CHAPTER SEVEN

Summary and Conclusions

This chapter is presented in four sections. In the first section, the results of the present research are discussed within the context of the relevant literature, which was identified in Chapter Two. The second section explores how these findings might be integrated with the existing research and theory in this area to verify or challenge various aspects of the current conceptualisation of ADHD, which was examined in Study One. Where appropriate, those modifications to the prevailing understanding of ADHD which are suggested by the data obtained in the present study will be identified and discussed. Section Three considers the methodological implications which have arisen from the present research, and discusses ways in which these factors might be addressed in subsequent studies. Finally, Section Four outlines the suggested directions for future research and provides concluding comments.

Research summary

The present study sought to contribute to the ongoing development of theory and understanding about ADHD. Two separate, yet inter-related, studies were employed for this purpose. The initial exploratory study (Study One) employed individual interviews with a number of leading international scholars in the field of ADHD to examine the current conceptualisation of ADHD. This was then followed by a large-scale empirical investigation which sought to investigate the conceptualisation of ADHD as purported by the leading international scholars and the research literature. These two studies were sequential in that Study One provided the theoretical framework within which the subsequent empirical investigation could proceed, and Study Two served to validate aspects of the conceptual model established in Study One.

The interviews employed in Study One allowed a fuller understanding of recent advances in the field of ADHD to be obtained and this assisted in the development of an overall conceptualisation of ADHD. The main findings of this exploratory study revealed that the current emphasis in the conceptualisation of this condition is very much underpinned by Barkley's (1997a) Unifying Theory of ADHD, which according to the participants represents the most scientifically comprehensive theory to date. In line with this, participants emphasised the role played by executive functions and the concomitant difficulties in organisation, self-monitoring, inhibition, and storing and recalling information that children with ADHD experience (e.g., Barkley, 1997a; Denckla, 1996; Houghton et al., 1999; Pennington & Ozonoff, 1996). These suggestions are very much in line with recent research on ADHD which appears to have focused on response inhibition (e.g., Nigg, 2000; Oosterlaan & Sergeant, 1998; Schachar et al., 2000), working memory (e.g., Kaplan et al., 1998; Kuntsi et al., 2001; Oie et al., 1999), attention (e.g,. Cepeda et al., 2000), and the concept of time (e.g., Barkley et al., 1997; Sonuga-Barke et al., 1998).

Previous research (e.g., Dane, Schachar, & Tannock, 2000; Houghton et al., 1999) has clearly identified two distinct ADHD subtypes, and in the present study there was overwhelming support for the existence of these subtypes. Participants made clear distinction between those children with inattention problems only (i.e., the Predominantly Inattentive Type), and those who also present with hyperactivity, impulsivity, and inattention (i.e., the Combined Type). It should be noted however, that while participants' responses were indicative of two ADHD subtypes, the majority acknowledged the existence of a third subtype, comprised of children with hyperactivity/impulsivity only. Thus the demarcation between two or three distinct subtypes was not clear.

A major finding in Study One pertaining to the conceptualisation of ADHD was the identification of four broad areas of executive impairment in children with ADHD. In line with previous research, participants consistently cited deficiencies in response inhibition (Nigg, 1999; Schachar et al., 2000), verbal and non-verbal working memory (Kaplan et al., 1998; Kuntsi et al., 2001; Oie et al., 1999), and perception (or concept) of time (Barkley et al., 1997; Dooling-Litfin, 1997) in their discussions. Specifically, the inability to stop an ongoing response, the inability to hold information in mind, and problems with reproducing intervals of time were thought to be particularly pertinent for further investigation. With reference to attention, there was a degree of uncertainty in participants' responses that indicated that they were less sure about what particular aspects of attention that might be impaired in children with ADHD.

