# CHAPTER FIVE

## Study Two: Response inhibition, working memory, attention, and concept of time as executive functions in boys with ADHD

### Method

The purpose of Study Two was to compare the performance of boys with ADHD and Control boys on measures sensitive to the predicted executive impairments of ADHD children, which were identified in the literature and in Study One. In particular, four such impairments were advanced as characteristic of ADHD children, namely: deficiencies in response inhibition, working memory, sustained attention, and the concept of time. The nature of these predicted impairments was examined in further detail in the previous chapter, where instrumentation designed to be sensitive to each of these areas was identified and discussed. This chapter therefore describes the sample of participants that was recruited, the manner in which data were gathered and analysed, and the hypotheses that were tested in Study Two.

#### Participants

The ADHD participants in the present study were recruited through a Consultant Paediatrician (Dr Whiting) who had agreed to collaborate on the research. All of the ADHD participants had been diagnosed by the Consultant Paediatrician as meeting the DSM-IV (American Psychiatric Association, 1994) criteria for ADHD and had subsequently been referred to a clinical psychologist (by the paediatrician) for the assessment of undiagnosed comorbid disorders. All participants with ADHD were administered, among other measures, the Child Behavior Checklist (Achenbach & Edelbrock, 1986), which is a broad-band rating scale providing coverage of the major dimensions of child psychopathology. Only ADHD children with no diagnosed comorbid conditions were included in the present study. Data were obtained from 67 ADHD boys (22 of whom had been diagnosed as ADHD Predominantly Inattentive Type, and 45 as ADHD Combined Type) and 68 non-ADHD Control boys.

The Control Group was comprised of boys from Grades Two through Seven who were recruited from one local public primary school which is situated in an area of moderate socio-economic status. None of the participants with ADHD attended this school. All children at the participating school are screened each year to identify those students who are "at risk of educational failure" (according to the criteria stipulated by the Education Department of Western Australia, EDWA, 1998), and for reading disabilities (using the Neale Analysis of Reading Ability, Neale, 1989). Children who are identified through this process are referred to the resident school psychologist for further evaluation. None of the participants included in the present study had been identified in the screening procedure at any time in their school life, nor had they received unsatisfactory academic grades indicating work difficulties on any of their school term reports. As an additional check the school principal, in consultation with the resident school psychologist, confirmed the absence of learning difficulties and/or other conditions. The vision of all participants was normal or corrected and none had major sensori-motor difficulties.

Descriptive statistics, including the mean Age, Verbal IQ, and Performance IQ, are presented for the ADHD-PI, ADHD-CT and Control group in Table 2. Estimates of Verbal and Performance IQ were obtained for all participants using the Vocabulary, Similarities, Block Design and Object Assembly subscales of the Wechsler Intelligence Scale for Children, 3rd Edition (WISC-III, Wechsler, 1991). This subset of the WISC-III has been found to correlate .93 to .95 with the full administration of the WISC-R (Sattler, 1988). An estimated Verbal or Performance IQ of 80 or more was a minimum requirement for inclusion in the study (Malone & Swanson, 1993).

Participants in the ADHD-PI group were aged between 8 years 6 months and 16 years 1 month, with estimated Verbal IQ scores between 78 and 141 and Performance IQ scores between 58 and 146. In the ADHD-CT group, participants were aged between 6 years 6 months and 16 years 0 months, with Verbal IQ scores between 83 and 133 and Performance IQ scores between 87 and 146. Participants in the non-ADHD Control group were aged between 6 years 7 months and 12 years 6 months, with Verbal IQ scores between 72 and 133 and Performance IQ scores between 70 and 155.

Table 2

Pre-matching means and standard deviations (in parentheses) of participants' Age, Verbal IQ (VIQ), and Performance IQ (PIQ) according to Group

| Group | n | Age Mean (SD) | VIQ Mean (SD) | PIQ Mean (SD) |
|---|---|---|---|---|
| ADHD-PI | 22 | 12.0 (2.07) | 111.1 (17.41) | 113.9 (22.82) |
| ADHD-CT | 45 | 10.6 (2.30) | 106.2 (13.36) | 112.6 (14.82) |
| Controls | 68 | 9.9 (1.77) | 102.2 (15.63) | 113.7 (18.01) |

Matching measures

Preliminary statistical analyses revealed significant differences between the mean Ages of the three Groups [$F(2,132) = 9.40$, $p < .001$]. In particular, Scheffé post hoc comparisons revealed that the ADHD-PI boys were significantly older than both the ADHD-CT boys ($p = .034$) and the Control boys ($p < .001$). Given these significant Age differences, and in view of the anticipated Age-related performance on the dependent measures, it was considered inappropriate to compare the performance of the ADHD-PI, ADHD-CT and Control boys directly. Instead, where possible the ADHD and Control boys were individually matched on Age to reduce the potentially confounding effects of developmental differences. The nature of the matching procedure and its implications for the analysis of data, along with a statement of rationale, are discussed in further detail later in this chapter.

