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The Central Auditory Processing and Continuous Performance of children with Attention Deficit Hyperactivity Disorder (ADHD) in the medicated and non-medicated state

By

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Submitted in partial fulfilment of the requirements for the Degree DPhil: Communication Pathology, Faculty of Humanities, University of Pretoria, Pretoria

May 2003

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ACKNOWLEDGEMENTS

Dedicated to children with Attention Deficit Hyperactivity Disorder and their families

I would like to thank the following people:

Prof. Erna Alant, my supervisor and mentor, an exemplary academic role model and researcher, for the privilege of completing this dissertation under her guidance.

Prof. Teri Bellis (University of South Dakota, USA), my co-supervisor and a leading international expert in the field of CAPD, for her expertise and invaluable guidance.

Prof. Gail Chermak (Washington State University, USA) and Dr Wayne Wilson (University of Queensland, Australia), the external examiners of the dissertation, for their invaluable comments and recommendations.

The Mellon Foundation Mentoring Program for awarding the Mellon Award to Prof. Alant and myself for three consecutive years.

The school, and in particular the children, who took part in this study.

Mr J. Grimbeek and Mrs E. Mauer for the statistical analysis of the data.

Mrs Hester Bezuidenhout for her expertise with the typographical layout.

Mrs E. Maritz for her expertise with the editorial care.

My colleagues and friends in the Department of Communication Pathology and at the Pretoria Cochlear Implant Program, in particular Prof. Brenda Louw, Mrs. Glenn Goldblum, Mrs. Anna-Marie Wium, Mrs. Nellie Venter, Mrs. Lidia Pottas, Mrs. Maggi Soer, Dr Odette Guy, and Dr Dunay Schmulian.

My husband and best friend, Alister, and our much loved children, Cara and Neil, for believing in me and creating a happy, relaxed and supportive work environment in our home.

My parents, Nicholas and Elero, for their loving support and fostering a passion for books and learning in me from a tender age. My brothers, Nico, Stephan, André and their families, and well as my family-in-law for their continued support through the years.

My many good friends for their support and interest in this study.

Knowledge is proud that he has learned so much;
Wisdom is humble that he knows no more
(Cowper, 2000: 1)

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ABSTRACT

Title:	*The Central Auditory Processing and Continuous Performance of children with Attention Deficit Hyperactivity Disorder (ADHD) in the medicated and non-medicated state*
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Attention Deficit Hyperactivity Disorder (ADHD), the most commonly occurring neurobehavioral disorder in children, has received increasing attention in the past decade. The lack of congruity in defining ADHD as a disorder has lead to controversy surrounding the prevalence, diagnosis and treatment of ADHD in children. This lack of congruity is reflected in the wide variations in the diagnostic tools and criteria currently employed by different professionals in different clinical settings across countries in diagnosing ADHD.

Recently, there has been a shift in conceptualising ADHD as a behavioral regulation or executive function disorder rather than a primary attention disorder. It has also been suggested that tests of central auditory processing and continuous performance may be helpful in differentiating between ADHD and Central Auditory Processing Disorders (CAPD).

The aim of the research was to determine the central auditory processing and continuous performance patterns of children with ADHD in the medicated and non-medicated state. Three research groups were used to represent the three different types of ADHD (as outlined in the Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition (DSM-IV) of the American Psychiatric Association, 1994). Research group 1 consisted of 10 participants with the combined type of ADHD, research group 2 consisted of 10 participants with the predominantly inattentive type of ADHD, and research group 3 consisted of one participant with the predominantly hyperactive-impulsive type of ADHD.

A Between group (combined ADHD group, inattentive ADHD group and hyperactive-impulsive ADHD group) within-subjects design was used for two test conditions (with and without medication). The test conditions were counterbalanced to control for the order effect of the test conditions. A specific multi-dimensional test battery comprising of the CAPD test battery (recommended by Bellis and Ferre, 1999) and the Integrated Visual and Auditory Continuous Performance Test (IVA CPT) (Sandford and Turner, 2001) was administered to the participants in the medicated and non-medicated state. The SAS Program (SAS Institute Inc., 1999) was used in the statistical analysis of the results.

The results of the study show that:

- The incidence of the hyperactive-impulsive type of ADHD in children appears to be lower than for the combined and inattentive types of ADHD.

- Children with ADHD perform normally or poorly across all measures of CAPD, or with no clear error pattern emerging in the test results that can be linked to the primary subprofiles of CAPD. Some overlap was, however, noted between ADHD and one of the secondary subprofiles of CAPD.

- The attention and impulsivity deficits observed in children with the three different types of ADHD are supramodal in nature.

- Stimulant medication enhanced the performance of the children with the combined and hyperactive-impulsive types of ADHD on both the CAPD test battery and the IVA CPT, but did not appear to have a significant effect on the performance of children with the inattentive type of ADHD.

The results of the study thus provide some insights into the theoretical constructs underlying the three different types of ADHD and guidelines for clinical management. The importance of congruity in defining ADHD is underscored.

KEY WORDS: Attention Deficit Hyperactivity Disorder (ADHD), Inattention, Hyperactivity, Impulsivity, Central Auditory Processing Disorders (CAPD), Continuous performance, Stimulant medication, Medicated and non-medicated state, Executive dysfunction, Hyperkinetic disorder.

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OPSOMMING

Titel: *"The Central Auditory Processing and Continuous Performance of children with Attention Deficit Hyperactivity Disorder (ADHD) in the medicated and non-medicated state"*

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Aandagafleibare Hiperaktiwiteits Afwyking (AHA), die mees algemene neurogedragsafwyking onder kinders, het toenemend meer aandag ontvang oor die afgelope dekade. Die gebrek aan ooreenstemming in die definiëring van AHA het gelei tot kontroversie met betrekking tot die prevalensie, diagnose en behandeling van kinders met AHA. Hierdie gebrek aan ooreenstemming word weerspieël in die groot verskeidenheid diagnostiese middels en kriteria wat tans gebruik word deur verskillende professionele persone in verskeie kliniese kontekste in verskillende lande in die diagnose van AHA.

Onlangs het veranderings begin onstaan in die konseptualisering van AHA as `n gedragsregulerings- of `n uitvoerendefunksie-afwyking, eerder as `n primêre aandagafleibare-afwyking. Daar word voorgestel dat toetse vir die evaluering van sentrale ouditiewe prosessering en volgehoue uitvoering moontlik waardevol kan wees in die differensiëring tussen AHA en Sentrale Ouditiewe Prosesserings Afwykings (SOPA).

Die doel van die navorsing was om die sentrale ouditiewe prosessering en volgehoue uitvoeringspatrone van kinders met AHA met en sonder medikasie te bepaal. Drie navorsingsgroepe verteenwoordigend van die drie verskillende tipes AHA (soos uiteengesit in die "Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition (DSM-IV)" van die "American Psychiatric Association", 1994) is gebruik. Navorsingsgroep 1 het bestaan uit 10 deelnemers met die gekombineerde tipe AHA, navorsingsgroep 2 het bestaan uit 10 deelnemers met die oorwegend aandagafleibare tipe van AHA, en navorsinggroep 3, uit 1 deelnemer met die oorwegend hiperaktief-impulsiewe tipe AHA.

