	.97	.14	78.6	45.3	52.2
WM	.97	.15	42.9	69.8	64.2
Planning	.95	.07	50.0	81.1	74.6
AF	.95	.07	85.7	45.3	53.7
DRT	.86	.00	71.4	77.4	76.1
ChD	.99	.38	42.9	67.9	62.7

Note: DRT = delayed response task; AF = attentional flexibility; WM = working memory; ChD = choice delay

For the age 3 group, the planning task performed only marginally less well than the DRT/Cookie task in terms of correct classification, but it was less sensitive and therefore generated larger numbers of false negatives (i.e., AD/HD children incorrectly classified as controls). Of the other tasks, the WM/Noisy book and ChD/teddies tasks also demonstrated poor sensitivity, and the Inhibition/puppet and AF/Blocks tasks had poor specificity (i.e., control children incorrectly classified as AD/HD).

For the age 5 group, the pattern was very similar to that at age 3 with regard to sensitivity and specificity, with the exception of the inhibition task which here demonstrated poor sensitivity instead of poor specificity. It may be concluded that the DRT/Cookie and WM/Noisy book tasks seemed to be most useful as predictors of AD/HD for both age groups as both correctly predicted over 80% of cases, but the latter 'misses' AD/HD cases. The AF/Blocks task remained the most sensitive, whilst the two delay tasks plus WM/Noisy book appeared most specific but erroneously identify non-AD/HD cases.

Table 6.38. Individual tasks as predictors of AD/HD group membership at age 5

Tasks	Wilks' Λ	Significance	% Sensitivity	% Specificity	%correct
Inhibition	.99	.71	33.3	66.7	61.9
WM	.98	.24	41.7	88.9	82.1
Planning	.99	.66	50.0	59.7	58.3
AF	.99	.59	83.3	31.9	39.3
DRT	.79	.00	50.0	86.1	81.0
ChD	.98	.17	33.3	72.2	66.7

Note: DRT = delayed response task; AF = attentional flexibility; WM = working memory; ChD = choice delay

6.4.7.6. The sensitivity and specificity of tasks in predicting conduct disorder

It has been established that AD/HD and CD are highly associated, perhaps reflecting the overlapping nature of their symptoms. Although conduct problems did not account for any significant proportion of the variance in task performance in the regression analysis, it was still of interest to independently assess how well the task battery predicted CD group membership. Consistent with the above procedure, a discriminant function analysis was performed for each age group using the SDQ cutoff which identifies children whose conduct scores place them in the abnormal or clinical range. From the table below it appears that unlike AD/HD, which is strongly predicted by a single task at either age, different tasks predict CD at different ages. At age 3 the DRT task is the strongest predictor as it is for AD/HD, and this may reflect the undifferentiated nature of the two constructs at this early age. At age 5, planning is now the strongest predictor of CD.

Table 6.39. Table of weightings for each function

Age 3		Age 5	
Task	**Weighting**	**Task**	**Weighting**
DRT	1.0	**Planning**	1.0
Inhibition	.44	**AF**	.20
AF	.29	**WM**	.13
WM	.22	**ChD**	-.10
ChD	-.17	**Inhibition**	-.05
Planning	.15	**DRT**	.04

Note: DRT = delayed response task; AF = attentional flexibility; WM = working memory; ChD = choice delay

Table 6.40. Task battery as a predictor of CD group membership

	Wilks' Λ	Significance	% Sensitivity	% Specificity	% correctly identified
Age 3	.90	.01	69.0	60.0	65.7
Age 5	.94	.03	44.8	70.6	50.0

Based on these functions, sensitivity and specificity was lower than for AD/HD, which indicated the tasks do not predict CD to the extent that they predict AD/HD.

6.4.7.7. Commentary

Overall, the evidence presented here clearly suggests that hyperactivity is associated with delay aversion rather than executive functioning. The impact of hyperactivity on delay task performance has been demonstrated regardless of symptom severity and comorbid conduct problems. Within a regression analysis which controlled for IQ, hyperactivity was not a significant predictor of executive task performance but it consistently predicted delay aversion at both ages. This critical finding appeared to support the DA model, but as hyperactivity was also a significant predictor of inhibition performance at age 5 there was partial support for the EDF model. However, as the model was non-significant for the inhibition task factor it is unsafe to consider a significant predictor within a non-significant model, and caution is advised in interpreting this particular finding. Additionally, the fact that hyperactivity did not predict executive performance at either age weakens this account in which disinhibition underpins executive performance.

The EDF model views AD/HD as a discrete disorder and would therefore expect associations to be evident only in the extreme/clinical range. No support for this assumption was found as the impact of AD/HD on executive task performance is not significant, even in the extreme range of symptom severity. On the contrary it was delay aversion that showed a U-shaped relationship with AD/HD status. This means the effects found using a median split are likely to have underestimated the impact of AD/HD on delay aversion and we may have confidence in the conclusions we have reached.

Within the task battery the DRT/Cookie task was most effective in predicting AD/HD. It compares favourably to sensitivity, specificity and correct identification values reported by Perugini *et al.* (2000) for CPT: 67%, 73% and 70% respectively, and those reported by Solanto *et al.* (2000) for SST: 66%, 72% and 68% respectively, and

Choice Delay task: 77%, 64% and 72% respectively. The variation in sensitivity and specificity of the other tasks is also congruent with the suggestion that additional tasks within a battery analysis results in reduced overall sensitivity despite increased specificity indicating an unimpaired score does not reliably rule out the disorder (Perugini *et al.*, 2000). Although the DRT/Cookie task also predicted CD in the younger children this may reflect the relatively undifferentiated nature of the constructs at this age. This suggests the decision not to control for CD in all analyses was appropriate as it may have filtered out salient aspects of AD/HD in these younger preschoolers. For older children the tasks which most efficiently predict AD/HD do not predict CD to the same extent.

6.5. Chapter summary

Several important findings have emerged from the various analyses presented within this chapter and these are as follows:

1) Hyperactive status was not predictive of executive performance when IQ was controlled for. The evidence does not support the central assumption of the EDF model which assumes EDF is an outcome of the behavioural disinhibition which underpins AD/HD. As the model views AD/HD as a discrete disorder, supporting evidence would only be expected in the clinical range. The fact that this was not the case severely undermines this account.

