Background

Attention Deficit Hyperactivity Disorder (ADHD) is a common condition affecting 3-5% of school aged children and is characterised by pervasive impairments in attention, hyperactivity and impulsivity. Impaired working memory (WM) has emerged as a key focus of ADHD research and seems likely to make a contribution to the difficulties faced by these children (Kempton et al., 1999; Martinusson, 2005; Rhodes et al. 2004, 2005; Willcutt at al 2008). A popular theoretical model (Baddeley and Hitch, 1974; Baddeley, 1986) has identified several features of WM, including components where information is maintained in memory and a ‘central executive’ which is involved in the control and manipulation of the information stored within these subsystems. Unfortunately studies examining WM in children with ADHD have mostly used complex neuropsychological tasks that rely on multiple cognitive processes making it impossible to determine whether the observed impairments relate to deficits in the storage or executive components of WM or both. Research in this area has almost exclusively focused on describing impairment in ‘executive’ aspects of WM but studies have used tasks that typically tap both ‘executive’ and ‘non-executive aspects’ (i.e. maintenance of information) of WM. Karatekin (2004) examined cognitive functioning in ADHD in relation to the WM components model but only investigated memory load and divided attention and did not assess the ability to manipulate information in WM.

We previously conducted the largest study of cognitive functioning in children with ADHD that have not previously been exposed to stimulant medication (Rhodes et al., 2004; 2005; 2006; Coghill et al., 2007). Children with ADHD were impaired on an ‘executive’ task of spatial WM and on 4 ‘non-executive’ tasks when compared with healthy control children (Rhodes et al., 2004, 2005). Our previous research suggests that the ability to manipulate information is impaired in ADHD but that this deficit is not re-mediated by methylphenidate (a.k.a. Ritalin, the treatment-of-choice for ADHD). This research also suggested that ‘non-executive’ aspects of memory functioning, such as the ability to maintain information in WM, are core impairments in ADHD. Indeed, children with ADHD were impaired on a range of ‘non-executive’ aspects of memory functioning, including delayed matching to sample, spatial span, and on spatial and pattern recognition memory tasks. Importantly and in contrast to the findings on the more complex manipulation task, methylphenidate selectively improved maintenance of information in WM on several of these tasks (Rhodes et al. 2004, 2006, Coghill et al., 2007). These data therefore suggest that the deficits in maintenance and manipulation may be separable and the possibility that the deficits on the “executive” task could be secondary to deficits in non-executive retention aspects of memory.

Unfortunately it was not possible to be more certain of these conclusions due to several factors inherent in the design of the previous study. The executive spatial working memory task we employed is a relatively complex task and taps both the ability to maintain and manipulate information and therefore impairment could reflect either ability. These impairments and effects of methylphenidate described above were shown across separate tasks making it difficult to directly compare the abilities to maintain and manipulate information in WM and tasks also varied in a number of other aspects. A key objective of the present study therefore was to characterize WM functioning in ADHD using tasks specifically designed to assess the components of WM. A set of standardized neuropsychological WM tasks were also included providing a comprehensive assessment of WM abilities in ADHD.

Recruitment to our previous study (Rhodes et al. 2004, 2005, 2006; Coghill et al. 2007), of children who were first time referrals to a regional Child and Adolescent Mental Health Service (CAMHS), revealed that only 24% of the sample met criteria for ADHD alone. More than two thirds of the sample (69%) also met criteria for oppositional behaviour disorders,
classified within diagnostic systems (DSMIV/ICD10) as oppositional defiant disorder (ODD) and conduct disorder (CD). Oppositional defiant disorder accounted for a particularly significant proportion (41%) of this co-occurrence. Epidemiological (see Angold et al., 1999 for meta-analysis), clinical (e.g. Biederman et al. 1996; Rhodes et al., 2004) and family genetic studies (Faraone and Biederman, 1994) have all documented high rates of ADHD co-occurring with oppositional behaviour problems. This high co-occurrence raises the question of the specificity of observed neuropsychological impairments to ADHD and whether impaired WM reported in children with ADHD is actually associated with the ADHD symptomatology or the oppositional behaviour problems? As far as we are aware no study to date has included WM tasks as part of their assessment of cognitive functioning in ODD/CD. Studies assessing other aspects of related executive functions e.g. inhibition, in children with ODD/CD in the absence of ADHD have produced inconsistent results; with some reporting impairment (Oosterlaan et al., 1998, Toupin et al., 2000) and others reporting no impairment in ODD/CD (Scheres et al., 2001; Oosterlaan et al., 2005). Studies employing executive functioning tasks other than inhibition are extremely limited and report similarly inconsistent findings; one study reported that children with CD are impaired in planning, attentional flexibility, and verbal fluency (Toupin et al., 2000) while another reports no impairment on similar tasks in the absence of ADHD (Oosterlaan et al., 2005). A further objective of the present study therefore was to undertake a comprehensive assessment of WM in ODD with and without a diagnosis of ADHD.