`n Tussengroep (gekombineerde AHA groep, aandagafleibare AHA groep en `n hiperaktief-impulsiewe AHA groep) binne-deelnemersontwerp is gebruik vir twee toestande (met en sonder medikasie). Die toetstoestande is teen mekaar opgeweeg om beheer uit te oefen oor die volgorde-effek van die toetsomstandigehede. `n Spesifieke multi-dimensionele toetsbattery bestaande uit `n SOPA toetsbattey (soos aanbeveel deur Bellis en Ferre, 1999) en die "Integrated Visual and Auditory Continuous Performance Test (IVA CPT)" (Sandford en Turner, 2001) is toegepas op die deelnemers met en sonder medikasie. Die SAS Program ("SAS Institute Inc.", 1999) is gebruik vir die statistiese analise van die resultate.

Die resultate van die studie toon die volgende:

- Die insidensie van die hiperaktief-impulsiewe tipe AHA onder kinders is laer as vir die gekombineerde en aandagafleibare tipes AHA.

- Kinders met AHA presteer normaal of swakker oor alle metings van SOPA, of toon andersins geen duidelike foutpatroon in die toetsresultate wat gekoppel kan word aan die primêre SOPA subprofiele. Daar is egter `n mate van oorvleueling tussen AHA en een van die sekondêre subprofiele.

- Die aandag- en impulsiwiteitsafwykings wat waargeneem word by kinders met die drie tipes AHA is supramodaal van aard.

- Stimulant medikasie het die prestasie van kinders met die gekombineerde en hiperaktief-impulsiewe tipes AHA verbeter op die SOPA toetsbattery asook die "IVA CPT", maar het nie `n betekenisvolle verskil gehad op die prestasie van kinders met die aandagsfleibare tipe AHA nie.

Die resultate van die studie verskaf sekere insigte in die teoretiese konstrukte onderliggend aan die drie tipes AHA asook riglyne vir kliniese hantering. Die belang van ooreenstemming in die definiëring van AHA word onderstreep.

SLEUTELWOORDE: Aandagafleibare Hiperaktiwiteits Afwyking (AHA), Hiperaktiwiteit, Impulsiwiteit, Sentrale Ouditiewe Prosesserings Afwykings (SOPA), Volgehoue uitvoering, Stimulant medikasie, Met en sonder medikasie, Uitvoerendefunksie-afwyking, Hiper-kinetiese afwyking.

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LIST OF ABBREVIATIONS

ADHD	Attention Deficit Hyperactivity Disorder
CAPD	Central Auditory Processing Disorder
dB	Decibel
dBSL	Decibel Sensation Level
dBSPL	Decibel Sound Pressure Level
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 1994)
Hz	Hertz
ICD-10	International Classification of Diseases-Tenth Edition (World Health Organization, 1992)
IQ	Intelligent Quotient
IVA CPT	Integrated Visual and Auditory Continuous Performance Test (Sandford and Turner, 2001)
IVA STAR	Integrated Visual and Auditory STAR (a narrative report writer for the IVA CPT)
MLD	Masking Level Difference
SA	South Africa
SABS	South African Bureau of Standards

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION AND RATIONALE

Attention Deficit Hyperactivity Disorder (ADHD), the most commonly occurring neurobehavioral disorder in children (Chermak, Hall III and Musiek, 1999) has received increasing attention in the past decade. Professional and public interest has increased along with debate in the media concerning the diagnostic process and treatment strategies used for children with ADHD (Gibbs, 1998). Particular concern has been expressed regarding the perceived over-diagnosis of ADHD pointing to the dramatic increase in prescriptions for stimulant medication among children in recent years (Safer, Zito and Fine, 1996, American Academy of Pediatrics, 2000). In addition, the significant variations in the type and amount of stimulants prescribed, as well as wide variations in the diagnostic methods and criteria currently employed, are questioned (American Academy of Pediatrics, 2000).

At the heart of the controversy lies the lack of congruity in defining ADHD as a disorder. The defining characteristics of children with ADHD in both clinical practice and many research studies have been subjective, poorly defined, frequently changing and disconnected from any theoretical construct or empirical base (Chermak and Musiek, 1997). This has lead to controversy concerning the etiology and prevalence of ADHD (and the different types of ADHD), and also the value of different assessment methods and treatment options in the management of children with ADHD.

The two primary diagnostic criteria classification systems used in diagnosing ADHD are the Diagnostic and Statistical Manual of Mental Disorders – Fourth edition (DSM-IV) (American Psychiatric Association, 1994) that is used in North America and Australia and the International Classification of Diseases – Tenth edition (ICD-10) (World Health Organization, 1992) that is used in Europe and the United Kingdom. The term ADHD used in North America refers to children with a consistent pattern of inattention and/or hyperactivity with an onset early in childhood (Chermak et al, 1999, American Academy of Pediatrics, 2000). The DSM-IV criteria (American Psychiatric Association, 1994) used in diagnosing ADHD, differentiate between three different types of ADHD, namely the combined type, the inattentive type and the hyperactive-impulsive type. In contrast, the term Hyperkinetic Disorder (based on the ICD-10 criteria of the World Health Organization (1992) used in Europe and the United Kingdom) is characterized by the early onset of both overactive and inattentive behaviors (McConnell, 1997). The Combined type of ADHD (DSM-IV criteria) thus shows some similarity to Hyperkinetic Disorder (ICD-10 criteria). This may explain the lower prevalence (1-2%) of Hyperkinetic Disorder in comparison with ADHD in children (reported prevalence rates vary from 3-9%) and may explain the perceived over-diagnosis of overactive and inattentive behavior in children and consequently the perceived over-prescription of stimulant medication in North America (McConnell, 1997).

Adding to the above controversy is the fact that, despite efforts to standardize the defining characteristics specified in the DSM-IV, these characteristics remain subjective and may be interpreted differently by different observers (American Academy of Pediatrics, 2000). Additionally, there is an increasing trend to use a wide variety of diverse teacher questionnaires and rating scales in diagnosing ADHD in children (American Academy of Pediatrics, 2000). These questionnaires and rating scales include both commercially available materials and clinic-based materials. Although questionnaires and rating scales may be useful for acquiring additional information, the American Academy of Pediatrics (2000) does not endorse the sole use of these measures in the diagnosis of ADHD in children.

The diagnosis of ADHD in children is further complicated by the variety of other psychological and developmental disorders that frequently co-exist with ADHD. As many as one third of children with ADHD, have a co-existing disorder such as conduct defiant disorder, depression, anxiety disorder, speech and language impairment, learning disability and/or central auditory processing disorder (American Academy of Pediatrics, 2000).

Differentiating between ADHD and Central Auditory Processing Disorders (CAPD) is a particular challenge for professionals as both groups are heterogeneous in nature and yet present with many similar characteristics (Keller, 1998, Chermak et al, 1999). Children diagnosed with ADHD are frequently reported to present with difficulties on tasks that challenge the central auditory nervous system (Chermak et al, 1999, Copeland, 2002). It has been proposed that CAPD and ADHD may even reflect a singular disorder (Gason, Johnson and Burd, 1986, Keller, 1998). The observed co-morbidity of CAPD and ADHD most likely reflects a shortcoming in the theoretical constructs of these disorders, as well as the diagnostic criteria and procedures used in differentiating ADHD and CAPD.

