CHAPTER 5: RESULTS AND DISCUSSION

5.1 INTRODUCTION

The results and discussion are presented according to the formulated sub-aims of the study and entail:

- a comparison of the inter- and intra-group tendencies of central auditory processing for the three research groups in the medicated and non-medicated state,
- a comparison of the inter- and intra-group tendencies of auditory and visual continuous performance for the three research groups in the medicated and non-medicated state,
- and an analysis of the specific multi-dimensional test battery results in relation to the different types of ADHD and subprofiles of CAPD.

As discussed in Chapter 4, statistical analysis of the data was only possible for research groups 1 (combined type of ADHD) and 2 (inattentive type of ADHD) as research group 3 (hyperactive-impulsive type of ADHD) consisted of only one participant. The results of the participant in research group 3 are discussed qualitatively against the background of the results of research groups 1 and 2. The identification of only one participant for research group 3 is consistent with reports in the literature (Millstein et al, 1998) of a lower incidence of the hyperactive-impulsive type of ADHD in children. Wilens et al (2002) estimate that in the ADHD population, 50-75% of children have the combined type of ADHD, 20% of children the inattentive type of ADHD, with only a "very small" percentage of children having the hyperactive-impulsive type of ADHD. Furthermore, Millstein et al (1998) report that symptoms of hyperactivity and impulsivity decrease more than symptoms of inattention from childhood to adulthood.

5.2 THE INTER- AND INTRA-GROUP TENDENCIES OF CENTRAL AUDITORY PROCESSING FOR THE 3 RESEARCH GROUPS IN THE MEDICATED AND NON-MEDICATED STATE

The discussion of the central auditory processing of the 3 research groups entails:

- a comparison of the behavioral CAPD test results of research groups 1, 2 and 3 (in the medicated and non-medicated state) with the CAPD normative data
- the results of ANOVA used to
  - determine the overall effect of medication on the CAPD test results, and
  - compare the overall CAPD test results of research groups 1 and 2
- an analysis of the inter- and intra-group tendencies of the CAPD test results of research groups 1, 2 and 3 in the medicated and non-medicated state

5.2.1 A comparison of the CAPD test results of research groups 1, 2 and 3 (in the medicated and non-medicated state) with the CAPD normative data.

The CAPD behavioral normative data used in the study were compiled as part of the pilot study (as discussed under 4.6, and included as Appendix XI). Bellis (1996, 2003a) recommends that clinicians compile age-appropriate normative data for their own clinical settings. It is recognized that the number of individuals used in the compilation of the normative data was limited, namely a total of 50 children with 10 children in each of the following age categories: 8 years, 9 years, 10 years, 11 years and 12 years of age. The normative data compiled (Appendix XI) did, however, allow for comparisons to be made with the CAPD test results of the 10 participants in research groups 1 and 2 respectively and the 1 participant in research group 3. Thus, although the number of children included in compiling the normative data was limited, these numbers were adequate for the purposes of the study.

The comparison of the CAPD test results of research groups 1, 2 and 3 (in the medicated and non-medicated state) with the CAPD behavioral normative data, are presented in Tables 5.1 and 5.2 respectively. As seen in Table 5.1 the results of research group 1 (combined type of ADHD) were significantly lower (at the 5% level of significance) than the normative data for the Dichotic digits test (right and left ear), the Frequency pattern test (labeling and humming condition: right and left ear), the Speech masking level difference test and the Low pass filtered speech test (right ear) in the non-medicated state, whereas only the Dichotic digit test (right and left ear) and Speech masking level difference measures were significantly lower in the medicated state. The results of research group 2 (inattentive type of ADHD) show that only the Dichotic digits test (right ear) and the Speech masking level difference test were significantly lower (at the 5% level of significance) than the normative data in the non-medicated state with no significant differences in the medicated state.

The results of the one participant in research group 3 are presented in Table 5.2. These results could not be statistically compared to the behavioral CAPD normative data, as there was only one participant in research group 3. A qualitative comparison does, however, show that the results with and without medication were lower than the normative data for all the behavioral CAPD tests in both the medicated and non-medicated state with the exception of the Low pass filtered speech test (left and right ear) where the scores obtained were slightly above the normative data values in the medicated state. Furthermore, the scores obtained with medication were better than those obtained without medication with the exception of the Speech masking level difference test where identical scores were obtained.

TABLE 5.1: Comparison of the CAPD test results of research groups 1 and 2 in the medicated and non-medicated state with the CAPD Normative data

	Research group 1 (Combined type of ADHD) n=10		Research group 2 (Inattentive type of ADHD) n=10		CAPD normative data n=50	Comparison of research group 1 without medication and the CAPD normative data	Comparison of research group 1 with medication and the CAPD normative data	Comparison of research group 2 without medication and the CAPD normative data	Comparison of research group 2 with medication and the CAPD normative data
	Mean without medication	Mean with medication	Mean without medication	Mean with medication	Means of the CAPD normative data	+ Z value	+ Z value	+ Z value	+ Z value
Dichotic digits test – right ear	72,75	77,75	83,50	87,00	91,20	4,00*	3,13*	2,53*	1,57
Dichotic digits test – left ear	66,50	73,50	80,25	84,00	86,80	3,23*	2,41*	1,14	0,58
Frequency pattern test: labeling condition – right ear	49,60	56,40	64,20	64,40	69,88	2,95*	1,96	1,06	0,67
Frequency pattern test: labeling condition – left ear	50,00	55,20	63,60	64,40	69,60	2,94*	2,07	1,16	1,05
Frequency pattern test: humming condition – right ear	52,80	60,40	67,20	69,20	73,80	2,96*	2,29	1,29	0,90
Frequency pattern test: humming condition – left ear	52,00	60,40	66,40	68,40	73,12	3,20*	2,15	1,54	0,88
Low pass filtered speech – right ear	43,00	49,50	48,00	53,50	54,30	2,48*	0,76	1,67	0,29
Low pass filtered speech – left ear	43,50	51,00	49,50	51,50	52,98	1,99	0,20	1,22	0,83
Speech masking level difference test	2,25	3,55	3,30	4,40	5,66	4,01*	2,97*	3,10*	1,67

KEY:

*	Z values that demonstrated a significant difference at the 5% level of significance (critical value = 2,39 for multiple comparisons)
+	Z value = observed value from standard normal distribution

TABLE 5.2: Comparison of the CAPD test results of the participant in research group 3 with the CAPD Normative data

	Research group 3 (Hyperactive-impulsive type of ADHD) n=1		CAPD normative data n=50
	Scores without medication	Scores with medication	Means of the CAPD normative data
Dichotic digits test – right ear	70	80	91,20
Dichotic digits test – left ear	62,5	67,5	86,80
Frequency pattern test: labeling condition – right ear	52	64	69,88
Frequency pattern test: labeling condition – left ear	56	68	69,60
Frequency pattern test: humming condition – right ear	52	60	73,80
Frequency pattern test: humming condition – left ear	48	64	73,12
Low pass filtered speech – right ear	45	55	54,30
Low pass filtered speech – left ear	40	55	52,98
Speech masking level difference test	0	0	5,66

The above results thus show an improvement in the CAPD test results of all three research groups in the medicated state as opposed to the non-medicated state, when compared to the normative data. The association between ADHD and poor performance on tests of CAPD is well documented and has arguably been seen in the past as evidence of the co-occurrence or co-morbidity of ADHD and CAPD (Chermak et al, 1999). In administering tests of CAPD to children with ADHD the effects of attention do, however, need to be considered.

To control for the effects of attention, Chermak et al (1999) and Bellis (2003a) recommend that CAPD testing be done in the medicated state for children with ADHD so that the child's actual central auditory abilities can be more accurately assessed.

When looking only at the medicated scores in Table 5.1 no significant differences are noted between the CAPD results of research group 2 and the normative data. The lower performance noted for research group 1 in the non-medicated state did, however, continue to occur in the medicated state for both the Dichotic digit test and the Speech masking level difference test. These results suggest that some children with the combined type of ADHD may continue to present with auditory processing deficits even when taking medication. The diagnosis of CAPD can, however, not be based on poor performance in only one or two isolated measures of CAPD. Specific patterns within the test results of a CAPD test battery need to be identified before the diagnosis of a specific subprofile of CAPD can be made (Bellis and Ferre, 1999, Bellis, 2003a). A more in-depth analysis of the patterns for the individual CAPD test results of the participants in the study is thus required and will be presented in 5.4.