- **Objectives**
  
  The first objective of the present study was to systematically characterize verbal and spatial executive and non-executive aspects of WM functioning in children with ADHD using a comprehensive set of specifically designed and standardized neuropsychological tasks. The second objective was to compare WM functioning in children with ADHD with children with ODD (with and without ADHD) to address the important unanswered question in the literature as to whether all aspects of WM impairment in ADHD are attributable to ADHD symptoms or whether any aspects are associated with oppositional behaviour problems. The project aimed to provide important knowledge about cognitive functioning in children with ADHD and ODD - description of which is crucial for the identification of the causes and mediators of problem behaviour associated with these conditions. We have fully met all of these objectives as described in the method and results below.

- **Methods**

  **Ethics**
  
  A medical ethics application was submitted and approved by NHS Fife and Forth Valley (11th April 2007), enabling recruitment of the 3 clinical groups and the typically developing (TYP) group. An additional ethics application was submitted and approved by Stirling (4th May 2007) and Perth Councils regarding TYP children as recruitment was conducted through local authority schools.

  **Participants: Assessment**
  
  123 children undertook full clinical assessment: 93 clinical boys and 30 TYP boys aged 7-13 years. Participants for the ADHD, ADHD + ODD and ODD groups were recruited from male out patients referred to the Developmental Psychiatry Team at the Tayside Child and Adolescent...
Mental Health Service (CAMHS). As we have previously reported evidence of tolerance to methylphenidate on cognitive tasks (Rhodes et al., 2004) only children who were drug naïve were invited to participate in the study.

Clinical Assessment

Clinical children: Parents of referred children completed the Strengths and Difficulties Questionnaire (SDQ, Goodman 2001) parent version in line with standard clinical practice. Children who had a T-score greater than 65 on either the hyperactivity and/or conduct scales of the SDQ were considered to be potential participants and were given detailed information sheets. Following this an initial baseline appointment was made for parents and children who wished to participate and the purpose and procedures of the study were further explained as required, informed consent was obtained from a parent or legal guardian and assent obtained from the participant. Children and their parents were interviewed by an experienced child and adolescent mental health clinician using the Kiddie Schedule for Affective Disorders and Schizophrenia for School Aged Children- Present and Lifetime version (K-SADS-PL) a semi-structured diagnostic interview, and the clinician also conducted The Child Attention-Deficit Hyperactivity Disorder Teacher Telephone Interview (CHATTI) a validated telephone teacher interview tool for the diagnosis of ADHD (Holmes et al. 2004). Current and previous school reports were also inspected wherever possible. The collated information from all assessments was reviewed by an experienced child and adolescent psychiatrist who had not participated in the assessment thus far, who also met with the family and confirmed the diagnosis. Diagnoses were made according to DSM-IV criteria (APA, 1994). Children with DSM-IV diagnoses of ADHD, ODD or ADHD + ODD were considered eligible to continue in the study. Participation in the study did not delay the initiation of treatment within the clinical groups.

Typically developing control group (TYP): Children were recruited from local school(s) in the Stirling and Perthshire areas. Children whose parents consented for them to take part and who themselves had given assent were screened for psychiatric symptoms using the SDQ and interviewed with the K-SADS to confirm that the child was not suffering from any DSM-IV mental or behavioural disorder. Symptom free children (T-score<60 on all subscales of the SDQ; Conners’ CPRS-27, and CTRS-28) who were not suffering from any DSM-IV mental or behavioural disorder, who fulfilled the other inclusion criteria and did not meet any of the exclusion criteria (see below) were matched with the clinical participants for age, sex, and IQ and asked to participate in the study.