The subsequent analyses also revealed slight significant Group differences for Verbal IQ [$F(2,132) = 3.12$, $p = .047$], although no differences were found on Performance IQ [$F(2,132) = .06$, n.s.]. Given the significant differences in the mean Age and Verbal IQ across the three Groups, an attempt was made to extend the individual matching of the ADHD and Control children on Age to include both of these variables. However, it was not possible to obtain a closely matched sample in this manner, since satisfactory matching on one variable (Age) could only be achieved at the expense of less satisfactory matching on the other (Verbal IQ).

Settings

Testing sessions were conducted with each participant individually. All of the ADHD children were tested in a room in The Centre for Attention and Related

Disorders, which is located within The Graduate School of Education, The University of Western Australia. The non-ADHD Control group were tested at their primary school, in a room specifically set aside for this purpose. In all instances, the rooms were quiet, free of extraneous distractors, and the layout of furniture and equipment was identical.

The results of earlier neuropsychological research (Houghton et al., 1999; Barkley, 1997b) has suggested that in order to control for potential confounding variables, test batteries should be administered in an environment which approximates that of the classroom, and at a common time of day. Thus all testing sessions conducted in the present phase of the research were arranged for mornings.

<u>Procedure</u>

Permission to conduct this research study was initially obtained from the Human Rights and Ethics Committee of The University of Western Australia. An information letter which explained the purpose of the research, was then sent to the parents of ADHD children who had been involved in an earlier study (Houghton et al., 1999), inviting them to allow their child(ren) to participate. The parents also received an informed consent to participate form (which was prepared in accordance with UWA Human Rights and Ethics Committee guidelines), advising them of what participation would entail. (A copy of the information letter and consent form sent to parents has been included in Appendix H.) Notices inviting participation were also placed in the newsletter of the Learning and Attentional Disorders Society of Western Australia (LADS) and in the rooms of one local Consultant Paediatrician who had agreed to collaborate on the current research. Parents who responded to these notices, and whose child(ren) met the criteria for participation, were also provided with copies of the information letter and consent form.

By the commencement of the testing phase, the parents of 67 ADHD boys had returned completed consent forms that had been signed by themselves and the participant(s). Appointment times for the testing sessions were subsequently arranged by telephone. As in previous research (Houghton et al., 1999), and with the approval of the child's paediatrician, parents' attention was drawn to the section of the information letter which requested that no stimulant medication be administered to their children on the afternoon and/or evening prior to testing. This was to allow sufficient time for the effects of the stimulant medication to dissipate, ensuring that medication status will not appear as a confounding factor in the results of the present research. A further verbal check was made on this immediately prior to testing, where it was found that all parents had complied with this request.

The non-ADHD Control Group was comprised of boys recruited from one local public primary school. Parents of all boys in Grades Two through Seven at the participating school received a copy of the information letter and consent form, requesting their assistance in the research. A 70% response rate was obtained. Of the children whose parents chose to allow them to participate in the research, approximately 20% were excluded because their school psychological assessments and/or academic records indicated diagnosed conditions (including learning difficulties).

Test administration

Children participating in Study Two were required to perform a number of tasks which previous research has shown they find non-threatening and enjoyable (Houghton et al., 1999). Tests were administered in a randomised order by two postgraduate (PhD) research students who were experienced in their administration. Each testing session began with a short general conversation before moving into the battery of four tests, which were administered in a randomised order. Each testing session lasted approximately 70 minutes and the test administrators reported that the test battery was not taxing and maintained the engagement of participants. Complete data were obtained for all of the tests administered, which along with the short duration of testing suggests that results were not unduly affected by fatigue (Siedman, Biederman, Faraone, Weber, Menin, & Jones, 1997). However, CMS data were not available for one of the Control participants due to an absence from school, and Timetest data were not collected for a number of ADHD participants due to timetabling difficulties. This reduced the final matched sample size for these measures to 49 and 44 respectively, but the individual matching on Age was unaffected.

In addition, during the testing period, the parent/guardian of each of the boys with ADHD was asked to complete the long form of the Conners' Parent Rating Scale - Revised (Conners, 1997). These data were used as an objective measure of hyperactivity-impulsivity and inattention amongst the Age-matched ADHD-PI and ADHD-CT samples, and are reported in Chapter Six (see p. 133). Although data were unavailable for one of the boys with ADHD, this was not considered sufficient grounds to exclude this participant from the study.