5.2.2 The results of ANOVA used to determine the overall effect of medication on the CAPD test results and to compare the overall CAPD test results of research groups 1 and 2

The results of ANOVA for determining the overall effect of medication on the CAPD test results is presented in Table 5.3, and the results of the ANOVA for determining whether differences occur in the overall CAPD test results of research groups 1 and 2 are presented in Table 5.4

As seen in Table 5.3 the combined results of research groups 1 and 2 with medication were significantly higher (p=<0,05) than the results without medication for all of the CAPD measures, with the exception of the Frequency pattern test (labeling condition: left ear). The probability value for the Frequency pattern test (labeling condition: left ear) was 0,0516 and thus close to the cut-off value of p=< 0,05 that was used. These findings suggest that the medication resulted in improved scores for the combined results of research groups 1 and 2 on CAPD measures, and thus support the recommendation of the American Academy of Pediatrics (2001) that stimulant medication be considered in the treatment of ADHD in children. The effect of medication on the CAPD measures of the two different research groups, namely research groups 1 and 2 does, however, warrant further investigation and is addressed under 5.2.3.

The ANOVA results for determining the overall differences between the CAPD test results of research groups 1 and 2 (combining the scores with and without medication), as seen in Table 5.4, show that the CAPD scores of research group 2 were significantly higher (p=<0,05) than those of research group 1 for all the CAPD scores. These results suggest that the difficulties experienced by children with the combined type of ADHD are more severe than for children with the inattentive type of ADHD. This finding is corroborated when reviewing the DSM-IV criteria (American Psychiatric Association, 1994) (as outlined in Table 1.1) that require children with the combined type of ADHD to meet 6 or more of the

Table 5.3: Results of ANOVA for determining the overall effect of medication on the combined CAPD test results of research groups 1 and 2

Medication			
CAPD Tests	**Without medication**	**With medication**	**Comparison with and without medication**
	Means (n=20)	**Means (n=20)**	**Probability factor (p)**
Dichotic digit test – right ear	78,13	82,38	0,0001*
Dichotic digit test – left ear	73,38	78,75	0,0131*
Frequency pattern test: labeling – right ear	56,90	61,40	0,0003*
Frequency pattern test: labeling – left ear	56,80	59,80	0,0516
Frequency pattern test: humming – right ear	60,00	64,80	0,0038*
Frequency pattern test: humming – left ear	59,20	64,40	0,0080*
Low pass filtered speech test: right ear	45,50	51,50	0,0005*
Low pass filtered speech test: left ear	46,50	51,25	0,0015*
Speech masking level difference test	2,78	3,98	0,0051*
KEY:			
*	Significant difference at the 5% level of significance (Probability factor values (p) <0,05 = significant difference)		

Table 5.4: Results of ANOVA for determining whether differences occurred between the overall CAPD test results of research groups 1 and 2.

	Research group		
CAPD Tests	**Research group 1 (Combined type of ADHD)**	**Research group 2 (Inattentive type of ADHD)**	**Comparison of research groups 1 and 2**
	Means (n=20)	**Means (n=20)**	**Probability factor (p)**
Dichotic digit test – right ear	75,25	85,25	<,0001*
Dichotic digit test – left ear	70,00	82,13	<,0001*
Frequency pattern test: labeling – right ear	53,00	65,30	<,0001*
Frequency pattern test: labeling – left ear	52,60	64,00	<,0001*
Frequency pattern test: humming – right ear	56,60	68,20	<,0001*
Frequency pattern test: humming – left ear	56,20	67,40	<,0001*
Low pass filtered speech test: right ear	46,25	50,75	0,0053*
Low pass filtered speech test: left ear	47,25	50,50	0,0196*
Speech masking level difference test	2,9	3,85	0,0211*

KEY:

*	Significant difference at the 5% level of significance (Probability factor values (p) <0,05 = significant difference)

symptoms of inattention, as well as 6 or more of the symptoms of hyperactivity-impulsivity. In contrast, children with the inattentive type of ADHD are only required to meet 6 or more of the symptoms of inattention listed in Table 1.1.

5.2.3 An analysis of the inter- and intra-group tendencies of the CAPD test results of research groups 1, 2 and 3 in the medicated and non-medicated state.

The results of the inter-and intra-group tendencies of the behavioral CAPD test results of research groups 1 and 2 in the medicated and non-medicated state are presented in Table 5.5. The behavioral CAPD results of the participant in research group 3 (as presented in Table 5.2) will be discussed qualitatively against the background of the results of research groups 1 and 2. Finally, the stapedial acoustic reflex test results of research groups 1, 2 and 3 (as presented in Table 5.6) will be discussed.

As seen in Table 5.5, the results of research group 1 were significantly higher (at the 5% level of significance) in the medicated state than for the non-medicated state for all but 2 of the behavioral CAPD measures, namely the Dichotic digit test (left ear), and the Frequency pattern test (labeling condition: left ear). The results of research group 2 showed no significant difference between the medicated and non-medicated state. The results of the one participant in research group 3 (as presented in Table 5.2) showed an improvement in the behavioral CAPD scores in the medicated state with the exception of the Speech masking level difference test where identical scores were obtained.

These findings suggest that children with the combined type of ADHD benefited from their medication, whereas the children with the inattentive type of ADHD do not appear to have benefited significantly from the medication they received. This finding is supported by both Barkley (1998) and Chermak et al (1999) who view executive dysfunction as the primary source of dysfunction in children with

Table 5.5: The inter- and intra-group tendencies of the CAPD test results for research groups 1 and 2 in the medicated and non-medicated state

	Research group 1 (Combined type of ADHD) n=10		Research group 2 (Inattentive type of ADHD) n=10	
	Mean Without medication	**Mean With medication**	**Mean Without medication**	**Mean With medication**
Dichotic digit test – right ear	72,75(a)	77,75(b)	83,50(c)	87,00(c)
Dichotic digit test – left ear	66,50(a)	73,50(a,b)	80,25(b,c)	84,00(c)
Frequency pattern test: labeling – right ear	49,6(a)	56,40(b)	64,20(c)	66,40(c)
Frequency pattern test: labeling – left ear	50,00(a)	55,20(a)	63,60(b)	66,40(b)
Frequency pattern test: humming – right ear	52,80(a)	60,40(b)	67,20(c)	69,20(c)
Frequency pattern test: humming – left ear	52,00(a)	60,40(b)	66,40(b,c)	68,40(c)
Low pass filtered speech test: right ear	43,00(a)	49,50(b)	48,00(a,b)	53,50(b)
Low pass filtered speech test: left ear	43,50(a)	51,00(b)	49,50(b)	51,50(b)
Speech masking level difference test	2,25(a)	3,55(b)	3,30(a,b)	4,40(b)
KEY:				
a, b, c (Based on the groupings of the Scheffe's multiple comparisons test results)	The CAPD test scores with different alphabetic symbols are significantly different (at the 5% level of significance), while CAPD test scores with the same alphabetic symbol show no significant difference (at the 5% level of significance). Comparisons are only applicable within each CAPD test and not between the different CAPD tests.			

Footnote:	
Age	Significant differences were noted with an improvement of CAPD test scores with increasing age. The probability value was <0,0001 for all of the CAPD tests. The probability values of each CAPD test are provided in Appendix XIII.
Order of test condition	No significant differences were noted in the CAPD test results for the order effect in which the testing was done, i.e. whether the participants were tested with or without medication. The probability values were all > 0,05. The probability values ranged from 0,1601 to 0,7676. The probability values of each CAPD test are provided in Appendix XIII.

Table 5.6: The stapedial acoustic reflex test results of research groups 1, 2 and 3

Research group	Right ear				Left ear			
	Percentage of participants with two or more of the three acoustic reflexes at 500, 1000 and 2000Hz within the normal range		Percentage of participants with two or more of the three acoustic reflexes at 500, 1000 and 2000Hz elevated (>90dBSL) or absent at maximum intensity settings		Percentage of participants with two or more of the three acoustic reflexes at 500, 1000 and 2000Hz within the normal range		Percentage of participants with two or more of the three acoustic reflexes at 500, 1000 and 2000Hz elevated (>90dBSL) or absent at maximum intensity settings	
	Ipsi-lateral reflexes	Contra-lateral reflexes	Ipsi-lateral reflexes	Contra-lateral reflexes	Ipsi-lateral reflexes	Contra-lateral reflexes	Ipsi-lateral reflexes	Contra-lateral reflexes
Combined type of ADHD (Research group 1) n = 10	80% (n=8)	50% (n=5)	20% (n=2)	50% (n=5)	80% (n=10)	40% (n=4)	20% (n=20%)	60% (n=6)
Inattentive type of ADHD (Research group 2) n = 10	100% (n=10)	80% (n=8)	0% (n=0)	20% (n=2)	80% (n=8)	70% (n=7)	20% (n=2)	30% (n=3)
Hyperactive-impulsive type of ADHD (Research group 3) n = 1	0% (n=0)	0% (n=1)	100% (n=1)	100% (n=1)	100% (n=1)	0% (n=0)	0% (n=0)	100% (n=1)

the combined and hyperactive-impulsive types of ADHD. Barkley (1998) and Chermak et al (1999) thus support the pharmacological management of the combined and hyperactive-impulsive types of ADHD. Stimulant medication is thought to exert a therapeutic effect by enhancing executive function by facilitating dopamine transmission in the prefrontal cortex (Volkow et al, 2001). In contrast, the inattentive type of ADHD is viewed as an input or information processing deficit, and Barkley (1998) and Chermak et al (1999) have suggested that this type of ADHD is thus unlikely to derive any greater benefit from stimulant medication than do normally functioning children.