In the literature there are three opposing theoretical schools of thought regarding the conceptualization of ADHD and CAPD. In the first school of thought, CAPD is considered to be a specific disorder of the auditory modality, while ADHD is suspected to be supramodal in nature. Included in this school of thought is the model of McFarland and Cacace (1995) who view auditory modality specificity as a criterion for diagnosing CAPD, and recommend using similar tasks in multiple (auditory and visual) sensory modalities to differentiate between auditory specific and supramodal disorders. In the second school of thought, CAPD is viewed as an auditory specific deficit but the possible existence of co-existing multimodality symptoms based on a shared neurophysiological site of dysfunction is acknowledged. In contrast, ADHD is ascribed to executive dysfunction and thought to be supramodal in nature. In this school of thought there are three models, namely the model of Chermak et al (1999), the Bellis/Ferre Model (Bellis, 2003a) and the model of Barkley (1998). Finally, in the third school of thought, CAPD is not viewed as an auditory modality specific disorder but rather as a multimodal disorder. Included in this school of thought is the Buffalo Model of Katz, Smith and Kurpita (1992).

Although the above three opposing theoretical schools of thought provide some interesting hypotheses and insights into ADHD and CAPD in children, research is required in order to validate that the deficits associated with the three different types of ADHD are supramodal in nature, as suggested by McFarland and Cacace (1995), Chermak et al (1999) and Bellis (2003a). McFarland and Cacace (1995) recommend using similar tasks in multiple (auditory and visual) sensory modalities to differentiate between auditory specific and supramodal disorders. There are a number of commercially available tests of continuous performance that assess either the visual or the auditory modality such as The Auditory Continuous Performance Test and The Visual Continuous Performance Test compiled by Morris, O'Neil, Crawford and Mockler (Riccio, Reynolds and Lowe, 2001). The Integrated Visual and Auditory Continuous Performance Test (IVA CPT) (Sandford and Turner, 2001) has an advantage over other commercially available tests as it combines both auditory and visual stimuli into a single measure (Kane and Whiston, 2001). Further research using a measure such as the IVA CPT (which combines both auditory and visual stimuli) could provide valuable insights into the nature of the deficits associated with ADHD.

Research is also necessary to determine the value of tests of CAPD in differentiating between ADHD and CAPD in children. Bellis and Ferre (1999) and Bellis (2003a) have suggested that tests of CAPD may be useful in differentiating between ADHD and CAPD and suggest that children with ADHD can be expected to perform normally or poorly across all measures of CAPD, with no clear error patterns that can be linked to the CAPD subprofiles. Bellis and Ferre (1999), however, do not differentiate between the different types of ADHD.

Further research examining the central auditory processing of the three different types of ADHD, namely the combined type, the inattentive type and the hyperactive-impulsive type, is warranted and may provide a new understanding of the relationship/s between ADHD and CAPD and the theoretical constructs underlying these disorders.

By compiling a "specific multi-dimensional test battery", comprising of a measure of (auditory and visual) continuous performance and a CAPD test battery to assess children diagnosed with the three different types of ADHD, it is possible that new insights may develop into the theoretical constructs underlying ADHD. The term "specific multi- dimensional test battery", as used here, encompasses two concepts, namely "specific" and "multi-dimensional". The concept "specific" refers to specific measures of both central auditory processing and continuous performance. The term "multi-dimensional" refers to the complexity and diversity of the factors being considered, namely both central auditory processing, and auditory and visual continuous performance.

An important consideration in administering the above, specific multi-dimensional test battery, is the decision of whether tests of CAPD and continuous performance should be administered to children with ADHD in the medicated or non-medicated state. Chermak et al (1999) suggest that the purpose of the testing should guide the decision of whether the testing takes place in the medicated or non-medicated state. For example, by administering tests of CAPD in the medicated state to children with ADHD, aspects such as attention can be controlled, thus providing a more accurate representation of the child's central auditory processing abilities. If, on the other hand, the purpose of the testing is to determine the child's attention and vigilance (continuous performance), then, testing the child in the non-medicated state would be more appropriate. If, however, the purpose of the testing is to determine the effect of medication on the child's functioning, then testing in the medicated state, or at least a comparison of the child's functioning in both the medicated and non-medicated state, is recommended. By assessing children in both the medicated and non-medicated state, information can be gleaned about the central auditory processing abilities of children diagnosed with the three different types of ADHD, the nature of the deficits associated with ADHD (i.e. supramodal or modality-specific), as well as the effect of medication on the children's functioning.

The above controversy surrounding the diagnosis of ADHD is also reflected in the management of ADHD in children. The American Academy of Pediatrics (2001) recommends the use of stimulant medication and/or behavioral therapy (modifying the environment to alter or change behavior) in the treatment of children with ADHD. Stimulant medication is thought to exert a therapeutic effect by enhancing executive function by facilitating dopamine transmission in the prefrontal cortex (Volkow, Wang, Fowler, Logan, Gerasimov, Maynard, Ding, Gatley, Gifford, and Franceschi, 2001). Unlike most other medications, stimulant dosages are not weight dependent and dosing schedules should be carefully determined and monitored in each child (American Academy of Pediatrics, 2001). Chermak et al (1999) have suggested that the recent conceptualization of the combined and hyperactive-impulsive types of ADHD as an executive dysfunction supports the pharmacological management of these disorders. In contrast, Chermak et al (1999) view the inattentive type of ADHD as a processing disorder and have suggested that stimulant medication may not necessarily be the most effective form of treatment in this group of children. Further research is required to determine the value of stimulant medication in treating the different types of ADHD.

Against this background the rationale underlying the study is to determine the central auditory processing and the (auditory and visual) continuous performance of children diagnosed with the three different types of ADHD in the medicated and non-medicated state. It is hoped that the results of the study will provide new insights into the theoretical construct underlying ADHD, assist in the validation of ADHD as a disorder, and provide guidelines for the management of ADHD in children.

1.2 DEFINITION OF TERMINOLOGY

In order to facilitate understanding of the fundamental issues of the study and avoid misunderstanding, it is necessary to define the terminology used in the study. The terms that will be defined in this section are "Attention Deficit Hyperactivity Disorder" (ADHD), "Central Auditory Processing Disorder" (CAPD), "Continuous performance", and a "Specific multi-dimensional test battery".

1.2.1 Attention Deficit Hyperactivity Disorder (ADHD)

The two primary diagnostic classification systems used in diagnosing ADHD are the DSM-IV criteria (American Psychiatric Association, 1994) used in North America and Australia and the ICD-10 (World Health Organization, 1992) used in Europe and the United Kingdom. The term ADHD used in North America refers to children with a consistent pattern of inattention and/or hyperactivity with an onset early in childhood (Chermak et al, 1999, American Academy of Pediatrics, 2000). The DSM-IV criteria used in diagnosing ADHD differentiate between three different types of ADHD, namely the combined type, the inattentive type and the hyperactive-impulsive type. In contrast, the term Hyperkinetic Disorder (based on the ICD-10 criteria used in Europe and the United Kingdom) is characterized by the early onset of both overactive *and* inattentive behaviors (McConnell, 1997). The Combined type of ADHD (DSM-IV criteria) thus shows some similarity to Hyperkinetic Disorder (ICD-10 criteria).