2) Hyperactive status was associated with, and predictive of, delay task performance. The evidence consistently shows AD/HD children have difficulties on tasks that

measure delay aversion, and this is predicted by AD/HD status. This critical finding provides robust support for the predictions of the DA model that assumes delay aversion underpins AD/HD.

3) The association between hyperactive status and delay performance was evidenced using both median split and extreme cutoff scores on behavioural measures, despite the evidence for stronger associations in the extreme range. This evidence supports the DA model that assumes delay aversion is an extreme expression of a naturally occurring behaviour. This suggests that AD/HD is not a categorical disorder, that impairment is evidenced at different levels of symptom severity. It also suggests that delay tasks are proportionately more difficult for those exhibiting extreme symptoms relative to those with lesser symptoms. This also confirms that evidence found using a median split has likely underestimated the effect of AD/HD and we may have confidence in the results.

4) Hyperactive status predicted delay performance even when conduct problems (which become more associated with hyperactivity with age) and IQ (which was more associated with hyperactivity than conduct problems) were controlled for. Given the evidence that CD may make a contribution to observed deficits through symptom overlap, and the possibility that CD may interact with and possibly change the nature of AD/HD, the finding that impairments are independent of CD further strengthens the DA account of AD/HD. That this dissociation is evident in the preschool children where, it is accepted, the disorders may not be so well differentiated is a powerful indicator of the uniqueness of the association. The fact

that IQ does not account for a significant proportion of the variance in delay task performance suggests the difficulty resides in motivation rather than cognitive aspects of behaviour.

5) The association between hyperactive status and delay performance was evident for males and females, and in both age groups. This suggests delay aversion is not a consequence of the early-occurring inhibitory deficits, nor a particular outcome of the gendered expression of AD/HD. It emerges as a distinct feature of AD/HD that is independent of gender and age.

6) Hyperactive boys appeared to be more delay averse than hyperactive girls. This offers some insight into why AD/HD boys are often viewed as having more inhibition problems than girls as their delay reduction behaviours may be erroneously attributed to inhibition failures where inhibition and delay reduction are not dissociated. If this reflects true gender difference it may also account for the higher proportion of males identified as AD/HD.

7) The delayed response task, which involves an element of inhibition as well as measuring delayed response, was found to be the best predictor of AD/HD. Given that both disinhibition and delay aversion are emerging as features of AD/HD that are independently associated with the disorder, it is unsurprising that the task which involves elements of both is the most powerful predictor.

8) The tasks which effectively identify AD/HD do not also identify CD at age 5. This indicates that in the preschool period CD and AD/HD become differentiated from each other. By age 5, the cognitive profiles associated with either disorder are distinct and can be independently assessed.

9) The association between hyperactivity and executive performance was carried on the inhibitory component. This supports the assumption of the EDF model that presupposes disinhibition underpins AD/HD. Clearly AD/HD children do have problems on inhibition tasks. However, the lack of any evidence for executive failures as a consequence of behavioural disinhibition questions the further assumption of EF deficits which are contingent upon disinhibition.

10) EF and inhibition were more closely allied in the younger preschool children. This suggests that these skills become more differentiated (i.e., fractionated) with increasing age.

11) IQ was associated with, and predictive of, executive performance and not inhibition or delay performance. This suggests IQ may be the important factor in EF skill development, and EF deficits may be attributed to IQ and not disinhibition as the EDF model assumes.

CHAPTER SEVEN: DISCUSSION

7.1. Introduction

This chapter aims to summarise the findings from both studies contained within the thesis. The findings will be considered in the context of the predictions of the EDF and DA models of AD/HD. It is proposed that the findings support the DA model, but offer little support for the EDF model. This raises a question regarding why the predictions of the dominant model of AD/HD are not upheld in this preschool population. Reasons for this will be discussed and the theoretical and practical implications will be examined

7.2. Summary of the main findings

Study One findings suggested the preschool children were naturally delay averse (i.e., there was a main effect of condition for two out of three out of three delay tasks). Age appeared to impact differently upon DA and EF, with no apparent age-related trend for DA but strong age effects for EF that followed a linear trend. Despite sharing this general trend towards better performance for older children, inhibition appeared to have a different trajectory to planning and WM suggesting a dissociation between inhibition and other EF skills. This was supported by weak associations between EF tasks and a similar pattern of associations at each age with WM and planning forming the strongest associations. Associations between delay tasks were not strong but the relationship between the EvD/penguin and VI Schedule/Squares was stronger in the older children, and these two delay tasks formed a single factor. The common feature of these two delay tasks appeared to be the continuous performance requirement that is better met by older children. EF and DA emerged as relatively independent of each other (i.e., there were no significant correlations between EF and DA tasks, and they loaded onto separate factors). IQ also impacted differently upon DA and EF; although IQ was not associated with EF task performance it was a significant predictor of EF when age was controlled for.

Study Two, which introduced an additional DA and EF task, also found weak associations between EF tasks but, unlike Study One, these associations were weaker in the older age group. This difference may be an artifact of the factor approach which finds different associations when other EF domains are represented, and gender specific analysis was conducted. In general it appeared that EFs were more closely allied in the younger preschoolers (i.e., the associations between EF tasks were stronger for the younger children and formed different factors at different ages). The fact that inhibition was separate from other EFs in the older children supports the findings from Study One that suggested a fractionation of EFs with maturation. Study Two also confirmed that AD/HD children were more delay averse than controls (i.e., there was a main group by condition interaction for the ChD/teddies and DRT/Cookie tasks) and boys appeared to be more delay averse than girls as measured by the ChD/teddies task, although there was no main effect of gender at the level of the factors. Crucially, AD/HD status was predictive of DA and not EF, although it did predict inhibition at age 5. This association was found for both sexes at both ages and was independent of CD and IQ. This association was not found for CD and this is supported by the fact that the task which best predicted AD/HD did not also predict CD to the same extent. As in Study One, IQ predicted EF at both ages and was not associated with AD/HD. These findings held using both median split and clinical cutoffs so did not appear to be a function of the dimensional approach. Contrary to expectations there was a non-linear association between DA and AD/HD whilst the EF-AD/HD association was linear. The findings reported here are likely to have underestimated the relationship between DA and AD/HD where a median split was applied to define group status.

7.3. The findings in relation to the Executive Dysfunction (EDF) model

This section reports on the findings in relation to certain predictions of the EDF model. Other predictions concerned with the uniqueness and independence of the relationships are dealt with separately.

Prediction: EF deficits will be present in preschool hyperactive children at age 3 and 5 as it is deemed the core feature of AD/HD.