The results of this study thus support the pharmacological management of children with the combined and hyperactive-impulsive types of ADHD, but question whether this is the most appropriate form of management in children with the inattentive type of ADHD. These results may assist in providing guidelines for the clinical management of the different types of ADHD. There is currently significant variation in the type and amount of stimulants that are prescribed by physicians, as well as wide variations in the diagnostic methods and procedures currently employed in the diagnosis of ADHD (American Academy of Pediatrics, 2000). This has led to some concern about the perceived misuse and over-prescription of stimulant medication among children, particularly in the North American region, where the use of the DSM-IV criteria (American Psychiatric Association, 1994) are advocated (Safer et al, 1996, American Academy of Pediatrics, 2000).

Against this background, it is interesting to revisit the ICD-10 (World Health Organization, 1992) criteria used in the diagnosis of Hyperkinetic disorders in the United Kingdom and Europe. As discussed in Chapter 2, Hyperkinetic disorder is characterized by the early onset of both overactive and inattentive behaviors and is thus similar to the combined type of ADHD, diagnosed using the DSM-IV criteria of the American Psychiatric Association (1994) (Taylor and Hemsley, 1995). Professionals in the United Kingdom and Europe have criticized their North American counterparts for the over-prescription of stimulant medication for children with overactive and inattentive behaviors and, particularly, the use of stimulant medication in children presenting with only inattentive behaviors (McConnell, 1997). The results of this study thus provide some support for the concerns expressed by professionals in the United Kingdom and Europe regarding the possible over-prescription of stimulant medication, particularly for children with the inattentive type of ADHD (McConnell, 1997).

In summary, the medical management of the combined and hyperactive-impulsive types of ADHD appears to be the most beneficial management regime at this time, whereas the use of medication for children with the inattentive type of ADHD should be carefully considered.

The inter-group comparison of research groups 1 and 2 (Table 5.5) in the non-medicated state show that the behavioral CAPD scores of research group 2 were significantly higher (at the 5% level of significance) for all the CAPD scores with the exception of the Low pass filtered speech test (right ear) and the Speech masking level difference test. The inter-group comparison in the medicated state yielded similar results with all the CAPD scores being significantly higher (at the 5% level of significance) again for research group 2, with the exception of the Low pass filtered speech test (left and right ear) and the Speech masking level difference test. These results suggest that the central auditory processing abilities of children with the combined type of ADHD are significantly poorer (in both the medicated and non-medicated state) than those of children with the inattentive type of ADHD. A more in-depth analysis of the individual CAPD test results of the participants in the study is warranted and will be presented in 5.4.

As seen in the footnote of Table 5.5, significant differences ($p<0,05$) were noted with an improvement in all behavioral CAPD test scores with increases in age. The probability values for each CAPD test are included in Appendix XIII. The improvement in the CAPD test scores with increases in age can be attributed to the maturation of the central auditory nervous system that continues until approximately the age of 12 years (Bellis, 1996, Keller, 1998, Bellis, 2003a). Regarding the order of the test conditions (footnote of Table 5.5), no significant differences ($p>0,05$; with values ranging between 0,01601 to 0,7676) were noted in the CAPD test results for the order in which the testing was done, i.e. whether participants were tested first in the medicated or non-medicated state. The order in which the specific multi-dimensional test battery was administered, did not have a significant effect on the CAPD test results. The probability values for each CAPD for the order of the test condition are included as Appendix XIII.

The stapedial reflex test results presented in Table 5.6 show that the ipsi-lateral acoustic reflexes of research groups 1 and 2 were mostly within the normal range of 70-90dBSL with scores ranging between 80 to 100% for both the right and left ear. The contra-lateral reflexes of research group 1 showed a higher percentage of elevated and/or absent reflexes than research group 2 (50 to 60% of the participants in research group 1 presented with two or more elevated or absent reflexes for the right and left ear respectively, as opposed to 20 to 30% for research group 2). The ipsi-lateral stapedial reflexes of the left ear were within the normal range for the participant in research group 3, but were elevated/absent for the right ear. The contra-lateral reflexes of the participant in research group 3 were elevated/absent for both ears. A more in-depth analysis of the stapedial acoustic reflexes together with the behavioral CAPD test results of the participants (against the background of the different subprofiles of CAPD) is presented in 5.4.

Summarizing to this point, the results of the study show that stimulant medication enhanced the performance of research group 1 (combined type of ADHD) and research group 3 (hyperactive-impulsive type of ADHD) on the CAPD measures, but does not appear to have had a significant effect on the performance of children in research group 2 (inattentive type of ADHD). This supports the pharmacological management of the combined and hyperactive-impulsive types of ADHD (Barkley, 1998, Chermak et al, 1999), but suggests that the use of stimulant medication in children with the inattentive type of ADHD be carefully considered.

5.3 THE INTER- AND INTRA-GROUP TENDENCIES OF CONTINUOUS PERFORMANCE FOR THE 3 RESEARCH GROUPS IN THE MEDICATED AND NON-MEDICATED STATE.

The discussion of the continuous performance of the 3 research groups entails:

- a comparison of the IVA CPT and IVA STAR scores of research groups 1, 2 and 3 (in the medicated and non-medicated state) with the IVA CPT and IVA STAR normative data

- the results of ANOVA used to
  - determine the overall effect of medication on the IVA CPT and IVA STAR scores, and
  - compare the overall IVA CPT and IVA STAR scores of research groups 1 and 2

- an analysis of the inter- and intra-group tendencies of the IVA CPT and IVA STAR scores of research groups 1, 2 and 3 in the medicated and non-medicated state

5.3.1 A comparison of the IVA CPT and IVA STAR scores of research groups 1, 2 and 3 (in the medicated and non-medicated state) with the IVA CPT and IVA STAR normative data

As seen in Table 5.7, 16 of the 28 *IVA CPT scores of research group 1* (combined type of ADHD) in the non-medicated state were lower than the IVA

Table 5.7: Comparison of the IVA CPT scores with the IVA CPT normative data (scores of 85-115 representing the "normal range")

	Research group 1 (Combined type of ADHD) n=10		Research group 2 (Inattentive type of ADHD) n=10	
	Mean Without medication (n= 4-8)	Mean With medication (n= 7)	Mean Without medication (n= 7-10)	Mean With medication (n= 8-9)
Full Scale Control Quotient	79,25*	86,00	104,71	106,13
Auditory Response Control Quotient	72,67*	81,71*	97,90	105,33
Visual Response Control Quotient	76,60*	93,86	108,57	106,13
Full Scale Attention Quotient	77,50*	92,00	88,29	98,25
Auditory Attention Control Quotient	71,00*	91,14	82,70*	101,89
Visual Attention Control Quotient	80,80*	86,43	93,29	95,38
Fine Motor Regulation / Hyperactivity	64,75*	89,29	90,50	104,44
Response Control				
Auditory prudence	81,67*	84,00*	107,00	109,11
Visual prudence	76,40*	88,00	108,29	99,50
Auditory consistency	72,33*	80,57*	91,30	99,22
Visual consistency	79,80*	93,86	108,29	106,38
Auditory stamina	94,17	97,86	99,00	102,33
Visual stamina	95,20	106,14	99,00	104,75
Attention				
Auditory vigilance	69,17*	96,00	80,70*	102,22
Visual vigilance	87,60	96,57	98,43	95,88
Auditory focus	78,00*	77,43*	92,60	98,78
Visual focus	79,40*	98,00	105,00	105,38
Auditory speed	95,83	109,43	93,20	103,11
Visual speed	91,80	94,86	82,86*	91,13
Attribute				
Balance	117,25	117,86	114,43	117,75
Auditory readiness	90,17	96,43	105,60	106,67
Visual readiness	104,80	94,00	108,00	100,88

Table 5.7 continued

	Research group 1 (Combined type of ADHD) n=10		Research group 2 (Inattentive type of ADHD) n=10	
	Mean Without medication (n= 4-8)	Mean With medication (n= 7)	Mean Without medication (n= 7-10)	Mean With medication (n= 8-9)
Validity				
Auditory comprehension	47,57*	81,86*	77,60*	96,78
Visual comprehension	57,83*	86,00	93,71	98,00
Auditory persistence	104,60	93,29	104,00	110,00
Visual persistence	99,00	102,14	101,14	114,00
Auditory sensory motor	101,33	111,14	108,00	101,00
Visual sensory motor	103,20	87,43	79,71*	84,25*
KEY:				
*	IVA CPT scores poorer than 85 (lower limit of the "normal range")			

CPT normative data. In the medicated state only 5 of the 28 IVA CPT scores were lower than the "normal range" (scores in the 85-115 range). The composite and primary scores affected in the non-medicated and medicated state include both response control and attention scores, suggesting that the participants in research group 1 experience problems with both impulsivity and inattention. Problems with both impulsivity and attention are also reflected in the poor scores (<85) seen for the Fine motor regulation as well as the Auditory and Visual comprehension validity scales that suggest high levels of off-task behaviors with the mouse (multiple, spontaneous, and anticipatory clicks as well as trials where the mouse is held down) and high levels of random responses (Sandford and Turner, 2001). These findings are consistent with the DSM-IV criteria (American Psychiatric Association, 1994) that require the presence of behaviors of both inattention and hyperactivity/impulsivity for the diagnosis of the combined type of ADHD to be made.