In summary, Study One was exploratory in nature and confirmed much of the previous research pertaining to executive deficits in children with ADHD. The recent development of theoretical models of ADHD, such as Barkley's (1997a), which emphasise the underlying component processes of the disorder, has represented a significant advance in the field (Tannock, 1998). Study One therefore accessed the views of six leading international scholars who provided new information which could be incorporated into our current theoretical conceptualisation(s) of ADHD and tested in the subsequent empirical study.

Study Two involved 50 children diagnosed as ADHD (14 of whom were Predominantly Inattentive and 36 Combined Type) and 50 non-ADHD Controls. A battery of tests commensurate with the suggestions made in Study One were administered to the sample. Findings revealed that the performance of the ADHD and non-ADHD Control boys was differentiated on measures of response inhibition, verbal memory, attentional switching, and time

reproduction. In all cases, the ADHD boys were found to underperform relative to their Age-matched Controls, except on the SART measure of False Positives, on which they made less errors than their non-ADHD counterparts. While this result appears to conflict with previous research that has suggested that ADHD children make more omission errors than Controls (e.g., DeWolfe, Byrne, & Bawden, 1999; Losier, McGrath, & Klein, 1996; Oades, 2000; Swaab-Barneveld et al., 2000), it must be acknowledged that the results of such studies have been somewhat equivocal.

Nevertheless, the finding that the boys with ADHD recorded less False Positives than Controls on the measures derived from the SART would appear to challenge the suggestion that ADHD boys have an impairment in response inhibition. In addition, the present study also found that the ADHD boys were in fact slower to respond than Control boys on those occasions when a response was provided, which is contrary to the expected pattern of impulsive responding. While these results seem to contrast with recent theories (e.g., Barkley, 1997a), they do appear to conform with a growing body of literature which suggests that ADHD children have slower stop signal reaction times than Controls (e.g., Leth-Steensen et al., 2000; Nigg, 1999; Purvis & Tannock, 1997; Schachar & Logan, 1990).

It was also found that the ADHD boys recorded significantly more Misses than the Control boys on the measure provided by the SART. This appears to be in line with the results of research using Continuous Performance Tests (CPT) (e.g., DeWolfe, Byrne, & Bawden, 1999; Losier, McGrath, & Klein, 1996; Oades, 2000; Swaab-Barneveld et al., 2000), and the stop signal task (e.g., Oosterlaan & Sergeant, 1995; Pliszka et al., 1997; Schachar et al., 2000). Although the number of Misses (or Commission Errors) recorded on these tasks are considered to

represent failures of sustained attention, it must be acknowledged that there were no significant differences observed on the measure of sustained attention provided by the TEA-Ch. However, it is also possible that the failure to detect differences in sustained attention using the TEA-Ch might have been the result of a potential ceiling effect.

With regards to memory, the ADHD boys appeared to underperform on the measures of verbal memory provided by the CMS. In particular, the ADHD boys were significantly impaired on both the immediate and delayed recall measures of the stories and word pairs subtests of the CMS. Boys with ADHD also answered less story comprehension questions correctly than the Control boys, resulting in poorer performance on the delayed recognition measure. Furthermore, the ADHD boys were found to be less proficient than Controls on the CMS sequences subtest, which has been advanced as a measure of attention/concentration (Cohen, 1997). In contrast, there was no apparent impairment amongst the ADHD group on the measures of non-verbal memory, or the delayed recognition component of word pairs, which required participants to distinguish those pairs which they had been asked to remember previously from those that were new to them.

While systematic investigations of working memory have been rare (Tannock, 1998), the results of the present study appear to be consistent with the existing research. Relative to Controls, ADHD children have been found to under-perform on a range of tasks which load working memory, including repetition of digits forwards and backwards (Barkley, Murphy, & Kwasnik, 1996; Kuntsi et al., 2001), mental arithmetic (Zentall & Smith, 1993), and the Tower of Hanoi (Pennington, Grossier, & Welsh, 1993). Recent research has also suggested that children with ADHD perform more poorly on verbal working memory (Kaplan

et al., 1998; Oie, Sundet, & Rund, 1999) and sentence span tasks (Kuntsi et al., 2001) than non-ADHD Controls. However, the results of these studies have also intimated these deficits are not specific to ADHD. For example, Oie at al. (1999) found that adolescents with schizophrenia exhibited impairments in both visual and verbal working memory, and Kaplan et al. (1998) reported that impairments in verbal working memory were even greater in the RD and ADHD + RD comparison groups.