There is no evidence for EF deficits in this preschool sample. Although EF performance was poorer in the AD/HD group generally there were no significant group differences in the multivariate analysis of EF task performance. The main assumption of the model has not been upheld.

Prediction: Inhibitory deficits underpin EF deficits and should be associated with EF deficits, in particular WM which the model holds as crucial to the functions within other executive domains.

The inhibition/puppet task was not significantly correlated with other EF tasks although there was a stronger (though non-significant) association between WM/noisy book and inhibition/puppet for the younger girls. For boys, WM was more associated with planning and AF than inhibition. This implies there is no strong relationship between these functions, and this questions the extent to which inhibition underpins EF skills. Although inhibition loaded onto the same factor in Study One, and for the younger children in Study Two, EF and inhibition were dissociated at age 5.

Prediction: Disinhibition is the central feature of AD/HD therefore will be associated with AD/HD

Inhibition task performance was not significantly correlated with hyperactivity ratings. However, for the age 5 group where the inhibition and EF factors were separate AD/HD was a predictor of the inhibition factor within the regression analysis.

Prediction: EF Deficits will emerge only in the clinical range

The EDF model views AD/HD as a categorical disorder it may be assumed that the relationship between AD/HD and EDF is evident in the extreme range of symptoms, and a median split analysis would mask these associations. This was addressed in two ways: firstly, the linearity of EF tasks with hyperactivity was assessed and evidence suggested a linear relationship characterised the relationship between EF and AD/HD and secondly, a clinical group were identified and subsequent analyses showed hyperactivity did not predict EF performance in the extreme range of symptoms. This poses a difficulty for the EDF model.

The overall picture that emerges shows that weak associations are found between inhibitory deficits and AD/HD in this young age group, with no relationship between disinhibition and EF deficits. Inhibition is closely allied to other EFs at age 3 (i.e., they load onto the same factor) and it is possible that poor EF performance observed in the AD/HD group was partly due to the inhibitory element of many executive tasks. This is demonstrated in the older group where the executive and inhibitory functions are more differentiated (i.e., load onto different factors) and AD/HD predicted inhibition, not EF, performance. These results suggest global EF deficits are not the inevitable consequence of inhibitory deficits as Barkley asserts. Partial support for Barkley's assumption of inhibitory deficits in AD/HD comes from the finding that AD/HD predicts inhibition at age 5.

7.4. The findings in relation to the Delay Aversion (DA) model

This section discusses the findings in relation to certain predictions of the DA model. Other predictions concerned with the uniqueness and independence of the relationships are discussed separately.

Prediction: Delay aversion will be present in hyperactive preschool children at both ages.

The delay task factor was significantly associated with PHR at age 3 and age 5. Also AD/HD is predictive of the delay factor in the regression analysis and this relationship hold for both age groups. This confirms that DA is a core feature of AD/HD in the preschool years. Although separate analysis of the ChD/Teddies task suggests the effect is carried on the boy's performance (i.e., boys, not girls, show delay averse characteristics), analysis using the combined delay tasks (i.e., the delay factor) shows gender is not a predictor of delay performance.

Prediction: As AD/HD is viewed as a continuum the association between AD/HD and DA will not be restricted to the extreme range of symptoms.

The association between AD/HD and DA is found using both median split and clinical cutoffs on the hyperactivity rating. It was expected that the relationship between DA and AD/HD would be linear but the findings suggest the relationship is better characterised as 'U'-shaped. This does not mean the continuum approach is not valid as there is no evidence to suggest hyperactivity is qualitatively different in the extreme range, only that problems may be exacerbated with symptom severity. However, it is surprising to find greater delay aversion in children who exhibit very few AD/HD symptoms relative to those who are rated as moderately hyperactive.

The picture that emerges is that AD/HD is associated with, and predictive of, DA. That this relationship is evidenced using both median split and clinical cutoffs, and holds for both sexes at both ages, and is significant even when IQ and CD are controlled for in the regression analysis, provides robust support for the DA model. It has been clearly demonstrated here that a motivational account of AD/HD can add considerably to our understanding of AD/HD, describing an early-emerging feature of hyperactive behaviour which cannot be accounted for by the EDF model.

7.5. The findings in relation to the independence of EF and DA

The EDF and DA models can be distinguished from each other in terms of genetic origins, the underlying psychological mechanisms, and their cognitive/motivational profile. These mutually exclusive accounts suggest that EF and DA will be distinct from each other. There was no association between EF and delay tasks at any age, and the tasks loaded onto separate factors in both studies and for all age groups. This suggests DA and EF are independent constructs that are both associated with AD/HD. This raises the question as to whether each model (a) accounts for a particular sub-type of AD/HD whose aetiologies may be different or (b) accounts for one aspect of AD/HD behaviour. As there was no investigation of AD/HD subtypes here, it is not possible to answer this question but reference to previous research on school children which suggested two factor (cognitive and motivational) components of impulsivity which may represent two distinct physiological pathways to the same overt behaviour (Kindlon, Mezzacappa & Earls, 1995) offers clues. If phenotypic impulsivity can have several different forms, and different aetiologies, it is useful to consider there may be more than one route into AD/HD and more than a single predetermined outcome.

Despite the independence of EF and DA there are other relationships that may exist. The DA model does not assume EF deficits but allows that they may be a developmental complication of early occurring DA. The findings suggest that this may not be the case. Delay tasks do not significantly correlate with EF tasks at either age, and delay tasks load onto a separate factor to EF tasks at each age. This dissociation would suggest that the relationship between DA and EF is weak and has no obvious developmental course. However, the fact that AD/HD status is predictive of the inhibition factor at age 5 suggests the possibility that disinhibition becomes a more salient for the older AD/HD child. It is interesting to speculate whether links between DA and disinhibition would emerge at a later stage of development (i.e., if children were tested at 7 years).

A related question concerns whether observed inhibitory deficits at age 5 are skills-based (as suggested by the EDF model) or performance-based (as suggested by the DA model). As the performance vs. skill distinction is primarily a theoretical one and in practical terms both would result in poor task performance, it was not possible here to establish whether observed deficits were skills-based or due to poor on-task behaviour. As other studies indicate performance can be improved with guidance and skills training and external cues, it is proposed that deficits are likely to be performance-based. It would have been useful to confirm this, but multiple (and equivalent) tasks would be required to assess performance under different conditions because familiarity with any single task would automatically improve performance. This was beyond the scope of the present study.