Additionally, it is noteworthy that the scores of research group 1, affected in the non-medicated state include both the auditory and visual modality scores, i.e. the Auditory and Visual response control quotient, the Auditory and Visual attention control quotient, Auditory and Visual prudence, Auditory and Visual consistency, Auditory and Visual focus, and Auditory and Visual comprehension. These results suggest that the attention deficits seen in children with the combined type of ADHD are likely to be supramodal in nature. These results offer support for Chermak et al's (1999) conceptualization of the supramodal nature of the attention deficits associated with the combined type of ADHD.

In a study, using an earlier version of the IVA CPT, Sandford et al (1995) reported that children with ADHD are likely to be more aurally impulsive and to make more errors of commission (responses in the absence of the target stimulus) in response to auditory than to visual stimuli. Sandford et al (1995) included 26 children between the ages of 7 and 12 in their study, who were all previously diagnosed with ADHD by either a physician or a psychologist.

Limitations of the study of Sandford et al (1995) are: that no differentiation was made between the different types of ADHD; the diagnostic material/criteria used in making the diagnosis of ADHD are not defined; and finally, it is not clear whether the participants were assessed in the medicated or non-medicated state and/or whether other co-existing disorders were present.

Interestingly, the scores of research group 1, that continued to be affected in the medicated state only have bearing on the auditory modality, for example, the Auditory response control quotient, Auditory prudence, Auditory consistency, Auditory focus and Auditory comprehension. Based on these results, it appears that the medication the participants in research group 1 (the combined type of ADHD) are receiving has a greater impact on visual inattention and impulsivity deficits than for auditory inattention and impulsivity deficits. Sandford et al (1995) have suggested that different types of medication and treatment may only be effective or may be more effective for one sensory modality and thus recommend using continuous performance measures that include measures of both the auditory and visual modalities. Further research is necessary to substantiate the findings of this study and the hypothesis of Sandford et al (1995).

A comparison of the IVA CPT scores of research group 2 (inattentive type of ADHD) in the non-medicated state with the IVA CPT normative data (as seen in Table 5.7) shows that 5 of the 28 IVA CPT scores were lower than the "normal range". These five scores include three auditory scores (Auditory attention control quotient, Auditory vigilance and Auditory comprehension) and two visual scores (Visual speed and Visual sensory motor). The presence of deficits, in both auditory and visual IVA CPT scores in the non-medicated state, supports Chermak et al's (1999) conceptualization of the supramodal nature of the attention deficits associated with the inattentive type of ADHD. The composite and primary scores affected in the non-medicated state are restricted to the attention scores, suggesting that the participants in research group 2 experience problems with attention but not impulsivity.

In the medicated state, only the visual sensory motor score of research group 2 remained below the "normal range". The visual motor score was just below the cut off score of 85 (scores of 85-115 representing the normal range). The scores of research group 2 were mostly better than those of research group 1 for both the medicated and the non-medicated state suggesting that the deficits associated with the inattentive type of ADHD may be less severe than for the combined type of ADHD. This finding is corroborated when reviewing the DSM-IV criteria (American Psychiatric Association, 1994) (as outlined in Table 1.1) that require children with the combined type of ADHD to meet 6 or more of the symptoms of inattention, as well as 6 or more of the symptoms of hyperactivity-impulsivity. In contrast, children with the inattentive type of ADHD are only required to meet 6 or more of the symptoms of inattention listed in Table 1.1.

As seen in Table 5.8, 7 of the 11 IVA STAR scores of research group 1 in the non-medicated state were lower than the IVA STAR normative data while all scores in the medicated state were within the "normal range". Again (as for the IVA CPT scores) the scores affected in the non-medicated state reflect both the auditory and visual modality, supporting the notion of the supramodal nature of the attention deficit associated with the combined type of ADHD, as suggested by Chermak et al (1999).

The comparison of the IVA STAR scores of research group 2 with the IVA STAR normative data were within the "normal range" in both the medicated and the non-medicated state with the exception of one of the primary scales, namely the Auditory steadiness score in the non-medicated state. Auditory steadiness refers to the percentage of correct responses when targets are infrequent and thus reflects problems in sustaining attention. As for the IVA CPT scores, the deficits are restricted to the attention scores, suggesting that the participants in research group 2 experience problems with attention but not impulsivity.

Table 5.8: Comparison of the IVA STAR scores with the IVA STAR normative data (scores of 85-115 representing the "normal range")

	Research group 1 (Combined type of ADHD)		Research group 2 (Inattentive type of ADHD) n=10	
	Mean Without medication (n= 4-6)	Mean With medication (n= 7)	Mean Without medication (n= 7-10)	Mean With medication (n= 8-9)
Primary Scales				
Auditory alertness	76,83*	103,86	96,30	106,56
Visual alertness	93,40	98,29	99,14	98,13
Auditory steadiness	67,00*	96,14	78,40*	100,67
Visual steadiness	82,00*	93,43	97,29	97,38
Auditory promptness	92,33	107,00	96,80	107,89
Visual promptness	94,20	91,14	87,86	90,13
Auditory constancy	83,83*	92,86	96,00	108,00
Visual constancy	84,20*	90,57	100,14	102,13
Combined Scales				
Auditory specific	71,83*	99,71	87,60	107,89
Visual specific	84,60*	91,43	94,57	95,50
Global (Auditory and Visual)	76,50	94,14	92,43	102,25
KEY:				
*	IVA STAR scores poorer than 85 (lower limit of the "normal range")			

5.3.2 The results of ANOVA used to determine the overall effect of medication on the IVA CPT and IVA STAR scores and to compare the overall IVA CPT and IVA STAR scores of research groups 1 and 2

ANOVA was used to determine the overall effect of medication on the IVA CPT (Table 5.9) and the IVA STAR (Table 5.10) on the combined scores of research groups 1 and 2. The combined scores of research groups 1 and 2 were significantly lower ($p<0,05$) in the non-medicated state than the medicated state for 9 of the 28 IVA scores. As seen in Table 5.10, the combined scores of research groups 1 and 2 were significantly lower ($p<0,05$) in the non-medicated state than for the medicated state for 7 of the 11 IVA STAR scores. These results show an improvement in the overall scores of research groups 1 and 2 in the medicated state for both the IVA CPT and the IVA STAR scores, suggesting that the medication enhanced the continuous performance of the participants. This finding supports the recommendation of the American Academy of Pediatrics (2001) that stimulant medication be considered in the treatment of ADHD in children. The effect of medication on the auditory and visual continuous performance of the two different research groups, namely research groups 1 and 2, does, however, warrant further investigation and is addressed under 5.3.3.