Contrary to expectations, the TEA-Ch measures of selective attention, sustained attention, or dual task performance did not discriminate between the ADHD and Control boys. However, the present study did find evidence to suggest that boys with ADHD are impaired on the measure of attentional switching, which is consistent with the results of Cepeda et al. (2000). While Manly et al. (1999) also found no significant differences in selective attention between 24 ADHD boys and similarly aged Controls using the TEA-Ch, significant differences were reported on measures of sustained attention, attentional switching and dual task performance. The failure to detect differences in sustained attention also appears contrary to the results of research using the CPT (Losier, McGrath, & Klein, 1996), although the results of such studies have been somewhat equivocal (Swaab-Barneveld et al., 2000). Alternatively, it may be that the CPT and the measure provided by the TEA-Ch, which was specifically designed to be sensitive to sustained attention, are in fact examining different attentional constructs. It is also possible that the failure to detect significant differences on the measures of selective and sustained attention was the result of potential ceiling effects (see Chapter Six).

The ADHD boys were also found to be less accurate than Controls on the visual time reproduction task. In an interesting discrepancy, no significant differences

were apparent for the auditory form of the task. As has been consistently reported in the literature (e.g., Barkley et al., 1997; Dooling-Litfin, 1997), the absolute time reproduction error (i.e., absolute discrepancy) increased for both groups in direct proportion to the duration to be reproduced. Examination of the coefficient of accuracy scores revealed a significant Group x Mode x Time interaction, indicating that the ADHD boys tended to overestimate shorter time intervals and underestimate longer intervals relative to Controls on the visual task, while their performance could not be distinguished on the auditory task. To date, few studies appear to have examined time reproduction in ADHD children, although the results of such studies do suggest that ADHD children do have impairments in this area. In particular, Tannock (personal communication, March 2, 2001) confirmed that a similar pattern of results has recently been obtained amongst her research group. The present study therefore sought to extend previous research by examining the effect of distractors and the mode of presentation (i.e., visual or auditory) on time reproduction in boys with ADHD.

Of particular interest to the present study was the finding that the distractors used in the present study had no effect on the performance of either the ADHD or Control children. However, a number of explanations might account for this surprising finding, which despite a wealth of anecdotal evidence to the contrary, seems to suggest that the ADHD boys are no more distractible than Controls. It may be that the computer-generated distractors used in the present study were ineffective because they were presented on the same screen or speaker as the stimulus, and therefore did not require participants to divert their attention from the computer. Alternatively, it might be as Barkley (personal communication, March 29, 2000) suggested, that the time intervals used in the present study were too short for the distractors to be effective, since

Zakay (1990) found that non-ADHD children can master five to six second intervals by five years of age.

Advancing the conceptualisation of ADHD

While the development of theoretical models of ADHD has represented a significant advance in the field (Tannock, 1998), and such models have had a perceptible influence on the current conceptualisation(s) of the disorder, the results of Study One revealed that the present understanding of the disorder remains largely heterogeneous. However, the results of Study Two have provided a clearer understanding of the deficits associated with ADHD by confirming the predicted impairments in the areas of memory, attention, and concept of time. This section will examine how these findings verify or challenge aspects of the current conceptualisation of ADHD, and how they serve to further contribute to the understanding of ADHD that was developed in Study One.