ADHD consists of a persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequent and severe than is typically observed in individuals at a comparable level of development; manifests in at least two settings; interferes with developmentally appropriate social, academic, or occupational functions; and presents before age 7 years (American Psychiatric

Association, 1994). Patterns of inattention, hyperactivity and impulsivity are used to differentiate between the three different types of ADHD (American Psychiatric Association, 1994). The predominantly inattentive type presents primarily with symptoms of inattention. The predominantly hyperactive-impulsive is considered a behavioral regulation disorder and the combined type is characterized by both hyperactivity-impulsivity and inattention. The criteria for the diagnosis of the three different types of ADHD, as stipulated by the American Psychiatric Association (1994), are presented in Table 1.1. The DSM-IV criteria for the diagnosis of the different types of ADHD require the presence of six or more symptoms of inattention and/or hyperactivity-impulsivity persisting for 6 or more months. The combined type of ADHD meets criteria A and B, as outlined in Table 1.1, the predominantly inattentive type meets criterion A, but not B, and the predominantly hyperactive-impulsive type meets criterion B, but not A.

Although the broader diagnostic criteria of the DSM-IV (American Psychiatric Association, 1994) will primarily be used in the study, the results will also be considered against the background of the ICD-10 criteria (World Heath Organization, 1992).

1.2.2 Central Auditory Processing Disorder (CAPD)

Consensus on a definition of CAPD has plagued audiologists and other interested professionals for decades, with much disagreement among factions and disciplines (Bellis, 1999, Bellis, 2003a).

Definitions of CAPD have, according to Bellis (1999), ranged from the very general (i.e., "What we do with what we hear", Katz, 1992) to the very specific (i.e., an auditory modality-specific deficit in bottom-up processing of acoustic features of speech, McFarland and Cacace, 1995).

Table 1.1: DSM-IV Criteria for diagnosis of the different types of ADHD (American Psychiatric Association, 1994)

A. Inattention
1. Poor attention to details or careless mistakes
2. Difficulty sustaining attention in tasks
3. Does not seem to listen when spoken to
4. Does not follow through on instructions and tasks
5. Difficulty organizing tasks
6. Difficulty with sustained mental effort
7. Loses things necessary for tasks
8. Often distracted by extraneous stimuli
9. Often forgetful in daily activities
B. Hyperactivity-Impulsivity
Hyperactivity
1. Fidgets or squirms
2. Leaves seat in classroom
3. Runs or climbs excessively
4. Difficulty in engaging in quiet activity
5. "On the go" or acts as if "driven by a motor"
6. Talks excessively
Impulsivity
7. Blurts out answers
8. Difficulty waiting turn
9. Interrupts or intrudes on others

The ASHA Task Force on Central Auditory Processing Consensus Development (1996: 41) recognized this dilemma and convened a task force who collaborated and defined CAPD as "an observed deficiency in one or more of the following processes:

- Sound localization and lateralization
- Auditory discrimination
- Auditory pattern recognition
- Temporal aspects of audition, including
  - temporal resolution
  - temporal masking
  - temporal integration
  - temporal ordering

- Auditory performance decrements with competing acoustic signals
- Auditory performance decrements with degraded acoustic signals".

Chermak et al (1999) further refined the above definition by adding the central auditory processes responsible for generating the auditory evoked potentials. Chermak et al (1999: 290) define CAPD as "a deficit in one or more of the central auditory processes responsible for generating the auditory evoked potentials and the behaviors of sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal processing (for example, temporal resolution, temporal masking, temporal integration, and temporal ordering), auditory performance with competing acoustic signals, and auditory performance with degraded acoustic signals".

Although the above definitions succeed in isolating audition into some of its constituent behaviors, both definitions fail to uncover underlying mechanisms responsible for these behaviors. These definitions also fail to acknowledge the possible interdependency and/or linkages between these behaviors and difficulties in listening, language, learning and communication (Bellis, 1999, Bellis, 2003a). Finally, Jerger (1998) criticizes the definitions, as they do not provide a sufficient conceptual framework for understanding CAPD as a phenomenon.

Based on the above discussion, the definitions of CAPD proposed by the ASHA Task Force on Central Auditory Processing Consensus Development (1996) and Chermak et al (1999) as well as the criticisms of Jerger (1998) and Bellis (1999, 2003a), the following integrated definition of CAPD will be used in the study:

> *CAPD refers to a breakdown in the auditory modality, and more specifically of the central auditory processes, attributable to central nervous system pathology and/or the functioning of these pathways, usually in the absence*

of a peripheral hearing impairment, which may co-exist with high level complex behaviors such as listening, language and learning based on the interconnectedness of the central nervous system.

The above central auditory processes refer to those processes which are responsible for generating auditory evoked potentials as well as the behaviors responsible for sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal processing, and auditory performance with degraded acoustic signal and in the presence of competing acoustic signals.

Although it is recognized that CAPD may occur in individuals with a peripheral hearing impairment, the participants included in this study were required to have intact peripheral hearing. The motivation for this decision (which is discussed in greater depth in Chapter 4) is to insure a more homogeneous participant population, representative of children typically presenting with CAPD in the clinical situation.

Finally, the term Central Auditory Processing Disorder (CAPD) rather than Auditory Processing Disorder (APD) will be used in this study despite the recommendations made by Jerger and Musiek (2000) at the Consensus Conference on the Diagnosis of Auditory Processing Disorders in School-Aged Children held in Dallas in April 2000. Jerger and Musiek (2000: 3) suggested that the term APD might be more "in keeping with the goals of maintaining operational definitions, avoiding the imputation of anatomical loci, and emphasizing the interactions of disorders at both peripheral and central sites". While the term APD may emphasize the interactions between the peripheral and central sites, it hazes the differentiation between CAPD and auditory neuropathy (a functional disorder of the inner hair cells of the cochlear and/or the auditory nerve) that may exhibit some symptoms similar to CAPD, but which remains a separate disorder. In the past CAPD has been seen as a disorder of the brainstem, cerebrum (auditory cortex), corpus callosum and efferent auditory pathways, with the term "central" referring to the auditory pathways superior to the auditory nerve. The inclusion of the term "central" thus helps to differentiate between auditory neuropathy and CAPD and emphasizes that CAPD is a central disorder, i.e. central to the peripheral auditory system.

Concern over the appropriateness of removing the term "central" has also been expressed, as it holds the potential danger of broadening the scope of the disorder to such a degree that it holds little or no clinical value (Bellis, 2003a). It remains to be seen whether audiologists will generally accept the use of the term APD as opposed to CAPD (Medwetsky, 2002, Bellis, 2003a).

1.2.3 Continuous Performance

Continuous performance is a collective term that will be used to refer to measures of attention and vigilance. Continuous performance can and will be measured for both the auditory and visual modalities. The Integrated Visual and Auditory Continuous Performance Test (IVA CPT) of Sandford and Turner (2001) combines both auditory and visual stimuli in a counterbalanced design, together with attention and vigilance. The IVA CPT (Sandford and Turner, 2001) will be discussed in greater depth in Chapter 4.

1.2.4 Specific multi-dimensional test battery

In this study a "specific multi-dimensional test battery" comprising of a measure of (auditory and visual) continuous performance and a CAPD test battery was compiled to assess children diagnosed with the three different types of ADHD. The term "specific multi-dimensional test battery", as used here, encompasses two concepts, namely "specific" and "multi-dimensional". The concept "specific" refers to specific measures of both central auditory processing and continuous performance that were included. The term "multi-dimensional" refers to the complexity and diversity of the factors being considered, namely both central auditory processing, and (auditory and visual) continuous performance of the children in the medicated and non-medicated state.