7.6. The findings in relation to the uniqueness of EF-AD/HD and DA-AD/HD

The DA model predicts holds that DA will be uniquely associated with AD/HD. No association was found between the delay factor and CD ratings, and AD/HD, not CD, was predictive of delay performance in the regression analysis. Given the significant correlation between PHR and PCR, the two derived behavioural ratings for hyperactivity and conduct problems, the fact that the relationship between AD/HD and DA is significant when CD is controlled for is especially important and does suggest the uniqueness of the association. Further support comes from the discriminant function analysis which showed a delay task (DRT/Cookie task) was the best predictor of AD/HD, correctly identifying 72% and 81% of cases in the age 3 and age 5 group respectively. This same task did not also predict CD to the same extent, identifying just 66% and 50% of cases in the age 3 and age 5 group respectively.

The EDF model holds that inhibitory deficits should be unique to AD/HD and not be associated with CD. It has been previously mentioned that AD/HD is a predictor of inhibition at age 5 only. However, there was no association between inhibition and CD, and CD itself was not a significant predictor of inhibition in the regression analysis. This is congruent with other research that finds inhibition tasks better predict AD/HD than aggressive behaviour disorders (Koojimans, Scheres & Oosterlaan, 2000) and does indicate the uniqueness of the association between AD/HD and inhibition, to the extent that such a relationship was only partially supported here.

A caveat to this conclusion is the lack of information concerning other comorbidities. Although CD is of particular importance being the most commonly co-occurring disorder and sharing many of the symptoms, any claim as to the uniqueness of any association must necessarily consider other common co-morbidities. In particular the literature does report inhibitory deficits in other disorders such as RD (Purvis & Tannock, 2000) disruptive disorders (Oosterlaan & Sergeant, 1998a; 1998b) CD (Oosterlaan, Logan & Sergeant, 1998) and TBI (Konrad *et al.*, 2000).

7.7. The findings in relation to existing EF literature

The findings of no EF deficits in this preschool population is at odds with the literature which consistently reports EF deficits in AD/HD children. A major question arises as to why this may be the case. Firstly, this may be attributed to developmental issues. The preschool EFs are not as distinct from each other as they are in middle childhood and EF deficits may not be so well evidenced in the younger group where executive skills are relatively under-developed. One would expect EF deficits in the older group where inhibitory deficits are confirmed in the younger group as the core inhibitory deficit would underpin executive deficits, but the fact remains that neither EF nor inhibitory deficits were confirmed for the age 3 group. AD/HD predicted inhibition at age 5 only and this suggests disinhibition is not so much a feature of preschool AD/HD as it appears to be in middle childhood. It is possible that disinhibition, and the associated EF deficits may not emerge at a later stage of development. However, the pattern of associations between inhibition and other EF tasks are stronger for the younger children and the findings from both studies support the notion of increasing fractionation of the EFs which no longer show the same degree of interdependence.

Secondly, studies reporting EF deficits typically identify a clinical AD/HD group and it is possible that EF deficits occur only in the extreme range of symptom severity consistent with this categorical approach. If this is the case, the use of a community sample may account for the lack of support for EF deficits. However, the extreme group analysis using a clinically-defined AD/HD group failed to show significant group differences for the EF factor, and suggested associations become more linearly related in older preschoolers. This suggests the lack of EF deficits in this sample cannot be attributed to symptom severity. A caveat to this conclusion is the aforementioned possibility that qualitative differences exist in a clinic-referred group. If the clinic-referred children differ systematically in ways other than symptom severity it is still necessary to replicate these findings in a clinic sample.

Thirdly, the lack of EF deficits may reflect the measures used. The EF tasks were adapted for use with preschoolers and this questions the extent to which they remain valid measures of EF. However, EF deficits in hyperactive preschoolers have been found using these modified tasks. Hughes, White and Dunn (1998) found deficits for planning using the ToL, but no WM deficit using their version of the 'Noisy book'. Mariani and Barkley (1997) have reported WM deficits using a range of WM measures but this study did not include girls.

On balance it appears that the finding of no EF deficits in the current sample is unlikely to be due to these explanations. The large sample size and the mixed gender groups allow confidence in the findings. As evidence for EF deficits in preschool hyperactive children is neither extensive nor consistent, it may be that EF deficits are not a feature of preschool AD/HD.

7.8. The findings in relation to preschool AD/HD

This study confirms that core AD/HD characteristics found in school-age and adolescent children are also found in preschool children. Assessment based on the same behavioural constructs applied to AD/HD school-age children also identifies

AD/HD preschoolers. This is consistent with evidence that parent-rated preschool AD/HD symptoms are correlated with behavioural and social problems (DeWolfe, Byrne & Bowden, 2000). The patterns of association are similar in profile and direction to that of older children. This indicates that measurement of hyperactivity in preschool children may usefully employ the same criteria.

Importantly this study has confirmed that DA exists in preschool hyperactive children, that it can be measured, and that it has at least as important a role as inhibitory failure which underpins the EDF model. The notion that a motivational aspect of AD/HD either co-exists or independently exerts its influence in early AD/HD opens up the possibility of more than one route into AD/HD.

When considering children's performance on inhibition tasks, the general rule is strong age effects. It is difficult to partial out the effects of maturation but the finding that the ChD/Teddies task and the DRT/Cookie task show no main effect of age indicates the advantage of temporal stability of these measures, which are therefore especially useful for the preschool population where development of self-control is rapid.

7.9. Limitations of the study

The previous sections have to some extent highlighted some limitations of the study (e.g., lack of information on comorbidities other than CD). This section considers further design or method limitations.

7.9.1. Using a cross sectional design

The use of cross-sectional design was a consequence of time limitation. In a developmental study the gold standard is longitudinal data, where changes over time are not confounded by cohort differences. A longitudinal study would allow for greater confidence in interpreting developmental change. Specifically it would be helpful to chart the individuals' trajectories of development to confirm what appears to be the fractionation of inhibition from EF. This would also allow sensitive consideration of the compensatory mechanisms which preserve executive functioning despite the original problem of disinhibition and delay aversion.