Although current theories of ADHD (such as Barkley, 1997a) tend to focus on the hyperactive-impulsive and combined types to the exclusion of the predominantly inattentive type, the present investigation also included those ADHD children who present with symptoms of inattention only (i.e., ADHD-PI). Since the ADHD-HI subtype is clinically rare, the performance of 45 ADHD-CT boys was compared to that of 22 ADHD-PI boys and 67 non-ADHD Controls. However, no significant differences were observed between the ADHD subtypes on any of the measures used in the present study. Although it is suggested that this result be interpreted with caution due to the limited size of the ADHD-PI sample, recent research by Dane, Schachar, and Tannock (2000) also found no significant differences in the mean activity level of ADHD children according to subtype. While other studies have reported evidence of

subtype differences between the ADHD-PI and ADHD-CT groups (e.g., Houghton et al., 1999), there remains little research to date that has systematically examined the subtypes as delineated by DSM-IV.

Recent theories of ADHD (such as Barkley, 1997a; Quay, 1997) have also proposed that response inhibition, and not attention, is the central impairment in ADHD. While there is considerable evidence to support this notion (see Barkley, 1999, for a review), it has also been suggested that ADHD is characterised more by significant variability in responding than any specific situational deficit (Leth-Steensen et al., 2000). This might also account for the failure to consistently observe impairments in attention amongst children with ADHD. However, there are also data which suggest that an impairment in response inhibition is also characteristic of children with Conduct Disorder (Oosterlaan & Sergeant, 1996; Schachar et al., 2000), or externalising behaviour disorders in general (Oosterlaan, Logan, & Sergeant, 1998), and is therefore not specific to ADHD. That the present investigation has demonstrated that boys with ADHD (and no diagnosed comorbid conditions) are unimpaired on the SART measure of response inhibition (and in fact perform better than Age-matched Control boys), is therefore a clearly significant finding.

This study also appears to be consistent with the growing body of literature that has reported that ADHD children have slower stop-signal reaction times (or are generally slower in their responding) than non-ADHD Controls (e.g., Houghton et al., 1999; Leth-Steensen et al., 2000; Nigg, 1999). There was also some evidence to suggest that the ADHD group were more variable in their responding than their non-ADHD counterparts, which Leth-Steensen et al. (2000) described as "the most consistent finding in the ADHD cognitive literature" (p. 168). Recently Leth-Steensen et al. (2000) examined the response

times of ADHD boys using a distributional approach, and found that they could be distinguished from those of age-matched Control boys by an increased number of abnormally slow responses, resulting in an abnormally large tail of the distribution. While such an analysis is beyond the scope of the present study, the data obtained using the SART could be examined further using a similar approach to verify or challenge the findings of Leth-Steensen et al. (2000), albeit with a suitably larger sample size.

The present study also used a new test to systematically examine memory in children with ADHD. That the results obtained revealed that boys with ADHD were impaired on measures of verbal memory and learning, but not on measures of non-verbal memory, appears to confirm the decision to examine verbal and non-verbal memory separately, and is consistent with the limited literature in this area. However, that recent research has reported significant impairments among ADHD boys using similar instrumentation might serve to qualify the finding that non-verbal memory is unimpaired in boys with ADHD. For example, while the results of the faces subtest revealed no significant differences between the ability of the ADHD and Control boys to recognise and remember faces, there is evidence from research which suggests that ADHD children have difficulty interpreting facial expressions. Furthermore, while no impairment was observed on dot locations, which involved reproducing a pattern of markers from memory, ADHD children appear to be impaired on the finger windows test, in which a finger must be pointed through a series of "windows" in sequential order (Kaplan et al., 1998; Tannock, 2001).