1.3 DIVISION OF CHAPTERS

The division of the chapters in this study is presented in Table 1.2.

1.4 SUMMARY OF CHAPTER 1

The orientation to and rationale underlying the study are presented in Chapter 1. The controversy surrounding the etiology and prevalence of ADHD (and the different types of ADHD), as well as the value of different assessment methods and treatment options in managing ADHD in children are discussed. In particular, the value of a specific multi-dimensional test battery comprising of a continuous performance test, as well as a CAPD test battery in investigating the theoretical constructs underlying ADHD, is presented. This is followed by a definition and discussion of the terminology used in the study as well as an overview of the division and content of the chapters in the dissertation.

Table 1.2: Division of Chapters

Division of chapters	Outline of content
Chapter 1: Introduction	Chapter 1 provides an introduction to the study and presents the orientation to and rationale for the study. In order to facilitate understanding of the fundamental issues of the study and to avoid misunderstanding, the terminology used in the study is defined. The terms that are defined are "Attention Deficit Hyperactivity Disorder" (ADHD), "Central Auditory Processing Disorder" (CAPD), "Continuous performance", and "Specific multi-dimensional test battery". An outline of the chapters of the study is also provided.
Chapter 2: ADHD in children: Controversies and directions for further research	Chapter 2 presents a critical review of the etiology of ADHD, the different diagnostic criteria and ensuing controversy, additional diagnostic tools, the prevalence rates of ADHD and the ADHD types, co-existing disorders and differentiating ADHD from CAPD, recent developments in the conceptualization of ADHD, the treatment of ADHD and finally, directions for further research.
Chapter 3: The value of tests of continuous performance and CAPD in differentiating between ADHD and CAPD in children	Chapter 3 highlights the challenges facing professionals in differentiating between ADHD and CAPD in children. The three opposing schools of thought regarding the conceptualization of ADHD and CAPD are presented and, against this background, the value of a specific multi-dimensional test battery (comprising of a measure of continuous performance and a CAPD test battery) is discussed.
Chapter 4: Research methodology	Chapter 4 presents the research methodology of the study, and entails a description and discussion of the aims, research design, participant selection criteria and procedures, as well as a description of the participants, apparatus and material and, finally, the data analysis procedures used in the study.
Chapter 5: Results and discussion	In Chapter 5 the results of the study are presented and discussed according to the formulated sub-aims. This 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 also 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.
Chapter 6: Conclusion	The conclusions of the study are presented in Chapter 6. This is followed by a critical evaluation of the study as well as a summary of the clinical implications of the study. Finally, recommendations are made for further research.

CHAPTER 2: ADHD IN CHILDREN: CONTROVERSIES AND DIRECTIONS FOR FURTHER RESEARCH

2.1 INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD), the most commonly occurring neurobehavioural disorder in childhood, is characterized by a consistent pattern of inattention and/or hyperactivity-impulsivity (Chermak et al, 1999, American Academy of Pediatrics, 2000). Recorded prevalence rates for ADHD vary due to different and changing diagnostic criteria as well as variations in the diagnostic tools used by different professionals in different clinical settings across countries (American Academy of Pediatrics, 2000).

Children with ADHD may experience significant functional problems such as academic underachievement, troublesome interpersonal relationships, and poor self-esteem (National Institutes of Health Consensus Committee, 1998, American Academy of Pediatrics, 2000). Adding to the complexities and controversy surrounding ADHD is the co-existence of ADHD with other conditions such as oppositional defiant disorder, conduct disorder, depression, anxiety disorder and many developmental disorders such as speech and language delays and learning disabilities (American Academy of Pediatrics, 2000; Copps, 2002). As many as one third of children with ADHD present with one or more of the above co-existing disorders (American Academy of Pediatrics, 2000). Additionally, differentiating between ADHD and *CAPD* in children is a challenge for professionals as both groups are heterogeneous in nature and yet present with many similar characteristics (Keller, 1998). It has been proposed that CAPD and ADHD may even reflect a singular disorder (Gason et al, 1986, Keller, 1998).

As discussed in Chapter 1 public interest in ADHD has increased, along with debate in the media concerning the diagnostic process and treatment strategies (Gibbs, 1998). Concern has been expressed about the over-diagnosis of ADHD by pointing to the dramatic increase in prescriptions for stimulant medication among children over the past decade (Safer et al, 1996, American Academy of Pediatrics, 2000). In addition, there are significant variations in the type and amount of stimulants prescribed by physicians as well as wide variations in the diagnostic methods and criteria currently employed (American Academy of Pediatrics, 2000).

Chapter 2 presents a critical review of the etiology of ADHD, the different diagnostic criteria and ensuing controversy, additional diagnostic tools, the prevalence rates of ADHD and the ADHD subtypes, co-existing disorders and differentiating ADHD from CAPD, recent developments in the conceptualization of ADHD, the treatment of ADHD and finally, directions for further research.

2.2 THE ETIOLOGY OF ADHD IN CHILDREN

Although the etiology of ADHD remains unknown, data from family genetic, twin, adoption and segregation analysis suggest a strong genetic contribution (Barkley, 1998, Swanson and Castellanos, 1998, Faraone and Biederman, 1999). Preliminary, molecular genetic studies have implicated several candidate genes, including the dopamine D2 and D4 (DRD4-7) receptors as well as the dopamine transporter (DAT-1) (Swanson and Castellanos, 1998, Faraone and Biederman, 1999). Dopamine is the neurochemical that is most highly represented in the frontal cortex. Consistent with these findings is the fact that Methelphenidate, a frequently prescribed stimulant for children with ADHD, is known to release stored dopamine from neurons (Welsh, 1994, Swanson and Castellanos, 1998).

Neuroimaging and electroencephalography studies have identified subtle anomalies in the frontal cortex and projecting subcortical structures of some individuals with ADHD (Swanson and Castellanos, 1998). Fillepek, Semrud-Clikeman, Steingard, Renshaw, Kennedy and Biederman (1997) used magnetic resonance imaging to study brain anatomy and reported that a group of children with ADHD had brain volumes about 10% smaller than normal in the anterior superior regions (posterior prefrontal, motor association, and midanterior cingulate) and anterior inferior regions (anterior basal ganglia). Castellanos, Giedd, March, Hamburger, Vaituzis and Dickstein (1996) have also reported that the right anterior frontal, caudate, and globus pallidus regions were about 10% smaller in an ADHD group than in a control group.

Despite the above evidence, the American Academy of Pediatrics (2000) does not endorse the routine use of brain imaging studies and electroencephalography in the diagnosis of ADHD (as discussed later under 2.4). Their decision is based on an extensive review of the literature that has shown that, although variations may occur in brain morphology of some children with ADHD, there is a high occurrence of both false-positive and false-negative results. Swanson and Castellanos (1998) contribute the high occurrence of both false-positive and false-negative results to the lack of validation of ADHD as a disorder that can be reliably assessed and researched. This lack of validation of ADHD as a disorder is possibly due to different and changing diagnostic criteria, as well as variations in the diagnostic tools, used by different professionals in different clinical settings across countries (American Academy of Pediatrics, 2000). Recent investigations of a refined phenotype defined by the ICD-10 / DSM-IV consensus criteria namely Hyperkinetic disorder or the combined type of ADHD (as discussed under 2.3) have, however, produced some converging evidence about the possible biological basis (both genetic variation and neurological damage) of this disorder (Swanson and Castellanos, 1998). Further research, that clearly defines the type/s of ADHD being investigated, is thus necessary.