7.9.2. The preschool population

Participants in this study are all considered preschool as they are below school-entry age. However, being of preschool age does not equate with 'no school experience' and it became apparent throughout that there are diversities in the preschool child's experience. These experiences ranged from no formal activity outside the home through mother-and-toddler groups and crèche to nursery, playschool and formal preschool experience which, in some cases, was extensive (e.g., several days per week). It is sensible to assume these early differences would impact upon executive performance generally through exposure to formal problem-solving tasks. Moreover there have been several references to the fact that school entry is an especially difficult time for hyperactive children due to increased demands on cognition and behaviour, but the impact would hardly be the same for the child with extensive school-like experience. These differences should have been controlled for as it is logical to assume that hard-to-manage children are less likely to have preschool education because (i) they would find adjustment to a more formal environment difficult (ii) mothers are likely to avoid situations and events in which difficult behaviours ordinarily managed at home become a problem. Anecdotal evidence suggests attempts at preschool education can leave both parent and child unhappy and typical comments from Mum are 'They didn't know how to cope with X' or 'X got so upset I stopped him going' or 'I just think X is not ready for preschool yet' and perhaps the saddest of all 'They've labelled him a naughty boy but he's not that bad. I'm not sending him there any more'. This is quite sufficient to question the homogeneity of preschool learning experiences and, together with the known association between hyperactivity and family adversity/low income, it is probable that children with impoverished home environments are less likely still to have extensive preschool experience. It is worth noting that the participants in this study were IQ tested and learning experience and task familiarity would presumably be reflected in task component scores, but further research could usefully assess preschool experience to statistically control for this in the same way that IQ is treated.

7.9.3. The behavioural measures

A recurring theme throughout this research is the importance of considering the impact of comorbid disorders, and the importance of using multiple informants in the assessment of hyperactivity. The behavioural measures adopted rated conduct problems in addition to hyperactivity. It has been mentioned that CD appears to be the comorbidity that most significantly impacts upon, and interacts with, AD/HD and it is a strength of the study that CD was controlled for in the regression analysis. In this way the association between delay and hyperactivity was established independent of

CD. Additionally the finding that tasks which best predict hyperactivity do not also predict CD to the same extent confirms that AD/HD and CD are dissociable despite the content overlap in symptoms, which is consistent with the literature. However, the study would be further strengthened with more extensive information on a range of comorbidities.

The measures adopted should have allowed multiple-informant assessment, but the index of hyperactivity used for multivariate analysis was a composite of parent ratings on the behaviour rating scale and semi-structured interview. The loss of teacher ratings was regrettable given the aforementioned evidence for significant genetic and behavioural differences in teacher vs. parent rated hyperactivity. At best we may confidently assume that the composite rating reflected pervasive hyperactivity (e.g., across different activities and environments) and this means there has been no undue bias in favour of the DA hypothesis which predicts situation-specific behaviours. At worst there remains the possibility that children who were rated as hyperactive by teachers but not parents constitute an important sub-set whose problems are cognitive rather than motivational, and it may well be that this group are particularly likely to have EF problems.

7.9.4. The task battery

The study employed a single inhibition task. Although the task involved response inhibition as do the most widely used measures of impulsivity (e.g., SST, Reversal tasks) it does not assess the inhibition of an ongoing response. Also, different forms of inhibition have been distinguished as interference control, cognitive inhibition, behavioural inhibition and oculomotor inhibition (Barkley, 1997a; Nigg, 2000) and further research should employ tasks which represent these four distinct aspects of inhibition to assess the extent to which the findings generalise to other definitions of inhibition not targeted by the Puppet task. Studies which have employed multiple inhibition tasks have found cognitive disinhibition does not always manifest overt behavioural impulsivity (Olsen, Schilling & Bates, 1999) and utilising a single measure invites the criticism that disinhibition, the focus of Barkley's model, was not fully explored.

It was intended that there would be three delay measures entered into the analyses. The fact that the EvD/Penguin task did not function well as a measure of delay aversion was disappointing and although the reason for this is unclear we speculate that this may be due to the continuous performance requirement of the task. It is known that CPT tasks (typically used as measures of sustained attention) in general correlate poorly with other measures so the low correlation between it and other the delay tasks is unsurprising, but as a rule the test-retest reliability is high (Corkum & Siegel, 1993) which was not the case here for the critical PRD condition. Corkum and Siegel's review offers some insight as they assert CPT are especially sensitive to external variables which affect response engagement and vigilance. It is possible to assume that task performance was hindered by particular attentional demands inherent in the task which were exacerbated by the lack of control the experimenter had over the testing environment. It is interesting to speculate whether identification of AD/HD subtypes, or screening for attentional problems would alter this result. The additional finding that the task did not correlate highly with hyperactivity ratings was more serious and would appear to support Corkum and Siegel's assertion that CPT may not be a suitable tool for AD/HD research. These problems meant it was no longer suitable for inclusion in the final analysis, which resulted in fewer than optimum numbers of variables being used in the factor analysis. In future research it would be advantageous to consider other experimental paradigms to develop age-appropriate measures of delay.

The inevitable confound in all research of this nature is the content overlap of the measures. Task measures are invariably multifaceted and a salutary lesson is learned when one considers the extent to which a single experimental paradigm (SST) has been used to support Barkley's model. It has been demonstrated here that even a simple task such as the DRT involves both inhibitory and delay elements. The efficacy of the task as a measure of delay aversion may to some extent explain why DoG tasks comprise a separate dimension of impulsivity (Kochanska *et al.*, 1996; Olsen, 1989) and it is vital that future research carefully considers the operationalising of a behavioural construct and the degree to which a measure taps that construct alone.

7.9.5. Gender differences

The issue of gender in hyperactivity is confused in all except the proportion of girls and boys identified as hyperactive. Perhaps because of the larger numbers of boys diagnosed, many studies do not include girls at all. Some researchers consider female AD/HD to be qualitatively different to male AD/HD (Olsen, Bates & Bayles, 1990) and this questions the usefulness of a mixed gender experimental group (e.g., presumed deficits may be gender specific and testing both girls and boys would cancel each other out). This would be particularly unfair to Barkley whose model does not account for the inattentive sub-type more associated with female AD/HD. However, studies that used similar measures to those employed here do report performance deficits for both girls and boys, and so girls were included in the current study. The investigation of sex differences was not a stated aim and any analysis by gender was opportunistic which is not ideal. In particular it is regretful that in Study One the normative development could not be considered for boys and girls separately due to small numbers. Where gender analysis was indicated, results suggest there are some differences. In particular it appeared that only boys were delay averse as measured by the ChD/teddies task. However, there are such similarities in the patterns of association for boys and girls that the writer favours the conclusions drawn by Biederman *et al.*, 1999) who assert that AD/HD symptoms are prototypic. If this is the case then taking a motivational perspective may account for gender differences in the expression of AD/HD which is consistent with gender socialisation theory. In particular it has been suggested in Chapter One that aggression is the behaviour that carries the greatest risk for continued problems in hyperactive boys and may even account for the gender differences in referral rates. This particularly virulent form of AD/HD is associated with family characteristics such as parenting style, familial physical and verbal aggression, and maternal depression (Stormont-Spurgin & Zentall, 1995).