ANOVA was also used to determine the differences between the overall IVA CPT (Table 5.11) and IVA STAR (Table 5.12) scores for research groups 1 and 2 when the scores in the medicated and non-medicated states were combined. As seen in Table 5.11 the IVA CPT scores were significantly lower ($p<0,05$) for research group 1 than for research group 2 for 17 of the 28 IVA scores. In Table 5.12 similar results indicate that the IVA STAR scores were significantly lower ($p<0,05$) for research group 1 than for research group 2 for 5 of the 11 IVA STAR scores. These results suggest that the deficits associated with the inattentive type of ADHD may be less severe than for the combined type of ADHD. This finding is corroborated when reviewing the DSM-IV criteria (American Psychiatric

Table 5.9: Results of ANOVA for determining the overall effect of medication on IVA CPT scores

	Medication		
IVA CPT scores	**Without medication**	**With medication**	**Comparison with and without medication**
	Mean (n= 11-18)	**Mean (n= 15-16)**	**Probability factor (p)**
Full Scale Control Quotient	94,45	96,73	0,2482
Auditory Response Control Quotient	88,44	95,00	0,0561
Visual Response Control Quotient	95,25	100,40	0,3644
Full Scale Attention Quotient	84,36	95,33	0,0003*
Auditory Attention Control Quotient	78,31	97,19	0,0017*
Visual Attention Control Quotient	88,08	91,20	0,0073*
Fine Motor Regulation / Hyperactivity	79,06	97,81	<,0001*
Response Control			
Auditory prudence	97,50	98,13	0,8913
Visual prudence	95,00	94,13	0,8402
Auditory consistency	84,19	91,06	0,1016
Visual consistency	96,42	100,53	0,2213
Auditory stamina	97,19	100,38	0,4181
Visual stamina	97,42	105,40	0,0707
Attention			
Auditory vigilance	76,38	99,50	0,0173*
Visual vigilance	93,92	96,20	0,1713
Auditory focus	87,13	89,44	0,3113
Visual focus	94,33	101,93	0,0852
Auditory speed	94,19	105,88	0,0062*
Visual speed	86,58	92,87	0,0652
Attribute			
Balance	115,46	117,80	0,5346
Auditory readiness	99,81	102,19	0,6196
Visual readiness	106,67	97,67	0,0308*
Validity			
Auditory comprehension	65,24	90,25	0,0037*
Visual comprehension	77,15	92,40	0,0067*
Auditory persistence	104,20	102,69	0,9778
Visual persistence	100,25	108,47	0,3963
Auditory sensory motor	105,50	105,44	0,7444
Visual sensory motor	89,50	85,73	0,3818

KEY:	
*	Significant difference at the 5% level of significance (Probability factor values (p)<0,05 = significant difference)

Table 5.10: Results of ANOVA for determining the overall effect of medication on IVA STAR scores

	Medication		
IVA STAR scores	**Without medication**	**With medication**	**Comparison with and without medication**
	Mean (n= 11-16)	**Mean (n= 15-16)**	**Probability factor (p)**
Primary Scales			
Auditory alertness	89,00	105,38	0,0268*
Visual alertness	96,75	98,20	0,6726
Auditory steadiness	74,13	98,69	0,0029*
Visual steadiness	90,92	95,53	0,0040*
Auditory promptness	95,13	107,50	0,0104*
Visual promptness	90,50	90,60	0,3119
Auditory constancy	91,44	101,38	0,0203*
Visual constancy	93,50	96,73	0,1754
Combined Scales			
Auditory specific	81,69	104,31	<,0001*
Visual specific	90,42	93,60	0,0797
Global (Auditory and Visual)	86,64	98,47	0,0074*
KEY:			
*	Significant difference at the 5% level of significance (Probability factor values (p)<0,05 = significant difference)		

Table 5.11: Results of ANOVA for determining whether differences occur between the overall IVA CPT scores of research groups 1 and 2

IVA CPT scores	Research group		
	Research group 1 (Combined type of ADHD)	Research group 2 (Inattentive type of ADHD)	Comparison of research groups 1 and 2
	Mean (%) (n= 11-15)	Mean (%) (n= 15-19)	Probability factor (p)
Full Scale Control Quotient	83,55	105,47	0,0012*
Auditory Response Control Quotient	77,54	101,42	<,0001*
Visual Response Control Quotient	86,67	107,27	0,0017*
Full Scale Attention Quotient	86,73	93,60	0,0128*
Auditory Attention Control Quotient	81,85	91,79	0,0062*
Visual Attention Control Quotient	84,08	94,40	0,1651
Fine Motor Regulation / Hyperactivity	76,20	97,11	0,0020*
Response Control			
Auditory prudence	82,92	108,00	<.0001*
Visual prudence	83,17	103,60	0,0233*
Auditory consistency	76,77	95,05	0,0002*
Visual consistency	88,00	107,27	0,0012*
Auditory stamina	96,15	100,58	0,2800
Visual stamina	101,58	102,07	0,5598
Attention			
Auditory vigilance	83,62	90,89	0,1225
Visual vigilance	92,83	97,07	0,0757
Auditory focus	77,69	95,53	0,0019*
Visual focus	90,25	105,20	0,0051*
Auditory speed	103,15	97,89	0,0048*
Visual speed	93,58	87,27	0,0490*
Attribute			
Balance	117,64	116,20	0,8715
Auditory readiness	93,54	106,10	0,0714
Visual readiness	98,50	104,20	0,4503
Validity			
Auditory comprehension	64,71	86,68	0,0168*
Visual comprehension	73,00	96,00	0,0024*
Auditory persistence	98,00	106,84	0,1073
Visual persistence	100,83	108,00	0,3213
Auditory sensory motor	106,62	104,68	0,2013
Visual sensory motor	94,00	82,13	0,0307*

KEY:

*	Significant difference at the 5% level of significance (Probability factor values (p)<0,05 = significant difference)

Table 5.12: Results of ANOVA for determining whether differences occur between the overall IVA STAR scores of research groups 1 and 2.

	Research group		
IVA STAR scores	**Research group 1 (Combined type of ADHD)**	**Research group 2 (Inattentive type of ADHD)**	**Comparison of research groups 1 and 2**
	Mean (%) (n= 11-13)	**Mean (%) (n= 15-19)**	**Probability factor (p)**
Primary Scales			
Auditory alertness	91,38	101,16	0,0243*
Visual alertness	96,25	98,60	0,2403
Auditory steadiness	82,69	88,95	0,2566
Visual steadiness	88,67	97,33	0,0046*
Auditory promptness	100,23	102,05	0,9655
Visual promptness	92,42	89,07	0,2587
Auditory constancy	88,69	101,68	0,0059*
Visual constancy	87,92	101,20	0,0588
Combined Scales			
Auditory specific	86,85	97,21	0,0028*
Visual specific	88,58	95,07	0,1321
Global (Auditory and Visual)	87,72	97,67	0,0368*

KEY:	
*	Significant difference at the 5% level of significance (Probability factor values (p)<0,05 = significant difference)

Association, 1994) (as outlined in Table 1.1) that require children with the combined type of ADHD to meet 6 or more of the symptoms of inattention, as well as 6 or more of the symptoms of hyperactivity-impulsivity. In contrast, children with the inattentive type of ADHD are only required to meet 6 or more of the symptoms of inattention listed in Table 1.1

5.3.3 The inter- and intra-group tendencies of the IVA CPT and IVA STAR scores for research groups 1 and 2 in the medicated and non-medicated state

The inter- and intra-group tendencies of the IVA CPT scores and IVA STAR scores for research groups 1 and 2 are presented in Table 5.13 and Table 5.14 respectively. A comparison of the IVA CPT scores of research group 1 (combined type of ADHD) in the medicated and non-medicated state (as seen in Table 5.13) show significantly higher scores (at the 5% level of significance) in the medicated state for 4 of the 28 IVA CPT scores and a significantly lower score for one of the IVA CPT scores. The significantly higher scores include 2 composite scores, namely the Full-scale attention quotient and the auditory attention control quotient, the Fine motor regulation/hyperactivity scores as well as one of the validity scores, namely Auditory comprehension. These findings suggest that the medication enhanced the attention of the participants in research group 1 and helped to reduce impulsive behaviors such as off-task behaviors with the mouse and random responses. Barkley (1998) and Chermak et al (1999) support the pharmacological management of the combined type of ADHD. Stimulant medication is thought to exert a therapeutic effect by enhancing executive function by facilitating dopamine transmission in the prefrontal cortex (Volkow et al, 2001).

The Visual sensory motor score of research group 1, one of the validity scores, showed a significant lower score (at the 5% level of significance) in the medicated state than in the non-medicated state as seen in Table 5.13.