Matching procedure

The following procedure was undertaken because it was considered inappropriate to compare the performance of the ADHD-PI, ADHD-CT and Control Groups directly in view of the significant differences in the mean Age and Verbal IQ of the three Groups. In order to address these Age and Verbal IQ differences, it was decided to individually match the ADHD and Control children as closely as possible on both of these variables. Whilst a number of minor problems were encountered in using this approach, none were insurmountable, and all appeared to be less problematic than the potentially confounding effect of the significant Age and IQ differences themselves. It is, however, arguable that the matching of the two ADHD subgroups to the homogenous Control Group would itself result in an inappropriate statistical design, and this will be addressed in the following section. Each of the problems that were encountered in the matching process is outlined in detail below and the way in which it was addressed is discussed.

The initial attempt at matching revealed that a trade-off exists between the stringency of the applied matching criteria and the potential size of the matched sample. This is because the iterative process that results in successively closer matching also necessarily reduces the sample size, as participants who cannot be satisfactorily matched are removed. Hence, the closer the sample was individually matched (i.e., the more stringent the matching criteria), the smaller the size of the sample that would result. Alternatively, unless additional participants are introduced into the matching pool, the larger the desired sample size, the less accurate the individual matching becomes. In the present study, therefore, a decision had to be made that accommodated both the desired stringency of the matching criteria (i.e., as close as possible), and the sample size (i.e., as large as possible).

In a related problem, the individual matching of the ADHD and Control children on both Age and Verbal IQ simultaneously proved to be problematic. Although it was possible to individually 'match' a subset of the ADHD and Control boys to within 12 months of Age and 15 points on Verbal IQ, subsequent analysis revealed that it was not possible to obtain a satisfactory match on both Age and Verbal IQ simultaneously. A one-way repeated measures (or matched groups) multivariate analysis of variance (MANOVA) was used to evaluate the individual matching of the ADHD and Control boys, and revealed that these differences were nonetheless significant. Thus in order to maintain sufficient stringency in the matching criteria whilst retaining an adequate sample size, the attempt to match on both Age and Verbal IQ simultaneously had to be abandoned. Instead, a decision had to be made whether to match on either Age or Verbal IQ.

It was decided to match the ADHD and Control Groups as closely as possible on Age. This was due to a number of reasons, including the lower level of dispersion observed on Age than on estimated Verbal IQ, and previous research which has indicated that children with ADHD may experience a depressed Verbal IQ (e.g., Barkley et al., 1997c; Houghton et al., 1999). Furthermore, given the developmental nature of ADHD, and hence the anticipated Age-related nature of performance on the dependent measures, it was considered likely that developmental differences between the ADHD and Control Groups being compared would result in a potentially confounding effect.

The ADHD and Control children were therefore matched to within three months on Age, and this resulted in a final matched sample of 100 participants, consisting of 14 ADHD-PI boys, 36 ADHD-CT boys, and their 50 individually Age-matched Controls. Descriptive statistics for the post-matching sample are provided in the following chapter. A repeated measures MANOVA design was again used to evaluate the matching of the Groups on Age, Verbal IQ, and Performance IQ, and revealed no significant differences between the ADHD and Control Groups, indicating that the means for the two Groups did not differ on any of the three variables.

<u>Data analyses</u>

The matching procedures employed in the previous section were each evaluated using a repeated measures (or correlated groups) design. This is because under certain circumstances, such as when matched data or correlated samples are used, the repeated measures design is more appropriate and provides greater statistical power than the factorial design. This was the case in the present study since the individual matching of the ADHD and Control boys on Age induces a correlation between the measures taken on the ADHD and Control Groups. Hence matching has the effect of decreasing the error variance and of precluding the matching variables from becoming competing causal factors of any effects (Kirk, 1995). Naturally the matching variable must have reasonable correlation with the dependent variables, which was the case in the present study, where the correlations between Age and the dependent variables were as high as .74, with the majority above .40 (the 95% significance level). The correlations between the matching variable (Age) and the dependent variables for the SART, CMS, and TEA-Ch respectively are presented in Table 4 (p. 137), Table 7 (p. 141), and Table 10 (p. 148) in Chapter Six. Similar correlations were not calculated for the Timetest due to the large number of dependent variables.

Nevertheless the matching of two discrete ADHD subgroups to a homogeneous Control group remains a cause for concern. In particular, the inclusion of a between-subjects factor for ADHD Subtype in conjunction with the repeated measures Group factor (ADHD vs. Control) would arguably result in an inappropriate statistical design, since such a distinction is meaningless in the Control Group. Although this posed a potentially significant problem, preliminary analysis revealed that there were no significant differences between the performance of the ADHD-PI and ADHD-CT boys on any of the dependent measures, so this variable was excluded from the main analysis. It must be acknowledged however, that this result is based on the relatively small sample size of the ADHD-PI Group (n = 14), and thus has limited statistical power, suggesting that the result be interpreted with caution.