7.10. Implications of the study

7.10.1. Theoretical

The findings highlight the importance of considering the motivational aspects of AD/HD that are largely ignored by the EDF model. The DA model is not the only model that seeks to explain motivation in AD/HD but it subsumes to a large extent different motivational characteristics described by other motivational accounts (e.g., sensation-seeking, temporal sensitivity, shorter reinforcement gradients). However, the EDF model cannot be itself ignored. Whilst no support was found for early-occurring and enduring EF deficits there is some support for disinhibition in older preschool AD/HD children which hints that the EDF model has some value for school-age AD/HD. It can be said that neither model can fully account for the complex nature of AD/HD, and both appear to be sound theoretical accounts of a particular AD/HD characteristic. In this case it is inappropriate to view these models as competing and the logical way forward is to synthesise the two accounts. During the course of this research the continuing development of the DA model has seen its evolution from a single model to a dual route model (Fig. 7.1.) which represents a synthesis of the EDF and DA models. The dual-route model describes two independent pathways. One pathway, identified by the solid line in the model, is consistent with Barkley's account of cognitive and behavioural dysregulation arising from poor inhibitory control. The second, represented as a broken line in the model, is consistent with Sonuga-Barke's assumption of delay aversion arising from an altered reinforcement mechanism and environmental factors.

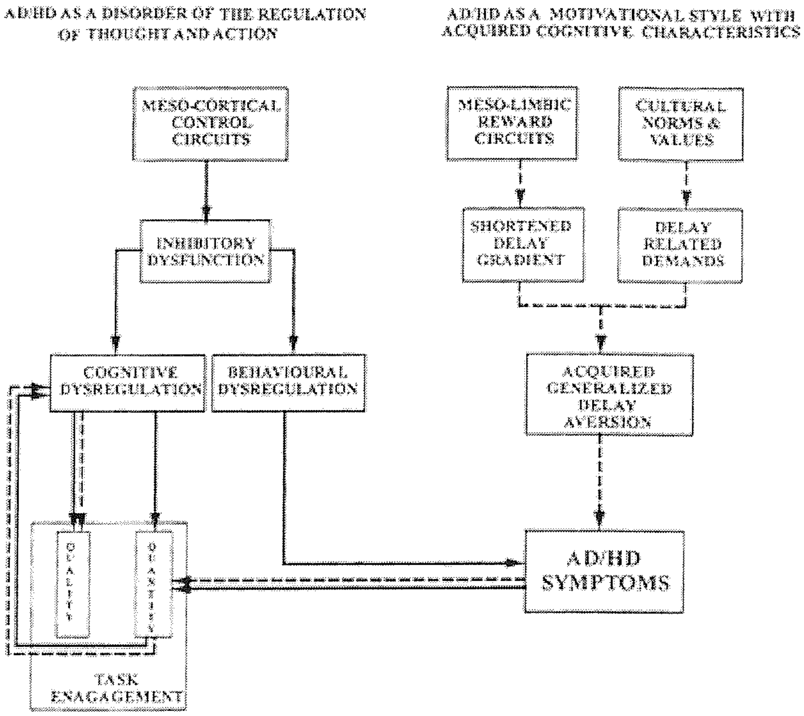

Fig. 1. A schematic representation of the dual pathway model of AD/HD. The solid line represents the pathway for AD/HD as a disorder of the regulation of thought and action. The dashed line represents AD/HD as a motivational style.

Figure 7.1. A schematic representation of the dual pathway model of AD/HD. The solid line represents the pathway for AD/HD as a disorder of the regulation of thought and action. The broken line represents AD/HD as a motivational style. Sonuga-Barke (2002), BBR, Vol 130. Reprinted with permission from the author.

The two pathways describe two distinct AD/HD sub-types: the first is associated with a categorical approach and generalised cognitive impairment, the second associated with continuously distributed symptoms and specific impairment of temporal cognitive functions. However, the pathways are not mutually exclusive as is possible that the independent routes may act in tandem, and the distinction is one of process. A particular strength of the model is that both pathways may interact to produce cognitive dysregulation.

The model implies that the search for a single psychological mechanism, a 'grand theory' is not useful as this cannot be achieved if more than one route into AD/HD exists. Similarly, the model suggests neurobiological research may usefully focus on two separate dopamine receptors: D1 (regulating prefrontal activity) and D2 receptors (involved in reward processes). In the model there is no direct link between EF and AD/HD symptoms and this is congruent with current research that finds stronger links between AD/HD and inhibitory control and weaker links between EF and AD/HD. As much of the support for inhibitory deficits comes from the SST, it is possible that such deficits arise from inter-stimulus interval effects (i.e. are an artifact of the temporal structure of SST). In this case the SST represents a specific context in which delay averse behaviour results in apparent disinhibition.

As neurological deficits are supposedly universal whereas motivational problems may be impacted upon by cultural differences in parenting, education and environment, this model creates a framework in which cross-cultural predictions may be tested and also gender differences which reflect within-culture differences. The gender issue is critical because although male and female AD/HD appear to be similar, AD/HD females are underidentified but they are equally, if not more, at risk and are overrepresented in adult samples compared to pediatric samples (Biederman *et al*, 1995). The increased risk to AD/HD boys of an antisocial family environment (Faraone *et al*, 1995) suggests the investigation of cultural and familial environment would be helpful basis on which to examine gender differences.

7.10.2. Diagnosis

The DSM IV diagnostic approach has been criticised for failing to take into account the impact of context and development, and specifically that it ignores the possibility that *under some circumstances and for some children* AD/HD behaviours may constitute adaptive behaviours that become maladaptive in certain settings (Jensen, 2000, p195). This study offers full support for this criticism.