Table 5.13: The inter- and intragroup tendencies of the IVA CPT scores for research groups 1 and 2 in the medicated and non-medicated state

	Research group 1 (Combined type of ADHD) n=10		Research group 2 (Inattentive type of ADHD) n=10	
	Mean Without medication (n= 4-8)	Mean With medication (n= 7)	Mean Without medication (n= 7-10)	Mean With medication (n= 8-9)
Full Scale Control Quotient	79,25(a)	86,00(a,b)	104,71(b)	106,13(b)
Auditory Response Control Quotient	72,67(a)	81,71(a)	97,90(b)	105,33(b)
Visual Response Control Quotient	76,60(a)	93,86(a)	108,57(b)	106,13(a,b)
Full Scale Attention Quotient	77,50(a)	92,00(b)	88,29(a,b)	98,25(b)
Auditory Attention Control Quotient	71,00(a)	91,14(b)	82,70(a)	101,89(b)
Visual Attention Control Quotient	80,80(a)	86,43(a)	93,29(a)	95,38(a)
Fine Motor Regulation / Hyperactivity	64,75(a)	89,29(b)	90,50(a)	104,44(c)
Response Control				
Auditory prudence	81,67(a)	84,00(a)	107,00(b)	109,11(b)
Visual prudence	76,40(a)	88,00(a)	108,29(a)	99,50(a)
Auditory consistency	72,33(a)	80,57(a)	91,30(b)	99,22(b)
Visual consistency	79,80(a)	93,86(a)	108,29(b)	106,38(a,b)
Auditory stamina	94,17(a)	97,86(a)	99,00(a)	102,33(a)
Visual stamina	95,20(a)	106,14(a)	99,00(a)	104,75(a)
Attention				
Auditory vigilance	69,17(a)	96,00(a)	80,70(a)	102,22(a)
Visual vigilance	87,60(a)	96,57(a)	98,43(a)	95,88(a)
Auditory focus	78,00(a)	77,43(a)	92,60(a,b)	98,78(b)
Visual focus	79,40(a)	98,00(a)	105,00(b)	105,38(a,b)
Auditory speed	95,83(a)	109,43(a,b)	93,20(a)	103,11(b)
Visual speed	91,80(a)	94,86(a)	82,86(a)	91,13(a)

Table 5.13 continued

	Research group 1 (Combined type of ADHD) n=10		Research group 2 (Inattentive type of ADHD) n=10	
	Mean Without medication (n= 4-8)	Mean With medication (n= 7)	Mean Without medication (n= 7-10)	Mean With medication (n= 8-9)
Attribute				
Balance	117,25(a)	117,86(a)	114,43(a)	117,75(a)
Auditory readiness	90,17(a)	96,43(a)	105,60(a)	106,67(a)
Visual readiness	104,80(a)	94,00(a)	108,00(a)	100,88(a)
Validity				
Auditory comprehension	47,57(a)	81,86(b)	77,60(a,b)	96,78(b)
Visual comprehension	57,83(a)	86,00(a)	93,71(b)	98,00(a,b)
Auditory persistence	104,60(a)	93,29(a)	104,00(a)	110,00(a)
Visual persistence	99,00(a)	102,14(a)	101,14(a)	114,00(a)
Auditory sensory motor	101,33(a)	111,14(a)	108,00(a)	101,00(a)
Visual sensory motor	103,20(a)	87,43(b)	79,71(b)	84,25(b)
KEY:				
a,b,c (Based on the groupings of the Scheffe's multiple comparisons test results)	The IVA CPT subtest scores with different alphabetic symbols are significantly different (at the 5% level of significance), while the IVA CPT subtest scores with the same alphabetic symbol show no significant difference (at the 5% level of significance). Comparisons are only applicable within each IVA CPT subtest and not between the different IVA CPT subtests			

Footnote:	
Age	No significant improvements were noted in the IVA CPT scores with increasing age (probability values >0,05). The probability values of each IVA CPT subtest are provided in Appendix XIV.
Order of test condition	A significant difference was noted for both "Balance" (probability value = 0,0176) and "Auditory prudence" (probability value = 0,0367). The participants' scores were higher for both "Balance" and "Auditory prudence" when the first condition was without medication and the second test condition was with medication. No significant differences were noted for the other IVA CPT scores (probability values >0,05). The probability values of each IVA CPT subtest are provided in Appendix XIV.

Table 5.14: The inter- and intragroup tendencies of the IVA STAR scores for research groups 1 and 2 in the medicated and non-medicated state

	Research group 1 (Combined type of ADHD) n=10		Research group 2 (Inattentive type of ADHD) n=10	
	Mean Without medication (n= 4-6)	Mean With medication (n= 7)	Mean Without medication (n= 7-10)	Mean With medication (n= 8-9)
Primary Scales				
Auditory alertness	76,83(a)	103,86(b)	96,30(a)	106,56(a,b)
Visual alertness	93,40(a)	98,29(a)	99,14(a)	98,13(a)
Auditory steadiness	67,00(a)	96,14(b)	78,40(a,b)	100,67(a,b)
Visual steadiness	82,00(a)	93,43(a)	97,29(a)	97,38(a)
Auditory promptness	92,33(a)	107,00(a)	96,80(a)	107,89(a)
Visual promptness	94,20(a)	91,14(a)	87,86(a)	90,13(a)
Auditory constancy	83,83(a)	92,86(a)	96,00(a)	108,00(a)
Visual constancy	84,20(a)	90,57(a)	100,14(a)	102,13(a)
Combined Scales				
Auditory specific	71,83(a)	99,71(b)	87,60(c)	107,89(b)
Visual specific	84,60(a)	91,43(a)	94,57(a)	95,50(a)
Global (Auditory and Visual)	76,50(a)	94,14(a)	92,43(a)	102,25(a)

KEY:	
a,b,c (Based on the groupings of the Scheffe's multiple comparisons test)	The IVA STAR subtest scores with different alphabetic symbols are significantly different (at the 5% level of significance), while the IVA STAR subtest scores with the same alphabetic symbol show no significant difference (at the 5% level of significance). Comparisons are only applicable within each IVA STAR subtest and not between the different IVA STAR subtests

Footnote:	
Age	No significant improvements were noted in the IVA STAR scores with increasing age (probability values >0,05). The probability values of each IVA STAR subtest are provided in Appendix XV.
Order of test condition	No significant differences were noted in the IVA STAR scores for the order effect in which the testing was done, i.e. whether the participants were tested with or without medication first. The probability values were all > 0,05. The probability values of each IVA STAR subtest are provided in Appendix XV.

The Visual sensory motor score is a measure of reaction time speed to simple, singular test stimuli and helps to screen for slow reaction times. The reason for a better score in the non-medicated state is not clear. It should, however, be noted that both the medicated and non-medicated visual sensory motor scores were above 85, reflecting functioning within the normal range for IVA CPT scores (Sandford and Turner, 2001)

A comparison of the IVA CPT scores of research group 2 (inattentive type of ADHD) in the medicated and non-medicated state (Table 5.13) shows significantly higher scores (at the 5% level of significance) in the medicated state for 3 of the 28 IVA CPT scores than in the non-medicated state. These scores include one composite score, namely the Auditory attention control quotient, the Fine motor regulation/hyperactivity score and the Auditory speed score (one of the primary attention scores). It is important to note here that the Fine motor-regulation/hyperactivity score and the Auditory speed score were already within the normal range for IVA CPT scores (>85) in the non-medicated state. Furthermore, the score for the Auditory attention control quotient in the non-medicated state was close to the normal range (85-115) with a score of 82,70. The value of stimulant medication for children with the inattentive type of ADHD (as seen in research group 2) presenting with IVA CPT scores within the normal range is questionable, as stimulant medication has also been reported to improve attention in normal children (Keller, 1998).

The inter-group comparisons of research groups 1 and 2 (Table 5.13) with and without medication show significantly higher scores (at the 5% level of significance) for research group 2 for 9 of the 28 IVA CPT scores in the non-medicated state, and 5 of the 28 scores in the medicated state. These results, again, suggest that the deficits associated with the inattentive type of ADHD are less severe than for the combined type of ADHD. This finding is corroborated when reviewing the DSM-IV criteria (American Psychiatric Association, 1994) (as outlined in Table 1.1) that require children with the combined type of ADHD to meet 6 or more of the symptoms of inattention, as well as 6 or more of the symptoms of hyperactivity-impulsivity. In contrast, children with the inattentive type of ADHD are only required to meet 6 or more of the symptoms of inattention listed in Table 1.1.

As seen in the footnote of Table 5.13 increases in age presented no significant differences in the IVA CPT scores. The probability values of each IVA CPT score are included as Appendix XIV. The consistency of the IVA CPT scores (showing no significant differences with increases in age) can be attributed to the fact that the IVA CPT quotient scores have a mean of 100 and a standard deviation of 15, the same as that used for most Intelligence Quotient (IQ) tests. The automated normative database (n=1700 normal individuals, ages 5-90+) thus takes gender and age into account and adjusts scores accordingly. Regarding the order of the test conditions (Table 5.13) significant differences ($p<0,05$) were noted for the Auditory prudence and Balance scores with participants presenting with higher scores in the medicated state when the first test condition was in the non-medicated state. "Auditory prudence" is a measure of response inhibition while "Balance" refers to whether the individual processes information more quickly visually aurally or equally. This finding suggests that some carry-over may have taken place for these scores between the first and second test conditions. No significant differences were noted for the other IVA CPT scores regarding the order of the test conditions, i.e. whether participants were tested in the medicated or non-medicated state first. The probability values for each IVA CPT score for the order of the test conditions are included as Appendix XIV.