The CMS also served to highlight the distinct nature of memory and working memory. In the present study, the ADHD boys were found to be impaired on the measure of working memory (i.e., sequences), which involved holding in

mind a series of letters, words, or numbers, and manipulating them. However, there was no evidence to suggest that the ability to hold information in mind (i.e., memory retention) was impaired in boys with ADHD. Thus it may be as Barkley and Tannock suggested (see Chapter Three) that the memory problems associated with ADHD are not the result of an underlying deficit in memory per se. Rather, the difficulties for ADHD children seem to be located within working memory, and appear to manifest when information must be manipulated (e.g., the sequences subtest) or recalled in a sequence (e.g., the stories subtest, finger windows subtest). The delayed recall measures would appear to provide further support for this notion, revealing that while the ADHD and Control group did not differ on the quantity of word pairs recalled, significant differences were apparent on the measure of story comprehension. There is evidence from research, however, that suggests that working memory impairments are not specific to ADHD, and may also be characteristic of children with Reading Disability (Tannock, 2001), autism, Tourette's syndrome, and conduct disorder (Pennington & Ozonoff, 1996).

Perhaps the most surprising result obtained in the present study was the failure to detect significant differences on the measures of selective and sustained attention provided by the TEA-Ch. Contrary to Barkley's hypothesis (see Chapter Three), there were no significant differences between the ADHD-PI and ADHD-CT groups on the measures of attention provided by the TEA-Ch, suggesting that the qualitative nature of the attentional impairment may not differ according to ADHD subtype. While this finding does seem to conflict with the results of earlier research (and the data obtained using the SART) which have suggested that children with ADHD have an impairment in attention (and in particular, sustained attention), these studies have used a diverse range of measures and produced equivocal results. In contrast, the

present study employed the TEA-Ch, which was specifically designed to be sensitive to attention in ADHD children.

That no significant differences were observed between the ADHD group and the non-ADHD Controls on the TEA-Ch measures of attention appears to provide partial support for recent conceptualisations of ADHD that have suggested that an impairment in response inhibition, and not attention, is characteristic of ADHD. The performance of the ADHD and non-ADHD Control boys was discriminated only by the measure of switching attention provided by the TEA-Ch, which required participants to hold information in mind (i.e., the creature count), so as to manipulate it (i.e., to change the direction of counting). Taken together, the results obtained using the CMS and TEA-Ch appear to suggest that working memory is impaired in ADHD. This also seems to be consistent with the results of Cepeda et al. (2000), who found that the switching costs (i.e., the time required to switch between two tasks being performed concurrently) were significantly larger for ADHD children. However, Cepeda et al. also found that stimulant medication alleviated these switching costs to a degree that no significant differences were apparent relative to non-ADHD Controls.

According to Barkley (see Chapter Three), the psychological concept of time arises from the ability to hold a series of events in mind in a sequence. The present study has provided evidence that the capacity for verbal memory and working memory might be impaired in children with ADHD, which could account for their observed difficulty in organising behaviour with respect to time. While the data obtained from participants in the semi-structured interviews suggested that the problem was more likely with the organisation of behaviour with respect to time than with time perception per se, the results

obtained using the Timetest appear consistent with the limited work to date in this area. An interesting discrepancy was also revealed between the visual and auditory forms of the time reproduction task. While this significant finding does not appear to have been reported in the literature to date, it should be interpreted with a degree of caution until it can be replicated.

Methodological implications

The purpose of Study Two was to examine the predicted executive impairments of children with ADHD, whilst systematically addressing the range of methodological limitations that were identified in the review of existing research. These included: limited sample sizes, inconsistent diagnostic procedures, poor age-matching between groups, and failure to control for comorbid disorders or medication status at the time of testing. While the present research addressed these issues, a number of other methodological considerations need to be acknowledged. First, it is possible that the informed consent procedures used in the present study might have resulted in a systematic sampling bias. While sampling bias has the potential to undermine the ecological validity of research, appropriate ethical standards were strictly maintained at all times and participation was entirely voluntary.

Second, many previous studies have failed to adequately operationalise the constructs that they have sought to examine. In these instances, the instrumentation used to assess a poorly defined construct (such as the executive functions) effectively defines the construct under examination. The present study sought to address this by using instrumentation that was specifically designed to be sensitive to the predicted impairments of ADHD children that were identified in Study One. However, it must be acknowledged that since the

instrumentation used in the present study is newly developed, to date there is only limited psychometric data pertaining to its reliability and validity.