All children

Parents of all participating children in the study (clinical and control groups) were asked to complete the Conners’ Parent’s Rating Scales, (CPRS-27) and teachers were asked to complete Conners’ Teacher’s Rating Scales (CTRS-28) and the Strengths and Difficulties Questionnaire (Goodman 2001) teacher version. All children were assessed on the British Picture Vocabulary Scale (BPVS, Dunn 1997), a measure of verbal IQ following the K-SADS interview. This vocabulary scale is chosen over traditional IQ tests to avoid confounding with measurement of executive functioning. An ANOVA revealed a significant difference in BPVS Percentile Rank (PR) scores between the clinical groups and TYP group (see Table 1). This was expected from our previous study and in line with previous research BPVS PR scores were included as a covariate in all analyses. A deprivation category score was calculated for each child based on their home postcode giving a measure of socioeconomic status. The deprivation category scores differed across groups (see Table 1). The exclusion criteria for participation in the study in either
the clinical or control group included: current or previous history of post traumatic stress disorder (PTSD), major depressive disorder, bipolar disorder, pervasive developmental disorder, psychosis, seizures, neurological disorder, history of alcohol or drug abuse, major vision problems.

Participants: Demographic Information
Completed datasets were achieved for 21 children in the ADHD group, 27 in the ADHD + ODD group, 21 in the ODD group, and 26 in the TYP group. The final sample sizes are more than adequate in relation to power calculations based on data collected by our group of the performance of children with ADHD on WM tasks from the CANTAB battery which suggest inclusion of a minimum of 15 children in each group (Rhodes et al., 2004, 2005, 2006, Coghill et al., 2007) and clinical studies that have previously employed the Eprime WM tasks we used (Cannon et al., 2005, Kim et al., 2004: both N=16) as described in the original grant application. Non-completers in the clinical groups included children whose parents decided to remove the child from the study prior to the first testing session [N= 4], children who refused to return for additional session(s) [N= 11], and children who were deemed by the researcher to not be engaging in the tasks (usually this was due to high levels of oppositionality e.g. walking around the room during tasks) [N= 9]. In the TYP group, 3 children met subclinical criteria for disorders and were managed in line with provisions set out in the medical ethics approval. One additional child withdrew from the study after assessment. The demographic characteristics of the children who completed tasks are outlined below in table 1.

Table 1: Demographic characteristics of participants

<table>
<thead>
<tr>
<th>Group</th>
<th>ADHD (mean, s.d.)</th>
<th>ADHD+ODD (mean, s.d.)</th>
<th>ODD (mean, s.d.)</th>
<th>TYP (mean, s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean, s.d.)</td>
<td>9.47 (2.01)</td>
<td>9.77 (1.82)</td>
<td>9.91 (1.94)</td>
<td>9.69 (1.46)</td>
</tr>
<tr>
<td>BPVS Percentile Rank (mean, s.d.)</td>
<td>41.29 (25.8)</td>
<td>39.63 (23.66)</td>
<td>33.19 (21.97)</td>
<td>65.27 (21.28)</td>
</tr>
<tr>
<td>Deprivation Category Score (mean, s.d.)</td>
<td>3.10 (1.29)</td>
<td>4.34 (1.32)</td>
<td>4.43 (1.67)</td>
<td>1.84 (.67)</td>
</tr>
</tbody>
</table>