Possible nongenetic etiologies linked to ADHD include suspected brain damage due to hypoxia and hypotension during fetal development that could damage neurons in the anatomical networks implicated in ADHD (Swanson and Castellanos, 1998). Fetal exposure to alcohol, lead, nicotine and other substances may also damage neurons in the implicated anatomical networks. Traumatic brain injury may also produce selective interneuron damage in the frontal cortex (Swanson and Castellanos, 1998).

Other proposed etiologies of ADHD include adverse reactions to foods or food additives, a lack of essential fatty acids resulting in a lack of prostaglandins that, in turn, leads to a weakening in neuron cell walls and thus poor transmission between neurons, as well as an emotional cause (Pooley, 2000). While these factors are likely to exacerbate ADHD in some children, most professionals view ADHD as a genetic disorder of neurological origin (Pooley, 2000).

2.3 THE DIFFERENT DIAGNOSTIC CRITERIA USED IN THE DIAGNOSIS OF ADHD.

ADHD is the term used in North America (United States of America and Canada) as well as Australia to describe children with a consistent pattern of inattention and/or hyperactivity-impulsivity with an onset in early childhood (Chermak et al 1999, American Academy of Pediatrics, 2000). In contrast, the term Hyperkinetic Disorder, used in the United Kingdom and by European professionals, is characterized by the early onset of both overactive and inattentive behaviors (McConnell, 1997). As a result, there has been considerable debate in recent years concerning the definition, prevalence and management of attention and hyperactive behavior in children. Using the stricter criteria of the ICD-10 criteria for Hyperkinetic disorder, the prevalence is restricted to approximately 1-2% of children (McConnell, 1997). This has sparked considerable controversy concerning the perceived over-diagnosis of overactive and inattentive behavior in children and consequently the over-prescription of stimulant medication in North America and more specifically the United States of America (McConnell, 1997).

When comparing the DSM-IV criteria (American Psychiatric Association, 1994), used to diagnose ADHD with the ICD-10 criteria for Hyperkinetic Disorder (World Health Organization, 1992), it becomes evident that Hyperkinetic Disorder is, in actuality, most likely one of the three different types of ADHD, namely the combined type that is characterized by both hyperactivity-impulsivity and inattention (Taylor and Hemsley, 1995).

The DSM-IV (American Psychiatric Association, 1994) uses patterns of inattention, hyperactivity and impulsivity to differentiate between the three different types of ADHD. The predominantly inattentive type presents, primarily, with symptoms of inattention. The predominantly hyperactive-impulsive is considered a behavioral regulation disorder and the combined type is characterized by hyperactivity-impulsivity and inattention. The criteria for the diagnosis of the three different types of ADHD types, as stipulated by the American Psychiatric Association (1994), are presented in Table 1.1. The DSM-IV criteria for the diagnosis of the different types of ADHD require the presence of six or more symptoms of inattention and/or hyperactivity-impulsivity persisting for 6 or more months. The combined type of ADHD meets criteria A and B, as outlined in Table 1.1, the predominantly inattentive type meets criterion A, but not B, and the predominantly hyperactive-impulsive type meets criterion B, but not A.

The term Hyperkinetic Disorder, used by European professionals, is characterized by early onset, a combination of overactive, poorly modulated behavior with marked inattention and lack of persistent task involvement; and pervasiveness over time of these behavioral characteristics (World Health Organization, 1992). The cardinal features of Hyperkinetic Disorder are impaired attention and overactivity; both are necessary for the diagnosis and should be evident in one or more situation, for example, both the home and classroom environment. Impaired attention refers to prematurely breaking off from tasks and leaving activities unfinished while overactivity refers to excessive restlessness in relation to the demands of a given situation (World Health Organization, 1992).

From the above discussion it is evident that the use of different diagnostic criteria such as the DSM-IV (American Psychiatric Association, 1994) and the ICD-10 criteria (World Health Organization, 1992) may lead to misunderstanding and subsequently controversy surrounding the prevalence, diagnosis and treatment of overactive and inattentive behavior in children. For this reason, although the broader diagnostic criteria of the DSM-IV (American Psychiatric Association, 1994) will be used in this study, the results will also be considered against the background of the ICD-10 criteria (World Health Organization, 1992).

2.4 ADDITIONAL DIAGNOSTIC TOOLS AND METHODS USED IN DIAGNOSING ADHD

Establishing the diagnosis of ADHD requires a strategy that minimizes over-identification and under-identification. Pediatricians and other primary care health professionals are advised to apply DSM-IV criteria, as outlined in Table 1.1, in the context of their clinical assessment of the child (American Academy of Pediatrics, 2000). In addition, but not as a substitution, a synthesis of information from parents, school reports, other involved professionals and an interview/examination of the child is recommended as an adjunct but not as a substitute for the DSM-IV criteria. The acquisition of additional information is necessary as the behavioral characteristics specified in the DSM-IV, despite efforts to standardize them, remain subjective and may be interpreted differently by different observers (American Academy of Pediatrics, 2000). Additionally, instruments used in the primary care practice will not reliably assess the nature and degree of the functional impairment of children with ADHD.

Behavior symptoms can be obtained from parents and teachers using a variety of methods, including open-ended questions, semi-structured interviews, questionnaires, and rating scales. Specific questionnaires and rating scales have been developed to review and quantify the behavioral characteristics of ADHD, such as the Conners Parent Rating Scale and the Conners Teacher Rating Scale based on the DSM-IV criteria (as discussed in American Academy of Pediatrics, 2000). Other examples of checklists and rating scales are the Child Behavior Checklist (Parent and Teacher Form) and the Barkley's School Situations Questionnaire (as discussed in American Academy of Pediatrics, 2000). Although a valuable adjunct in diagnosing ADHD, the questions included in these questionnaires and rating scales are often subjective and thus subject to bias. The results of questionnaires and rating scales may thus convey a false sense of validity and should, therefore, always be considered in the context of the overall evaluation of the child (American Academy of Pediatrics, 2000).

In addition to the above DSM-IV criteria, questionnaires and rating scales, other diagnostic tests such as brain imaging studies including electroencephalography as well as tests of continuous performance have been considered. The American Academy of Pediatrics (2000) does, however, not endorse the routine use of brain imaging studies and electroencephalography in the diagnosis of ADHD. Their decision is based on an extensive review of the literature that has shown that, although variation may occur in brain morphology of some children with ADHD, there is a high incidence of both false-positive and false-negative results.

The American Academy of Pediatrics (2000) also does not endorse the routine use of tests of continuous performance in the diagnosis of ADHD at this time due to the significant variations in the test material that is currently available. Continuous performance tests have been designed to obtain samples of a child's behavior (generally measuring vigilance and attention/distractibility) that are thought to correlate with behaviors associated with ADHD (American Academy of Pediatrics, 2000). Significant variations between tests have, however, been noted for the modality of presentation, the type of target, the assessment of errors as well as the speed of stimuli presentation. Additionally, research examining the relationship between continuous performance and the different types of ADHD is necessary to determine the reliability and validity of these measures. Although the American Academy of Pediatrics (2000) does not endorse the routine use of tests of continuous performance clinically, their use in research may facilitate the development of new insights into the nature of the attention deficits associated with the different types of ADHD. The value of tests of continuous performance in describing the attention deficits associated with the different types of ADHD will be discussed in greater depth in Chapter 3.