The inter- and intra-group tendencies of the IVA STAR scores for research groups 1 and 2 are presented in Table 5.14. A comparison of the IVA STAR scores of research group 1 in the medicated and non-medicated state shows significantly higher scores (at the 5% level of significance) in the medicated state for 3 of the 11 IVA STAR scores, namely Auditory alertness, Auditory steadiness and the Auditory specific combined scale. Interestingly, all the IVA STAR scores for research group 1 (combined type of ADHD) are within the "normal range" (scores in the 85-115 range) in the medicated state. These findings suggest that the medication led to improved attention in the participants included in research group 1. Stimulant medication is thought to exert a therapeutic effect by enhancing executive function and thus attention by facilitating dopamine transmission in the prefrontal cortex (Volkow et al, 2001).

A comparison of the IVA STAR scores of research group 2 in the medicated and non-medicated state (Table 5.14) shows a significantly higher score (at the 5% level of significance) in the medicated state for only one of the 11 scores, namely the Auditory specific combined scale. It should, however, be noted that both the medicated and non-medicated Auditory specific combined scores were above 85, reflecting functioning within the normal range for IVA STAR scores (Sandford and Turner, 2001).

The inter-group comparisons of research groups 1 and 2 for the IVA STAR scores (Table 5.14) with and without medication show a significantly higher score (at the 5% level of significance) for only one of the 11 IVA STAR scores, namely the Auditory specific combined score in the non-medicated state but no significant differences for the medicated state. As discussed in Chapter 4, the IVA STAR scores provide additional information about attention. Based on the above results it appears that there are some similarities been the attention skills of research groups 1 and 2. As seen in the DSM-IV criteria (American Psychiatric Association, 1994), children with the combined type of ADHD present with behaviors of both inattention and hyperactivity, whereas children with the inattentive type of ADHD present with behaviors of inattention. Inattention is thus expected in children with both the combined and inattentive type of ADHD.

As seen in the footnote of Table 5.14 no significant differences were noted in the IVA STAR scores with increasing age. The probability values for each IVA STAR score are included as Appendix XV. The consistency of the IVA STAR scores (showing no significant differences with increases in age) can be attributed to the fact that the IVA STAR quotient scores have a mean of 100 and a standard deviation of 15, the same as that used for most Intelligence Quotient (IQ) tests. The automated normative database (n=1700 normal individuals, ages 5-90+) thus takes gender and age into account and adjusts scores accordingly. Regarding the order of the test conditions, no significant differences (p>0,05) were noted in the IVA STAR scores for the order in which the testing was done, i.e. whether participants were tested first in the medicated or non-medicated state. The order in which the specific multi-dimensional test battery was administered, namely the medicated or non-medicated state first, did not have a significant effect on the IVA STAR scores. The probability values for each IVA STAR score for the order of the test conditions are included as Appendix XV.

5.3.4 The IVA CPT and IVA STAR scores for the participant in research group 3 in the medicated and non-medicated state

The IVA CPT and IVA STAR scores for the participant in research group 3 in the medicated and non-medicated state are presented in Tables 5.15 and 5.16 respectively. As seen in Table 5.15, 16 of the 28 IVA CPT scores were lower than the "normal range" (85-115) for the non-medicated state, whereas only 12 of the 28 were lower in the medicated state. In Table 5.16, 7 of the 11 IVA STAR scores are lower than the "normal range" (85-115) for the non-medicated state whereas all the scores in the medicated state were within the normal range.

Table 5.15: The IVA CPT scores of the participant in research group 3

IVA CPT scores	Without medication	With medication
Full Scale Control Quotient	70*	46*
Auditory Response Control Quotient	63*	56*
Visual Response Control Quotient	83*	44*
Full Scale Attention Quotient	75*	90
Auditory Attention Control Quotient	84*	97
Visual Attention Control Quotient	75*	87
Fine Motor Regulation / Hyperactivity	83*	85
Response Control		
Auditory prudence	59*	40*
Visual prudence	89	53*
Auditory consistency	76*	74*
Visual consistency	84*	76*
Auditory stamina	85	90
Visual stamina	93	63*
Attention		
Auditory vigilance	80*	91
Visual vigilance	78*	89
Auditory focus	65*	62*
Visual focus	79*	73*
Auditory speed	126	142
Visual speed	88	109
Attribute		
Balance	156	152
Auditory readiness	69*	79*
Visual readiness	106	99
Validity		
Auditory comprehension	90	103
Visual comprehension	60*	83*
Auditory persistence	97	103
Visual persistence	87	91
Auditory sensory motor	122	121
Visual sensory motor	102	109

KEY:	
*	IVA CPT scores poorer than 85 (lower limit of the "normal range")

Table 5.16: The IVA STAR scores of the participant in research group 3

IVA STAR scores	Without medication	With medication
Primary Scales		
Auditory alertness	78*	92
Visual alertness	77*	89
Auditory steadiness	100	102
Visual steadiness	71*	85
Auditory promptness	105	131
Visual promptness	93	108
Auditory constancy	67*	92
Visual constancy	92	99
Combined Scales		
Auditory specific	82*	106
Visual specific	80*	94
Global (Auditory and Visual)	73*	100

KEY:	
*	IVA STAR scores poorer than 85 (lower limit of the "normal range")

The above results suggest that the scores of both the IVA CPT and the IVA STAR showed improvement in the medicated state, and thus support the recommendation of Barkley (1998) and Chermak et al (1999) that the use of stimulant medication be considered in the management of children with the hyperactive-impulsive type of ADHD. Further research, including a larger number of participants is, however, necessary to substantiate this finding.

Summarizing, to this point, the results of the study show that:

- Stimulant medication enhanced the performance of research group 1 (combined type of ADHD) and research group 3 (hyperactive-impulsive type of ADHD) on the continuous performance measures, but did not have a significant effect on the performance of children in research group 3 (inattentive type of ADHD). This supports the pharmacological management of the combined and hyperactive-impulsive types of ADHD (Barkley, 1998, Chermak et al, 1999), but suggests that the use of stimulant medication in children with the inattentive type of ADHD be carefully considered.

- The attention and impulsivity deficits observed in children with the three different types of ADHD (combined, hyperactive-impulsive and inattentive) appear to be supramodal in nature, i.e. deficits occur in both the auditory and visual modalities, as seen in the continuous performance measures. This finding supports Chermak et al's (1999) model of the supramodal nature of the deficits associated with ADHD.

- Stimulant medication appears to have a greater impact on the visual modality than for the auditory modality, as seen in the continuous performance measures. Sandford et al (1995) have suggested that different types of medication and treatment may be more effective for one modality than another.

5.4 AN ANALYSIS OF THE SPECIFIC MULTI-DIMENSIONAL TEST BATTERY RESULTS IN RELATION TO THE DIFFERENT TYPES OF ADHD AND SUBPROFILES OF CAPD.

The analysis of the specific multi-dimensional test battery results in relation to the different types of ADHD and subprofiles of CAPD entailed:

- an analysis of the CAPD test results of the participants in research groups 1, 2 and 3 in the medicated state in relation to the CAPD subprofiles as outlined in the Bellis/Ferre Model (Bellis, 1999)

- an analysis of IVA CPT results, obtained in the non-medicated state, using the IVA CPT procedural guidelines (Appendix XII) for the diagnosis of the different ADHD types

The CAPD results obtained in the medicated state were used to enable the researcher to obtain a more accurate reflection of the participants' central auditory processing, while controlling inattentive and hyperactive-impulsive behaviors, as recommended by Chermak et al (1999). The purpose of the analysis of the IVA CPT results was to determine the accuracy of the IVA CPT in correctly diagnosing the different types of ADHD in the participants included in the study. The IVA CPT results obtained in the non-medicated state were thus used. As discussed in Chapter 3, Chermak et al (1999) suggest that that the purpose of the testing be used to dictate whether children with ADHD are assessed in the medicated or non-medicated state.

5.4.1 Analysis of the CAPD test results of the participants in research groups 1, 2 and 3 in the medicated state in relation to the CAPD subprofiles as outlined in the Bellis/Ferre Model (Bellis, 1999).

The CAPD results of the individual participants are presented in Appendices XVI to XXVI and the summarized results of research groups 1, 2 and 3 presented in Table 5.17. The summarized results listing specific participants are included in Appendix XXVII.

As seen in Table 5.17, 4 of the 10 participants (40%) in *research group 1* met the requirements of the Output-organization subprofile, with 4 participants (40%) failing one or more of the CAPD tests but with no clear CAPD subprofile test pattern, and 2 participants (20%) presenting with CAPD results within the normal range.