Materials and Procedure
Verbal and spatial WM components were assessed using tasks designed with the program Eprime to tap a) the phonological loop and visuo-spatial sketchpad (maintenance of information), and b) the phonological loop/visuo-spatial sketchpad + central executive (maintenance and manipulation of information). These tasks have been adapted by author SR for use with children based on tasks used in a number of published studies (e.g. Canon et al., 2005; Kim et al., 2004). In the maintenance conditions, participants had to maintain a string of 3 letters in memory (probe) or the location of three dots for a 6 second delay and then decided whether the target presented was a ‘match’ or ‘non-match’ to the probe. The manipulation task assesses increased demands on the central executive which is operationalized as an ability to simultaneously maintain and manipulate the information held in storage working memory systems (Baddeley, 1986). In the maintenance-and-manipulation conditions, participants had to alphabetize the letters and hold the manipulated version in their maintenance store during the delay or flip the dots to the opposite side of the screen and hold this manipulated version in their mind and then decide whether the target presented was a ‘match’ or ‘non-match’ of the manipulated version (Canon et al., 2005; Kim et al., 2004). All children also completed standardized neuropsychological WM tasks from the Cambridge Neuropsychological Test Automated Battery (CANTAB) (Morris et al., 1987): the Spatial Span, Spatial Working Memory, Spatial Recognition Memory, Verbal Recognition
Memory, and Delayed Matching to Sample tasks that have been extensively used with child populations (cf. Rhodes et al., 2004, 2005, 2006; Coghill et al., 2007). The CANTAB tasks were performed in the order of Spatial Span, Spatial Working Memory, Spatial Recognition Memory, Verbal Recognition Memory immediate, Delayed Matching to Sample, Verbal Recognition Memory delay for all children. The Spatial Span task is a non-executive test of spatial short-term memory capacity which assesses a participant’s ability to remember the spatial locations of a sequence of squares on a computer screen. The Spatial Working Memory task assesses the participant’s ability to retain spatial information and assess the capacity to simultaneously store and manipulate information in short-term memory. The Spatial Recognition Memory task is a test of visual spatial recognition memory in a 2-choice forced discrimination paradigm. The Verbal Recognition Memory task assesses immediate and delayed memory of verbal information under free recall and forced choice recognition conditions. The Delayed Matching to Sample task assesses the ability to remember the visual features of a complex abstract target stimulus and to select from a choice of four patterns after a variable delay and provides an index of non-executive delayed short-term memory functioning. Pilot testing revealed that clinical children tolerated the testing procedure best when divided into three sessions and therefore clinical children were assessed across these sessions in a counterbalanced order (see Table 2). TYP children were assessed in one session in line with practical limitations of the school testing situation.

### Table 2: Counterbalancing Order of Tasks for Children

<table>
<thead>
<tr>
<th>Order</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eprime Verbal</td>
<td>Eprime Spatial</td>
<td>CANTAB</td>
</tr>
<tr>
<td>2</td>
<td>Eprime Spatial</td>
<td>Eprime Verbal</td>
<td>CANTAB</td>
</tr>
</tbody>
</table>

The CANTAB tasks were presented on a high-resolution colour monitor utilizing a touch sensitive screen. The working memory E-prime tasks were performed on the same machine with participants responding by pressing buttons on a stimulus-response box.

### Statistical Analysis

All analyses were conducted using SPSS for Windows (v.16, SPSS Inc. Chicago, Ill.). Data were analysed using ANCOVA with a between subject factor of group, BPVS Percentile Rank as a covariate and difficulty levels as a within subject factor where appropriate (e.g. Delayed Matching to Sample). Separate ANCOVAs were conducted on each of the Eprime tasks as given the relatively modest sample size across groups it was deemed that adopting an analysis strategy of incorporating a larger scale repeated measures ANCOVA with factors of domain and executive/non-executive processing would be too fragile to detect differences. Thus, individual ANCOVAs were conducted on the verbal non-executive, verbal executive, spatial non-executive, and spatial executive tasks. Separate ANCOVAs were also conducted on verbal and spatial load tasks and on each of the CANTAB tasks in line with our previous research (e.g. Rhodes et al., 2004). Analyses on the DMtS task were conducted separately on simultaneous and delay conditions in line with other studies (e.g. Kempton et al., 1999; Rhodes et al., 2004).
Results
Overview
Children with ADHD and ODD and children who met criteria for both disorders showed impairments on a range of WM tasks. The study findings reveal considerable variations however in performance across the different tasks and between the participant groups. None of the clinical groups showed impairment on either the verbal non-executive maintenance task or the CANTAB verbal recognition and free recall tasks supporting the increasing consensus in the literature of relatively intact verbal WM functioning in ADHD. Importantly, our findings not only supports and builds on this emerging consensus by reporting impairment across a comprehensive set of WM component and standardized neuropsychological tasks in drug naïve boys with ADHD, but also extends these findings to include children with ODD but no ADHD.

The data also revealed considerable variation between clinical groups with respect to which aspects of WM were impaired.
- The ADHD+ODD group demonstrated the greatest range of impairments, with deficits on the Eprime verbal executive task, spatial non-executive and executive task, and both verbal and spatial load tasks, and on CANTAB Spatial Span, Spatial Working Memory, Spatial Recognition Memory, DMTS tasks.
- The ADHD group showed similar performance to the ADHD+ODD group but were not impaired on the Eprime verbal load task or on delay conditions of the CANTAB DMTS task.
- The ODD group also showed similar performance to the ADHD+ODD group but were not impaired on the Eprime spatial load task or on the CANTAB Spatial Working Memory task.