AD/HD symptoms are experienced by the parent and toddler in the preschool years. The exclusivity and adaptability of the home environment means the public are rarely exposed or inconvenienced, and this situation changes dramatically on school entry. Contrary to expectation the school entry year is not a 'great leveller' and any skills gap inevitably widens throughout school life. The low academic achievement associated with AD/HD has a profound effect on both child and society and it follows that early diagnosis is highly desirable. This study has shown that the characteristics which define AD/HD in older children are present in preschoolers and are amenable to measurement. Simply put, AD/HD is not qualitatively different in the preschool years. This is consistent with previous findings using a range of rating scales, but it is pleasing that the concise and easy-to-use SDQ has performed well and the clinical tool adapted for the preschool population has shown good reliability and validity. The NIMH conference indicated that a critical time for assessment is before the age of 6 years after which time primary prevention may be too late. Clearly there is a need for diagnostic measures that are suitable for preschoolers. The DRT/Cookie task has shown good sensitivity and specificity and appears to be promising as a diagnostic tool. It has the added advantage of being quick to administer, and may be a useful addition to a test battery.

7.10.3. Treatment

In relation to treatment two questions are raised: Firstly, do the findings offer some indications as to why traditional forms of treatment are not always effective, and secondly, would delay-related therapies be effective.

Much research has considered why different forms of treatment, especially methylphenidate (Ritalin), do not appear to offer improvements beyond the core symptoms. The finding of specific context-dependent deficits supposes that interventions could be targeted at specific problem areas rather than apply a one-size-fits-all approach, and resources could be allocated to improving particular weaknesses. The current situation in America which has seen a 35% increase in prescription drugs for AD/HD (20 million prescriptions in 2000) over the last 5 years has caused great concern and several states have legislated to ensure AD/HD referrals are medical not school-based, and approved resolutions for non-medical interventions for behaviour problems (Daly, 2001). There is clearly a suspicion that drugs are being used for behavioural control rather than treatment and it is crucial to address the public concern and find ways of improving the efficacy of behavioural interventions.

The notion of a motivational pathway indicates the usefulness of psychosocial interventions. Genetic studies described in Chapter Two which suggest heritability as high as 90% for AD/HD would seem to counter this but as Rutter and Plomin (1997) point out, even where genetic influences are great there is room for environmental manipulation which alters the expression of the gene. So why do psychosocial interventions show such modest achievements? Despite the NIMH claim that they offer little over-and-above the use of medication, Jensen (2000) points out that where psychosocial intervention and medication are offered together this often results in lower maintenance dosages which is highly desirable. Of the intervention studies reported in Chapter One, it is of special interest that successes are claimed for executive skills training, classroom intervention and parent training for the preschool population. Where intervention has not been successful in this age group, Barkley *et al.* (2000) points out that failure has been largely due to parent non-compliance. This would indicate preschool children are particularly amenable to treatments of this kind, and it is extremely important that reported improvements extend to areas which are relatively unaffected by drug therapy such as mother's wellbeing (Sonuga-Barke *et al.*, 2001). Such interventions could be more effective if delay averse characteristics are taken into account, and more effective still if preschoolers were targeted so the cycle of reinforcement can be broken before the problems are exacerbated by the demands imposed on school-entry.

There is no doubt about the excessive burden placed on the NHS by the large numbers of AD/HD children being referred. Psychosocial therapies are often unattractive because they are costly and labour-intensive. An interesting development in the New Forest is the provision in the community of clinics for preschool children with behavioural problems. These clinics are run by Health Visitors and serve to alleviate the burden on psychiatrists by allowing early risk assessment. Such clinics would be the ideal forum for the delivery of delay-related therapies.

7.11. Directions for future research

A typical feature of research is that more questions are raised than answered. There are many useful ways to expand upon the present research but the immediate requirements are the application of delay measures in a longitudinal design.

7.11.1. The development of delay measures

The question as to why the effortful performance measure was not successful as a delay task remains unanswered here, but it is likely that the continuous performance element of the task presents particular difficulties for very young children. The efficacy to two measures derived from the DoG paradigms has been established. The DRT/Cookie task involved the witholding of a response until a signal whilst the ChD/teddies task did not require this inhibitory element as the action of choosing involved only a consideration of the delay imposed. In this sense different forms of delay behaviours have been assessed in both choice and no-choice situations. The DRT/Cookie task appears to be especially suitable for assessment of delay aversion in preschoolers. Following the example of Mischel and colleagues who find that self-control is contingent upon what occurs during the delay period, it would be interesting to use this task to examine whether different strategies are employed by AD/HD children, and whether the known variables which impact upon children's performance also impact upon AD/HD children in the same way.

7.11.2. Longitudinal study

The developmental issues raised in this thesis are confounded to some extent by cross-sectional data. Although age-related changes are discussed the age group data come from different children. It would be valuable to address the developmental issues using a longitudinal design which is the gold standard in developmental research. A prospective study which followed preschoolers through school entry would need to address the limitations set out in this chapter and include the following: (i) parent and teacher assessment, (ii) identification of subtypes, (iii) assessment of comorbidities, (iv) gender groups within each subtype, and (v) assessment of preschool learning experiences as well as IQ

This thesis has examined the relationship between EDF, DA, and AD/HD. Although EF deficits were not found it was noted that hyperactive children generally performed less well on the EF tasks then control children. It would be of interest to examine the extent to which disinhibition and DA account for executive failures. The logical next step would be to incorporate delay as a dependent variable in EF task performance. For instance, in the ToL there could be a delay imposed after presentation of the goal state and before responding. As inhibition would impact equally on delay/no-delay conditions, any differences would clearly implicate delay independently of inhibition *within the same task format,* which would provide a robust assessment of DA controlling for inhibition.

7.12. Concluding statement

This study is one of the few that examine the predictions of both cognitive and motivational models of hyperactivity in the preschool population. The development of age-appropriate tasks was challenging but, when achieved, their application has given clear results that offer very limited support for EDF model and strong support for the

DA model. The consistent and enduring impact of delay aversion has been firmly established and the importance of motivational accounts of AD/HD is highlighted, culminating in a synthesis of cognitive and motivational accounts in a dual route model.

Research does not happen in a vacuum, and this study was undertaken at a time when the popular view of AD/HD was one of dysfunction. This word has harsh implications with regard to sub-normal functioning, poor outcomes and drug therapy, and offers little to the child or parent that is optimistic or encouraging outside the comfort of a label and blamelessness. The personal motivation underpinning this research was the conviction that AD/HD can be viewed, and therefore managed, differently. In demonstrating the adaptive nature of AD/HD behaviour the first steps towards a more comprehensive account of AD/HD is achieved.