It is interesting to note that a relatively high number of the participants (40%) in research group 1 met the requirements for the Output-organization subprofile of the Bellis/Ferre Model (Bellis, 1999). As discussed in Chapter 3, the Output-organization deficit is one of the two secondary subprofiles, with the other secondary subprofile being the Associative subprofile. The two secondary subprofiles have been seen to represent the gray area between audition, language and executive function and were thus differentiated from the primary subprofiles (namely, Auditory decoding deficit, Prosodic deficit and Integration

Table 5.17: The CAPD subprofiles of research group 1 (combined type of ADHD), research group 2 (inattentive type of ADHD) and research group 3 (hyperactive-impulsive type of ADHD) in the medicated state

	Research groups			
	Research group 1 (Combined group of ADHD) n = 10	Research group 2 (Inattentive group of ADHD) n = 10	Research group 3 (Hyperactive-impulsive group of ADHD) n = 1	Total
Auditory decoding deficit	0	0	0	0
Prosodic deficit	0	0	0	0
Integration deficit	0	0	0	0
Auditory associative deficit	0	0	0	0
Output/organization deficit	4	1	1	6
Failure on one / more CAPD tests but no clear test pattern suggesting a CAPD subprofile	4	5	0	7
CAPD results within the normal range	2	4	0	8
	10	10	1	21

deficit) (Bellis, 1999). The two secondary subprofiles have, interestingly, been found to yield definitive findings on central auditory assessment and thus included in the Bellis/Ferre Model (Bellis, 1999).

Recently Bellis (2003a) has questioned the inclusion of the secondary subprofiles and, in particular, the Output-organizational subprofile in the most recent version of the Bellis/Ferre Model (Bellis, 2003a). Bellis (2003b) suggests that the Output-organization subprofile more likely reflects an attention disorder than a CAPD. It is thus possible that future revisions of the Bellis/Ferre Model (Bellis, 2003a) may not include one or possibly both secondary subprofiles.

Stecker (1998) and Medwetsky (2002) have also suggested possible links between the Tolerance-fading memory category of the Buffalo Model (Katz et al, 1992) and ADHD. Individuals with the Tolerance-fading memory deficit are reported to present with similar characteristics to those with ADHD (Stecker, 1998, Medwetsky, 2002). Further research examining the possible links between the different types of ADHD, the CAPD categories of the Buffalo Model (Katz et al, 1992) and the CAPD subprofiles of the most recent version of the Bellis/Ferre Model (Bellis, 2003a) should yield further insights into the complexities and questions surrounding ADHD and CAPD in children.

As seen in Table 5.17, 1 of the 10 participants in research group 2 (10%) met the requirements for the Output-organization deficit CAPD subprofile, 5 of the 10 participants (50%) failed one or more of the CAPD tests but yielded no clear test pattern suggesting a CAPD subprofile, and for 4 of the 10 participants (40%) the CAPD results were within the normal range. The CAPD results of the 1 participant in research group 3 (Table 5.17) met the requirement of the Output-organization subprofile of the Bellis/Ferre Model (Bellis, 1999). As discussed above, Bellis (2003b) suggests that the Output-organization subprofile more likely reflects an attention disorder than a CAPD.

5.4.2 An analysis of the results obtained using the IVA CPT procedural guidelines for the diagnosis of the different ADHD types

The Integrated Visual and Auditory Continuous Performance Test Manual (Sandford and Turner, 2001) includes procedural guidelines based on the IVA CPT test scores to assist in the diagnosis of the different ADHD types. The 21 step procedural guidelines are included as Appendix XII.

The results of the above analysis for research groups 1, 2 and 3 are presented in Table 5.18. A more detailed analysis in terms of the specific participants is included in Appendix XXVIII.

As seen in Table 5.18, 5 of the 10 participants (50%) in research group 1 were correctly identified as having the combined type of ADHD, 2 of the 10 participants (20%) were incorrectly classified as having the inattentive type of ADHD, and 3 of the 10 participants (30%) presented with low test validity and a low fine motor regulation score. These results suggest a low "hit-rate" (50%) in the efficacy of the IVA in correctly diagnosing the combined type of ADHD. If the scores of the 3 participants in research group 1 with the low test validity and low fine motor regulation scores are ascribed to particularly severe manifestations of inattention and hyperactivity-impulsivity, then it is possible to reason that the "hit-rate" is 80% but that the severity of the disorder prevents classification of a specific ADHD type as suggested by Sandford and Turner (2001) in the Integrated Visual and Auditory Continuous Performance Test Manual. Sandford and Turner (2001) suggest that low comprehension scales despite cooperation from the individual being tested, can be ascribed to severe ADHD and/or difficulty in shifting mental focus between the two modalities.

Table 5.18: IVA CPT procedural guidelines for assisting in the diagnosis of ADHD types using scores obtained in the non-medicated state.

	Research groups			
ADHD type according to the IVA procedural guidelines	Research group 1 (Combined group of ADHD) n = 10	Research group 2 (Inattentive group of ADHD) n = 10	Research group 3 (Hyperactive-impulsive group of ADHD) n = 1	Total
Combined type of ADHD	5	1	1	7
Inattentive type of ADHD	2	3	0	5
Hyperactive-impulsive type of ADHD	0	0	0	0
No ADHD	0	6	0	6
Other – low test validity and a low fine motor regulation score	3	0	0	3
	10	10	10	21

The results of research group 2 (Table 5.18) show that 1 of the 10 participants (10%) were incorrectly identified as having the combined type of ADHD according to the IVA CPT procedural guidelines. Three of the 10 participants (30%) were correctly identified as having the inattentive type of ADHD and 6 of the 10 participants (60%) were incorrectly identified as having no ADHD.

As seen in Table 5.18, the 1 participant in research group 3 was incorrectly identified as having the combined type of ADHD.

To summarize, the above results suggest that the IVA CPT has an 80% correct "hit-rate" for the combined type of ADHD (when low test validity and low fine motor regulation scores are also ascribed to particularly severe manifestations of inattention and hyperactivity-impulsivity), a 30% correct "hit-rate" for the inattentive type of ADHD and a 0% correct "hit-rate" for the hyperactive impulsive type of ADHD (though it should be remembered that only 1 participant with the hyperactive impulsive type of ADHD was included in the study).

The American Academy of Pediatrics (2000) does not endorse the routine use of tests of continuous performance at this time and reports that continuous performance tests have a 70% sensitivity and specificity for ADHD. The results of this study support the reported 70-80% "hit-rate" for the combined type of ADHD, but the "hit-rate" for the inattentive and hyperactive impulsive types of ADHD was much lower. A limited number of participants were, however, included in the study and further research is necessary to substantiate these findings.

The American Academy of Pediatrics (2000) also expresses concern over the significant variations that occur between tests of continuous performance relating to the modality of the presentation, the type of target, the assessment of errors as well as the speed of the stimuli presentation. Kane and Whiston (2001) suggest that the inclusion of both visual and auditory attention measures in a single administration provides the IVA CPT (Sandford and Turner, 2001) used in this study with an advantage over other commercially available test materials. In addition, the scoring is computerized, removing the element of human error and by providing a number of scale quotients; the IVA CPT attempts to measure the multi-dimensionality of attention (Kane and Whiston, 2001).

Physicians are thus recommended to apply the DSM-IV criteria (American Psychiatric Association, 1994) in diagnosing ADHD at this time, though tests of continuous performance can be additionally considered (American Academy of Pediatrics, 2000).

Summarizing, to this point, the results of the study show:

- The analysis of the CAPD test results of the participants in the different research groups, in relation to the subprofiles outlined by Bellis (1999), suggest that a relatively high number (40%) of participants diagnosed with the combined type of ADHD also met the requirements for the Output-organization subprofile. It is not clear whether these two disorders reflect the same disorder or whether there is, perhaps, a higher co-occurrence of these disorders. Bellis (2003b) suggests that the Output-organization subprofile more likely reflects an attention disorder than a CAPD.

- The analysis of the specific multi-dimensional test battery results in relation to the IVA CPT procedural guidelines for diagnosing the different types of ADHD suggests that the IVA CPT has an 80% sensitivity for the combined type of ADHD (when low test validity and low fine motor regulation scores are also ascribed to particularly severe manifestations of inattention and hyperactivity-impulsivity), a 30% sensitivity for the inattentive type of ADHD and a 0% sensitivity for the hyperactive-impulsive type (though it should be remembered that only one participant with this type of ADHD was included in the study). The American Academy of Pediatrics (2000) has reported that tests of continuous performance have a 70% sensitivity and specificity for ADHD but do not differentiate between the different types of ADHD in their report.

5.5 SUMMARY OF CHAPTER 5

In Chapter 5 the results of the study are presented and discussed according to the formulated sub-aims. The discussion entails a comparison of the inter- and intra-group tendencies of central auditory processing and continuous performance of the three research groups in the medicated and not medicated state. The results of the specific multi-dimensional test battery are analyzed in relation to the different types of ADHD and subprofiles of CAPD. The results of the study are discussed against the background of the literature. A brief summary of the results is presented at the end of each section, namely 5.2, 5.3 and 5.4.