This is, we believe, the first report of WM functioning in ODD, and clearly suggests that ODD is characterized by a range of executive, non-executive and delayed WM deficits. The apparent dissociation in performance on verbal and spatial load tasks across disorders and the intact performance of ODD children on the SWM task suggests that spatial WM deficits are more closely associated with ADHD symptoms whilst verbal deficits are more closely associated with ODD symptoms. These findings have potential clinical significance for understanding the particular cognitive features and the similarities and differences between each of these two disorders.

Eprime Data
Statistical values for the key Eprime task measures are included in Table 3 below.
- The clinical groups did not differ from TYP children or each other on the verbal non-executive task.
- In contrast, on the verbal executive task all 3 clinical groups were less accurate than TYP children and the clinical groups did not differ from each other.
- On the spatial non-executive task all 3 clinical groups were less accurate than the TYP children. The clinical groups did not differ from each other.
- On the spatial executive task all of the clinical groups were less accurate than the TYP children and they did not differ from each other. As there were group differences on both the spatial non-executive and executive tasks, a further ANCOVA was conducted on spatial executive accuracy with spatial non-executive accuracy as a covariate (in addition to BPVS PR). This analysis revealed a borderline group difference (p=.06). However, post-hoc tests revealed that controlling for spatial maintenance ability differentially affected the performance of clinical groups. The ADHD+ODD boys alone continued to
show performance deficits on the executive task when spatial non-executive performance was controlled, suggesting that impairment on this task reflects the non-executive ability of maintaining information in memory in children with ‘pure’ ADHD and ODD.

- Interestingly, there were contrasting findings in performance on the verbal and spatial load tasks according to patient groups.
  - On the verbal task children with ADHD+ODD and ODD were significantly poorer than TYP children across the 4 load levels. In contrast, the ADHD group did not differ from TYP children. The 3 clinical groups did not differ significantly from each other.
  - On the spatial load task, children with ADHD and ADHD+ODD were impaired across the 4 load levels in comparison to TYP children, but ODD children showed no deficits on this task. The 3 clinical groups did not differ significantly from each other.

### Table 3: Summary of Eprime data analyses

<table>
<thead>
<tr>
<th>Measure/Group</th>
<th>ADHD Mean (s.e.)</th>
<th>ADHD+ODD Mean (s.e.)</th>
<th>ODD Mean (s.e.)</th>
<th>TYP Mean (s.e.)</th>
<th>F value</th>
<th>p value</th>
<th>Post-hoc summary Clinical vs. TYP (P value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Non-exec</td>
<td>76.6 (3.6)</td>
<td>74.8 (3.2)</td>
<td>80.2 (3.7)</td>
<td>84.5 (3.5)</td>
<td>F=1.51</td>
<td>NS</td>
<td>N/A N/A N/A</td>
</tr>
<tr>
<td>Verbal Executive</td>
<td>58.7 (3.9)</td>
<td>56.1 (3.5)</td>
<td>54.4 (4.0)</td>
<td>70.4 (3.9)</td>
<td>F=3.15</td>
<td>P&lt;.03</td>
<td>.039 .009 .008</td>
</tr>
<tr>
<td>Spatial Non-exec</td>
<td>57.9 (3.4)</td>
<td>59.0 (3.0)</td>
<td>59.5 (3.5)</td>
<td>72.4 (3.4)</td>
<td>F=3.85</td>
<td>P&lt;.02</td>
<td>.004 .005 .013</td>
</tr>
<tr>
<td>Spatial Executive</td>
<td>49.7 (2.8)</td>
<td>46.0 (2.5)</td>
<td>50.7 (2.9)</td>
<td>59.6 (2.7)</td>
<td>F=4.43</td>
<td>P&lt;.006</td>
<td>.01 .001 .03</td>
</tr>
<tr>
<td>Spatial Executive</td>
<td>50.8 (2.7)</td>
<td>46.8 (2.4)</td>
<td>51.5 (2.8)</td>
<td>57.2 (2.8)</td>
<td>F=2.49</td>
<td>P&lt;.06</td>
<td>NS .008 NS</td>
</tr>
<tr>
<td>(with S Non-exec as covariate)</td>
<td>69.1 (3.2)</td>
<td>62.9 (2.9)</td>
<td>65.6 (3.3)</td>
<td>75.5 (3.2)</td>
<td>F=2.78</td>
<td>P&lt;.05</td>
<td>NS .006 .04</td>
</tr>
<tr>
<td>Verbal Load</td>
<td>62.9 (3.2)</td>
<td>64.4 (2.9)</td>
<td>70.5 (3.3)</td>
<td>76.9 (3.2)</td>
<td>F=3.98</td>
<td>P&lt;.01</td>
<td>.003 .006 NS</td>
</tr>
<tr>
<td>Spatial Load</td>
<td>62.9 (3.2)</td>
<td>64.4 (2.9)</td>
<td>70.5 (3.3)</td>
<td>76.9 (3.2)</td>
<td>F=3.98</td>
<td>P&lt;.01</td>
<td>.003 .006 NS</td>
</tr>
</tbody>
</table>