There are a number of commercially available tests of continuous performance. One example, is The Auditory Continuous Performance Test compiled by Morris, O'Neil, Crawford and Mockler (Riccio et al, 2001). The individual is presented verbally with a randomized set of letters using the English alphabet and is required to respond to a target letter by pressing the space bar on a keyboard. The Visual Continuous Performance test by the same authors is a separate test during which letters are visually presented to the individual with the instruction to push the space bar when the target letter is seen. The above tests require a sound knowledge of the English alphabet and their corresponding phonemes and do not take aspects such as visual perception into account. Additionally, the auditory and visual modalities are assessed separately, and are thus not representative of the integrated modality demands placed on the child outside the test situation.

Another test of auditory continuous performance, with the same title namely the Auditory Continuous Performance Test, was compiled by Keith (1994). This auditory vigilance task requires the child to listen to a list of words and raise his/her thumb each time the target word is heard. This test thus requires a certain level of language competency and once again, only one modality, namely the auditory modality is assessed.

The Integrated Visual and Auditory Continuous Performance Test (IVA CPT) (Sandford and Turner, 2001) has addressed many of the criticisms directed at tests of continuous performance. This 20 minute computerized continuous performance test combines both auditory and visual stimuli. By combining the auditory and visual modes in a counterbalanced design, together with inattention and vigilance, the IVA CPT incorporates two continuous tests of performance into one. The test task is simple and requires the individual to click on the mouse only when s/he hears or sees the target (the number "1") and not to click when s/he hears or sees the non-target or foil item (the number "2"). Since the "1's" and "2's" are presented in a pseudo-random combination of visual and auditory stimuli, it is more demanding, than other tests of continuous auditory performance, as it challenges the individuals ability to change cognitive sets. Additionally, the test administration is automated and the presentation of auditory and visual stimuli is standardized.

Kane and Whiston (2001) suggest that the inclusion of both visual and auditory attention measures in a single administration provides the IVA CPT 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). Sandford, Fine and Goldman (1995) have reported that children diagnosed with ADHD assessed using the IVA CPT made more errors for auditory than for visual stimuli and were more likely to present with auditory modality impulsivity than their peers. A weakness in the study of Sandford et al (1995) is that the diagnostic criteria and methods used in their study are not adequately described and participants are simply described as having the diagnosis of ADHD.

2.5 THE PREVALENCE RATES OF ADHD AND THE DIFFERENT TYPES OF ADHD.

The recorded prevalence rates for ADHD vary, due to the different diagnostic criteria as well as variations in the diagnostic tools used by different professionals in different clinical settings across countries (American Academy of Pediatrics, 2000). The prevalence of ADHD has been estimated at between approximately 3 to 5% in children, aged between 2 to 8 years of age (American Psychiatric Association, 1994, National Institutes of Health Consensus Committee, 1998). More recently and based on an extensive review of reported prevalence rates, the American Academy of Pediatrics (2000) has estimated an ADHD prevalence of 9,2% for boys and 2,9% for girls. Studies based on parent reports indicate a persistence of ADHD of 60-80% into adolescence (Biederman, Faraone and Milberger, 1996, Mannuzza, Klein, Bessler, Malloy, and La Pudula, 1998, American Academy of Pediatrics, 2001).

The uncertainty surrounding the prevalence rates of ADHD is, in turn, reflected in the limited and varying reports of the prevalence rates of the different types of ADHD. Millstein, Wilens, Biederman and Spencer (1998) examined a group of 149 adults diagnosed with ADHD and found that 56% of the adults have the combined type of ADHD, 37% had the inattentive type, and only 2% had the hyperactive-impulsive type. For children diagnosed with ADHD, Wilens, Biederman and Spencer (2002) estimate that 50-75% of children have the combined type of ADHD, 20-30% of children have the inattentive type of ADHD with less than 15% of children meeting the criteria for the hyperactive impulsive type of ADHD. Furthermore, Millstein et al (1998) report that there is a greater decrease in symptoms of hyperactivity and impulsivity than in symptoms of inattention from childhood to adulthood.

When considering gender, there is a higher prevalence of ADHD reported for males than for females, with estimates ranging from 3:1 to 6:1 (Chermak et al, 1999). Interestingly, more females than males are diagnosed with the inattentive type of ADHD (National Institutes of Health Consensus Committee, 1998, Wolraich, Hannah, Baumgaertel, Pinnock and Feurer, 1998). Wolraich et al (1998) also report that co-existing learning disorders are more frequent in children with the inattentive and combined types of ADHD.

2.6 ADHD, CO-EXISTING DISORDERS AND CAPD

A variety of other psychological and developmental disorders frequently co-exist in children with ADHD. As many as one third of children with ADHD, have one or more co-existing disorders (American Academy of Pediatrics, 2000). Although the primary care clinician may not always be in a position to make a precise diagnosis of co-existing conditions, consideration thereof should be an integral part of the evaluation process (American Academy of Pediatrics, 2000). The evaluation and long-term care of the child with ADHD thus requires an ongoing and collaborative partnership among the child, physician, parents, teachers and other involved professionals.

The more common co-existing conditions (and their percentage of co-existence) include conduct and oppositional defiant disorder (35%), mood disorders/depression (18%), anxiety disorders (18%), speech and language impairment and learning disabilities (reported to range from 12-60%) (American Academy of Pediatrics, 2000). The relationship between the different types of ADHD and the different co-existing disorders is not documented in the literature and research in this area is thus required.

Differentiating between children with ADHD and CAPD is another challenge for professionals as both groups are heterogeneous in nature and yet present with many similar characteristics as highlighted in Table 2.1 (Keller, 1998). It has been proposed that CAPD and ADHD may even reflect a singular disorder (Gason et al, 1986, Keller, 1998). Children diagnosed with ADHD are frequently reported to present with difficulties on tasks that challenge the central auditory nervous system (Chermak et al, 1999, Copeland, 2002). Some researchers

Table 2.1: Characteristics of children with ADHD and CAPD (From: Keller, 1998)

Attention Deficit Hyperactivity Disorder (ADHD)	Central Auditory Processing Disorders (CAPD)

General characteristics
Inability to sustain attention
Impaired focused attention
Impaired selective attention
Impaired divided attention
Impaired vigilance
 	
Symptoms often seen in school setting
Disorganization
Short attention span
Impulsivity
Problems completing work
  Work completed impulsively
  Takes too long to complete work
Chronic academic underachievement
Variability in academic performance
Messy work, often carelessly done
Failure to follow instructions
Motor restlessness
Noisy/excessive talking
 	
Associated features
Cognitive deficits
  Specific learning disabilities
  Auditory processing disorders
  Problems with visual perceptual Processing
  Academic underachievement for Intelligence
	General characteristics
	Says "huh" and "what" frequently
	Inconsistent responses to auditory stimuli
	Often misunderstands what is said
	Constantly requests that information be repeated
	Poor auditory attention
	Easily distracted
	Difficulty following oral instructions
	Difficulty listening in the presence of background Noise
	Difficulty with phonics and speech-sound Discrimination
	Poor auditory memory
	Poor receptive and expressive language
	Slow and delayed response to verbal stimuli
	Reading, spelling and other academic problems
	Learns poorly through the auditory channel
	Exhibits behavior problems
	