Each of the tests administered in the present study was analysed using a one factor (Group: ADHD vs. Control) repeated measures MANOVA, except for the Timetest, in which two separate four factor (Group x Mode x Distraction x Time) repeated measures univariate analyses of variance (ANOVAs) were used. In the case of significant interaction effects, lower order interaction effects and simple main effects were considered. In order to claim substantive as well as statistical significance, where significant results are reported, they are accompanied by an associated Effect Size (ES). Effect Size is a standardised contrast calculated by dividing the difference in means by the estimated population standard deviation. This provides an estimate of the number of standard deviations between the means being compared. An Effect Size of 0.50 to 0.75 or greater is considered appreciable (Cohen, 1970).

Hypotheses

From the research questions presented at the end of Chapter Two, and the expected outcomes discussed in the previous chapter, a series of hypotheses have been formulated that will be examined in Study Two. The hypotheses generated relate to the predicted executive impairments of ADHD children that were identified in Study One, that is: impairments in response inhibition, working memory, attention, and concept of time. The hypotheses have been arranged according to these four domains of functioning and relate directly to the instrumentation that was chosen to assess each of these areas.

All hypotheses were tested at the 95% significance level using the statistical design described in the previous section. Any differences found therefore, are representative of significant differences between the ADHD and Control boys, and can not be attributed to variations in Age between the Groups.

Response inhibition (SART)

Hypothesis one (H1) parts (a) to (c) pertain to the Inhibition phase of the SART in which participants have to inhibit their response to infrequent targets (i.e., the digit "3"). Hypothesis two (H2) part (a) pertains to the Vigilance phase of the SART where participants are required to respond with a button press to the infrequent target digit (i.e., "3").

H1(a). There will be a significant difference between the number of False Positives made by the ADHD-CT, ADHD-PI and Control boys on the Inhibition Phase of the SART. Specifically, the ADHD boys will record significantly more False Positives than the Control boys.

H1(b). Boys diagnosed with ADHD-CT will be significantly more impulsive in their responding than the Control boys, resulting in smaller reaction times. However, boys diagnosed with ADHD-PI will be significantly slower in their reaction times than either the ADHD-CT and Control boys.

H1(c). There will be a significant difference between the number of Misses made by the ADHD-CT, ADHD-PI and Control boys on the Inhibition Phase of the SART. Specifically, the ADHD boys will record significantly more Misses than the Control boys.

H2(a). There will be a significant difference between the number of Misses made by the ADHD-CT, ADHD-PI and Control boys on the Vigilance phase of the SART. Specifically, the ADHD-CT will make significantly less, and the ADHD-PI boys will make significantly more, Misses than Control boys.

Working memory (CMS)

H3(a). There will be a significant difference between the performance of the ADHD and Control boys on the measures of verbal memory provided by the CMS. Specifically, the ADHD boys will be significantly impaired relative to the Control boys.

H3(b). There will be a significant difference between the performance of the ADHD and Control boys on the measures of non-verbal memory provided by the CMS. Specifically, the ADHD boys will be significantly impaired on measures of non-verbal memory relative to the Control boys.

H3(c). There will be a significant difference between the performance of the ADHD and Control boys on the measures of attention/concentration provided by the CMS. Specifically, the ADHD boys will be significantly impaired relative to the Control boys.

H4. There will be a significant difference in the memory retention of the ADHD and Control boys as measured by the immediate and the commensurate delayed recall tasks of the CMS. Specifically, the performance of the ADHD boys will be significantly impaired relative to that of Controls.

Attention (TEA-Ch)

H5(a). There will be a significant difference between the performance of the ADHD and Control boys on the measures of selective attention provided by the TEA-Ch. Specifically, the ADHD-PI boys will be impaired relative to the ADHD-CT and Control children.

H5(b). There will be a significant difference between the performance of the ADHD and Control boys on the measures of sustained attention provided by the TEA-Ch. Specifically, the ADHD-CT boys will be impaired relative to the ADHD-PI and Control children.

H5(c). There will be a significant difference between the performance of the ADHD and Control boys on the measures of attentional switching provided by the TEA-Ch. Specifically, the ADHD-CT boys will be impaired relative to the ADHD-PI and Control children.

H5(d). There will be a significant difference between the performance of the ADHD and Control boys on the measures of dual task performance provided by the TEA-Ch. Specifically, the ADHD boys will be impaired relative to the Control children.

Concept of time (Timetest)

H6(a). The ADHD boys will be significantly less accurate than Control boys in their reproduction of 0.5 to 6.0 second time intervals.

H6(b). The performance of the ADHD boys will be significantly further impaired by the presence of distractors, relative to that of Control boys.

H6(c). Boys with ADHD will tend to overestimate shorter time durations and overestimate longer time durations on the Timetest relative to the Control boys, consistent with the results reported by Tannock.