NB All means are adjusted for effects of BPVS Percentile Rank.

### CANTAB data

Statistical values for the key CANTAB task measures are included in Table 4. There were no significant differences between any of the groups on the verbal recognition memory and free recall measures of the Verbal Recognition Memory task. In contrast, the groups showed impairments on a range of spatial WM tasks although there were variations according to patient groups again with ODD children showing intact performance on a spatial task.

- Specifically, all three clinical groups had lower spatial span scores (ADHD were borderline significant) and reduced accuracy on the Spatial Recognition Memory task than TYP children and did not differ from each other.
- Children with ADHD and ADHD+ODD made a greater number of Between Search Errors on the Spatial Working Memory task than TYP children but children with ODD were not impaired on this task. The 3 clinical groups did not differ significantly from each other.

To cite this output:
other. There were no significant differences between any of the groups in Strategy score on this task.

- Children also performed a delayed short-term memory task to provide a comprehensive characterisation of WM abilities in ADHD and ODD. Children with ADHD+ODD and ODD were impaired on the delay conditions of this task and did not differ from each other on this measure. Interestingly, children with ADHD were not impaired on this task and showed a non-significant trend (p=.09) for superior performance in contrast to the ADHD+ODD group.

### Table 4: Summary of CANTAB data analyses

<table>
<thead>
<tr>
<th>Measure</th>
<th>ADHD Mean(s.e.)</th>
<th>ADHD+ODD Mean(s.e.)</th>
<th>ODD Mean(s.e.)</th>
<th>TYP Mean(s.e.)</th>
<th>F value</th>
<th>p value</th>
<th>Clinical vs. TYP (P value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRM: Recognition % Correct</td>
<td>22.68 (.45)</td>
<td>22.29 (.41)</td>
<td>22.35 (.45)</td>
<td>22.01 (.44)</td>
<td>F&lt;1</td>
<td>P=.77</td>
<td>N/A N/A N/A</td>
</tr>
<tr>
<td>VRM: Free Recall</td>
<td>5.47 (.4)</td>
<td>5.17 (.36)</td>
<td>5.35 (.4)</td>
<td>6.11 (.39)</td>
<td>F=1.02</td>
<td>P=.38</td>
<td>NS N/A N/A</td>
</tr>
<tr>
<td>Spatial Span Score</td>
<td>4.98 (.31)</td>
<td>4.39 (.27)</td>
<td>4.88 (.31)</td>
<td>5.8 (.3)</td>
<td>F=3.7</td>
<td>P&lt;.02</td>
<td>.06 .001 .047</td>
</tr>
<tr>
<td>SWM: Between Search Errors</td>
<td>16.02 (1.2)</td>
<td>17.19 (1.1)</td>
<td>15.19 (1.2)</td>
<td>12.33 (1.2)</td>
<td>F=2.97</td>
<td>P&lt;.04</td>
<td>.04 .005 NS</td>
</tr>
<tr>
<td>Spatial Recognition % Correct</td>
<td>69.1 (2.4)</td>
<td>64.8 (2.2)</td>
<td>66.8 (2.4)</td>
<td>76.4 (2.4)</td>
<td>F=4.3</td>
<td>P&lt;.007</td>
<td>.04 .001 .009</td>
</tr>
<tr>
<td>DMtS Simultaneous (%)</td>
<td>89.36 (3.8)</td>
<td>81.28 (3.5)</td>
<td>90.35 (3.4)</td>
<td>93.98 (3.7)</td>
<td>F=2.24</td>
<td>NS</td>
<td>N/A N/A N/A</td>
</tr>
<tr>
<td>DMtS Delay (%)</td>
<td>62.78 (4.1)</td>
<td>53.4 (3.7)</td>
<td>58.8 (4.1)</td>
<td>72.1 (4.0)</td>
<td>F=3.81</td>
<td>P&lt;.01</td>
<td>NS .001 .03</td>
</tr>
</tbody>
</table>

NB All means are adjusted for effects of BPVS Percentile Rank.