Third, given the high rates of comorbidity amongst ADHD children, it appears unlikely that the large sample of ADHD boys used in the present study could be entirely free of comorbid disorders, despite the confirmed absence of any diagnosed comorbidity by the Consultant Paediatrician. However, the ADHD boys in the present study were drawn from a larger sample of 3500 ADHD children, of whom only 122 had no diagnosed comorbidity, which appears to be in line with recent evidence from Barkley (2001a), suggesting that 3% of ADHD children have no diagnosed comorbidity.

Finally, the use of individually Age-matched samples in the present study does not appear to be common in current research. However, while it has been argued that matching on IQ might be inappropriate since ADHD children may have depressed IQ scores (Barkley, 1997b), there is no similar argument against matching on Age. Furthermore, the repeated measures design used in the present study was considered preferable to the use of Age-based norms, since ADHD appears to affect the course of normal development and only limited normative data were available for the instrumentation used. However, it must be acknowledged that the repeated measures design used in the present study would not have been possible if significant differences were observed according to ADHD subtype. This is because the combination of a single, homogeneous Control group with an ADHD-PI sample and an ADHD-CT sample would result in an inappropriate statistical design.

Directions for further research

While the present study has confirmed and contributed to the understanding of the executive impairments of boys with ADHD and no diagnosed comorbidity, there is also evidence which suggests these impairments are not specific to ADHD alone. Research has also found impairments in response inhibition to be characteristic of children with conduct disorder (Schachar et al., 2000) and possibly even externalising behaviour problems in general (Oosterlaan et al., 1998). Furthermore, impairments in working memory and attention are also apparent in children with Reading Disability (Kaplan et al., 1998; Tannock, 2001), schizophrenia (Oie at al., 1999), and autism (Pennington & Ozonoff, 1996). In order to address the issue of specificity, it is suggested that future research includes a disordered comparison group, such as children with Reading Disability or conduct disorder (Tannock, 2001).

The present study found that boys with ADHD were significantly impaired on measures of working memory and attentional switching, which appears to be consistent with Barkley's (1997a) Unifying Theory of ADHD. However, it might be that the impairments in emotional self-regulation also predicted by this model may be even more problematic for the child with ADHD, since they will impact on their relationship with their family, peers, and educators. These predicted impairments were not examined in the present study since they are yet to be adequately operationalised. The use of poorly defined constructs may account for some of the inconsistent results that have been obtained in many previous studies of ADHD. To address this issue might require the development and testing of new measures, such as those used in the present study, that are specifically designed to be sensitive to the predicted impairments of ADHD children. Furthermore, while little normative data are as

yet available for the measures used in the present study, this can only be addressed through further research.

The finding of modality-specific impairments on the measures of memory and time reproduction is an interesting finding that may be further explored in future research. That boys with ADHD were clearly impaired on measures of verbal memory, but showed no impairment on measures of non-verbal memory, might also have implications for the design of teaching and intervention strategies for children with ADHD. The measures of working memory also provided clear evidence of impairment in situations in which attentional switching is required, such as reversing the direction of counting or reciting sequences. This may also warrant further investigation in future research, particularly in classroom settings. Further to this future research should seek to examine the generalisability of the executive impairments found in the present study to ecologically valid domains of childhood functioning.

In conclusion, the present research has raised a number of important issues pertaining to ADHD. Whilst the continual evolution of the conceptualisation of ADHD has paralleled the progress of research, it has also contributed to its status as perhaps the most controversial disorder of childhood. In the present study, the current conceptualisation of ADHD was examined and systematically tested against a scientific model of the disorder, to be verified or challenged, and modifications suggested where appropriate. Clear evidence of significant impairments in working memory, attentional switching, and the concept of time, in boys with ADHD (and no diagnosed comorbidity), compared to Age-matched non-ADHD Control boys was demonstrated. This process has significantly contributed to the development of theoretical understanding about ADHD.