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Appendix i

Information and consent form for parents of children aged 5 years

Dear Parent

At Southampton University we are conducting research into the development of cognitive (thinking) skills in young children. We are especially interested in skills which emerge around age five.

As your child has reached the age where such skills as planning are rapidly developing, I am taking this opportunity to ask if you would allow your child to take part in a current study which is designed to investigate the relationship between thinking and behaviour.

Participation in the study means selected children will be tested using seven tests which are modified children's games. These tests take approximately 90 minutes in total (with frequent breaks) and are administered in school, with the emphasis on fun games and enjoyment of the children. This is followed by a short home-based interview with you, the parent, to assess the general behaviour of your child.

If you agree to your child taking part in the study, would you please complete the consent form below and return it to the class teacher.

Due to time constraints, giving consent at this stage does not mean your child will automatically be involved in this study. This is no reflection on your child or his/her capabilities.

Thank you for your co-operation which we rely on to advance our research.

Yours sincerely

Lindy Dalen BSc.

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CONSENT FORM

Name of parent   Telephone no.:

Name of child: Child's Date of Birth:

I give consent for my son/daughter* to participate in this study and am willing to be contacted to arrange an interview

* please delete as appropriate

Signed..   Date......................................

YOU HAVE THE RIGHT TO WITHDRAW CONSENT AT ANY TIME DURING THE STUDY
ALL RESULTS WILL REMAIN ANONYMOUS

Appendix ii

Information and consent form for parents of children aged 3 years

Dear Parent

At Southampton University we are conducting research into the development of cognitive (thinking) skills in preschool children. We are especially interested in skills which emerge around age three.

As your child has reached the age where such skills as planning begin to develop, I am taking this opportunity to ask if you would allow your child to take part in a current study which is designed to investigate the relationship between thinking and behaviour.

Participation in the study will involve testing children in the nursery/preschool environment using several modified children's games, plus a short home-based interview with the parent (usually Mother). The test session takes approximately 90 minutes with frequent breaks, and the emphasis is on fun for the child.

If you agree to your child taking part in the study, would you please complete the consent form below and hand it to your health visitor at the time of the three-year health check.

Thank you for your consideration, which we rely on to advance our research. We are most grateful for your participation.

Yours sincerely

Lindy Dalen BSc.

....

CONSENT FORM

Name of parent   Telephone no.:

Name of child: Child's Date of Birth:

I give consent for my son/daughter* to participate in this study and am willing to be contacted to arrange an interview

* please delete as appropriate

Signed..   Date.......................................

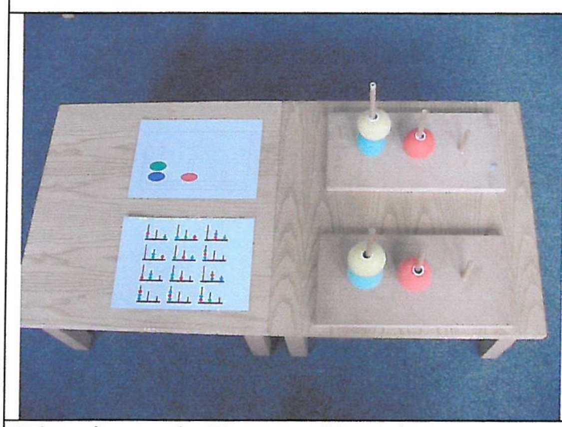
YOU HAVE THE RIGHT TO WITHDRAW CONSENT AT ANY TIME DURING THE STUDY
ALL INFORMATION WILL REMAIN ANONYMOUS

Appendix iii

Photographs of the executive function tasks

Inhibition task: Puppet says…

Working memory task: Noisy book

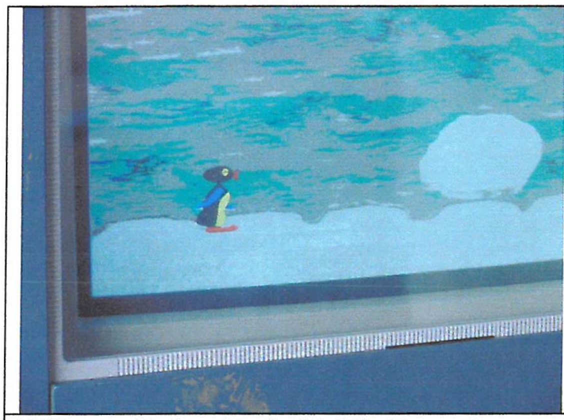


Planning task: Tower of London

Attentional flexibility task: Block sorting

Appendix iv

Photographs of the delay tasks

	
Effort v. Delay Task (EvD): Penguin game	Choice Delay Task (ChD): Teddies game
The computer screen shows a grey square on a coloured background. The background colour signalled the condition (blue = dense reward; yellow = less dense reward). Rewards were pictures of cartoon characters that flashed on screen for 5 seconds.	
Variable Interval (VI) Schedule: Squares game	Delayed Response Task (DRT): Cookie delay

Appendix v

Publications arising from the thesis: Abstract of a journal article

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Are Planning, Working Memory, and Inhibition Associated With Individual Differences in Preschool AD/HD Symptoms?

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Dave Daley, and Bob Remington

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The association between executive function (EF: planning, working memory, and inhibition) and individual differences in symptoms of attention deficit hyperactivity disorder (AD/HD) was explored in a sample of preschool children. One hundred sixty children (between the ages of 3 years, 0 months and 5 years, 6 months), selected so as to oversample high AD/HD scorers, performed 3 tasks previously shown to measure planning (Tower of London), working memory (Noisy Book) and inhibition (Puppet Says...). EF measures were reliable (k>.77) and were correlated with IQ (rs >.38) and age (rs = .59). Once IQ and age were controlled, planning and working memory (r = .41) were correlated. Planning and working memory were not correlated with inhibition (rs = .20). There was no association between ADHD and working memory or planning (rs = .12). There was a significant negative association between ADHD and conduct problems and inhibition (r = -.30 and r = -.25, respectively). Only the link with ADHD persisted after the effects of other factors were controlled for in a multiple regression. Specific deficits in inhibitory control rather than general EF deficits are associated with ADHD in the preschool period. This association is linear in nature, supporting the idea that ADHD is better seen as a continuum rather than a discrete category. This association provides evidence for Barkley's (1997) view that ADHD is underpinned by inhibitory deficits in the preschool period.