### Activities

We have already exceeded our intended outputs in relation to those detailed in the original application, particularly in relation to international presentations. The study findings have been widely disseminated to a range of academic and non-academic user audiences. The findings have been presented at 5 international (CNS 08, ICP 08, ICON X 08, AACAP ’08, SRCD 09 accepted) and 3 national (BPS Developmental 08 and Cognitive 08 Sections, BPS Annual 08) academic conferences covering the areas of developmental psychology, child psychiatry, cognitive neuroscience, cognitive psychology, and ADHD research specialists. Presentation of the findings has also been included in seminars to academic departments at various locations in the UK and Ireland (including University College Galway, University of York, University of Northumbria, University of Strathclyde). The findings have been presented at a research seminar held at Stirling University in February 2008 at which teachers, teaching support assistants, educational psychologists and local council representatives were in attendance. A talk to trainee educational psychologists is scheduled in March 2009 at the University of Strathclyde. Several presentations...
to clinicians active in the assessment and treatment of ADHD have been conducted including both seminars at Dundee (East of Scotland Neurodisability Interest Group), Aberdeen (junior psychiatrist training) and to the Scottish National Postgraduate Child and Adolescent Psychiatry Training Programme. DC has presented the findings as part of a recent research presentation tour to international clinicians and academics in Australia, Korea, China and Japan. SS presented findings at the 2008 annual meeting of the European Network for Hyperkinetic Disorders (EUNETHYDIS) in Mannheim. The findings were disseminated to the wider media through Press Releases which have been published on a dedicated website set up by SR to publicise the study (accessible at www.strath.ac.uk). The press releases lead to a live radio interview on the BBC Scotland Radio Drive Time Program on 21/01/09, an item on STV news on 22/01/09 and a report in ‘The Press and Journal’ Newspaper on 22/01/2009.

- Outputs

Two journal articles are currently being written up on the data and will be shortly submitted to the high impact factor journals ‘Journal of Child Psychology and Psychiatry’ and ‘Journal of the American Academy of Child and Adolescent Psychiatry’. A report on the preliminary study findings has been published on a commonly accessed government teacher website (www.teachernet.gov.uk).

List of published abstracts to date
• **Impacts**

The research has been well received in the academic and non-academic clinical and educational communities. This study has provided compelling evidence for deficits in basic non-executive memory processes in ADHD (in addition to the well-established executive deficits) and has, for the first time, demonstrated a range of memory deficits in children with ODD. These insights will support the development of specific accommodations and teaching styles for these children e.g. the routine use of course and lesson notes, reminders and other such techniques to help the child remember taught material. There is already interest in the development of cognitive training in ADHD and these studies suggest that specific modules designed to improve memory retention should be included in such programmes. A more controversial potential impact is the question that if methylphenidate improves memory in children with ADHD would it also benefit children with ODD? From the academic perspective these results are of interest to clinical and non-clinical researchers developing studies into the importance of memory, to those interested in the social neuroscience of behaviour, and the aetiology of developmental disorders.

• **Future Research Priorities**

The current findings concerning WM impairment in ODD provide critical information in the understanding of the disorder. This finding will therefore be followed up with a grant application to conduct a larger scale study of cognitive functioning in ODD incorporating a broader set of executive functioning tasks. Our previous study (Rhodes et al., 2004, 2005, 2006; Coghill et al., 2007) suggested that Methylphenidate, the treatment of choice for ADHD, improves non-executive aspects of WM functioning. We therefore intend to follow up this finding and the more specific characterization of WM we report in the current study with a large scale investigation of the effects of Methylphenidate on the components of WM in drug naïve children with ADHD. We also intend to further develop our understanding of these memory deficits by using neurophysiological, functional scanning and genetic methodologies in both healthy children and those with ADHD and ODD.

**References**