	Emotional difficulties
	Temper tantrum / explosive behavior
	Low self-esteem
	Problems interpreting others emotions
	Low frustration tolerance
	Mood swings
	Hyperactivity/hypermotionality
	
	Social difficulties
	Poor peer relationships
	Impulsiveness
	Hyperactivity
	Aggressiveness
	Noncompliance
	Lying / stealing
	Poor self-control
	Poor general social skills
	Alcohol/drug abuse
	
	Physical features
	Poor general health
	Enuresis / encopresis
	Increased incidence of otitis media
	Allergies / food sensitivities
	Disturbance in sleep patterns
	Poor motor coordination
	Suspected under-aroused central nervous system
	Minor physical anomalies
	Familial pattern

have suggested that the diagnosis of CAPD and/or ADHD may be a function of the profession of the diagnostician and diagnostic procedures rather than the specific disorder (Riccio and Hynd, 1996). ADHD is a medical diagnosis usually made by pediatricians, while CAPD is an audiological diagnosis (Chermak, Somers and Seikel, 1998). The observed comorbidity of CAPD and ADHD may reflect a shortcoming in the accuracy of differential diagnosis using current procedures and criteria (Riccio and Hynd, 1996) and is an area that warrants further research.

Despite the shortcomings in the conceptualization and differential diagnosis of ADHD and CAPD, Chermak et al (1998) reported that the pediatricians and audiologists included in their study viewed the predominant symptoms of ADHD and CAPD as being rather distinct, with only 2 (namely, inattention and distractibility) of the 11 most frequently cited behaviors reported as common to both conditions. Inattention and distractibility were ranked as the first and second most typical behaviors characterizing ADHD. Audiologists ranked these same behaviors as seventh and sixth respectively, in cases of CAPD. CAPD was characterized by a selective attention deficit and associated language processing and academic difficulties. In contrast, ADHD was characterized by inappropriate motor activity, restlessness, and socially inappropriate interaction patterns. The results of the study suggest that the pediatricians and audiologists included in the study perceived ADHD and CAPD to be separate entities despite the shortcomings in the conceptualization and differential diagnosis of these two disorders (Chermak et al, 1998).

More recently, Chermak, Tucker and Seikel (2002) continued this research by comparing audiologists' and pediatricians' rankings of 58 behavioral symptoms associated with CAPD and the inattentive form of ADHD. The audiologists ranked the degree to which each symptom pertained to individuals with CAPD and the pediatricians ranked the same behaviors as they relate to the inattentive form of ADHD. The analysis revealed that the audiologists and pediatricians identified a reasonably exclusive set of behaviors characterizing the two conditions. None of the four behaviors (i.e. inattention, academic difficulties, asking for things to be repeated, and poor listening skills) ranked 2 standard deviations above the means (depicting a higher incidence of the symptoms) was ranked in common.

Furthermore, Bellis and Ferre (1999) and Bellis (2003a) have suggested that children with ADHD can be expected to either perform normally or poorly across all measures of CAPD, with no clear error pattern emerging in the test results. Further research examining the CAPD of children with the three different types of ADHD, namely the combined type, the inattentive type and the hyperactive-impulsive type is indicated. The value of tests of CAPD in differentiating between ADHD and CAPD will be discussed in greater depth in Chapter 3.

Recent developments in the conceptualization of and assessment procedures used in diagnosing ADHD and CAPD, are predicted to provide new insights into the probable linkages and distinctions between these two disorders (Bellis and Ferre, 1999, Bellis, 2003a). The recent conceptualization of ADHD as an executive function disorder is discussed under 2.7 and serves as an introduction to Chapter 3 where the three opposing theoretical schools of thought regarding the conceptualization of ADHD and CAPD are presented. Against this background, the value of tests of auditory and visual continuous performance and central auditory processing, in defining the nature of the attention deficits associated with the different types of ADHD, are discussed.

2.7 THE RECENT CONCEPTUALIZATION OF ADHD AS AN EXECUTIVE FUNCTION DISORDER.

There has been a recent shift in the conceptualizing of ADHD as a behavioral regulation or executive function disorder rather than a primary attention disorder for the combined and hyperactive-impulsive types of ADHD (Chermak et al, 1999). Although executive functions are defined differently across disciplines, there are generally agreed on components (Singer and Bashir, 1999). These include inhibiting actions, restraining and delaying responses, attending selectively, setting goals, planning and organizing, as well as maintaining and shifting set (Singer and Bashir, 1999).

Executive function is a component of metacognition referring to a set of general control processes that ensure that an individual's behavior is adaptive, consistent with a goal and beneficial to the individual (Torgesen, 1996). Executive control processes thus coordinate cognitive and metacognitive knowledge in support of task analyses, planning, reflective decision-making and finally the transformation of this knowledge into appropriate behavioral strategies. These strategies include learning, problem solving, psychosocial function, goal directed behavior and listening (Chermak et al, 1999).

Executive functions are thus necessary for goal-directed behavior and include the skills of planning, working memory, organized search, flexibility and impulse control (Welsh, 1994). The frontal cortex of the brain is thought to mediate executive function. This supports the evidence pointing to a possible frontal lobe dysfunction (due to neurochemical perturbation) explanation for ADHD (Welsh, 1994). Volkow et al (2001) hypothesize that stimulants such as methylphenidate enhance executive function by facilitating dopamine transmission in the frontal cortex.

In the new conceptualization of ADHD, the combined and hyperactive-impulsive types of ADHD are perceived to be an output disorder or executive dysfunction. The sustained multi-modal attention deficit is thus seen to occur secondary to the behavioral disinhibition and poor self-regulation (Chermak et al, 1999). In contrast, the inattentive type of ADHD is perceived to be an input or information-processing deficit. The inattention accompanying the inattentive type is perceived to be selective and multi-modal in nature (Chermak et al, 1999). Differentiating between the inattentive type of ADHD and CAPD is more challenging as both disorders are considered to be an input or information-processing deficit. The differentiation lies in the conceptualization of CAPD as a specific auditory perceptual deficit presenting with both selective and divided deficits. In both the inattentive type of ADHD and CAPD, executive dysfunction is seen as the secondary disorder with attention as the primary dysfunction (Chermak et al, 1999). Executive function and attention in the different types of ADHD and CAPD are discussed in greater depth in Chapter 3.

Executive functions can be assessed using a variety of neuropsychological assessments such as the Wisconsin Card Sort, the Cambridge Neuropsychological Tests Automated Battery, Category test, and Trailmaking (Packer, 2002). There is, however, currently no agreed on test battery for assessing executive dysfunction in children (Packer, 2002). Computerized tests of continuous performance have also been reported to tap into executive function (Packer, 2002). Welsh (1994) reasons that although tests of continuous performance were originally designed to measure the global construct of attention, it is evident that sub-processes including effortful information processing over time and inhibition of irrelevant and impulsive responding are also tapped. Thus, the performance measures observed on these attention tasks may also reflect executive function deficits (Welsh, 1994, Packer, 2002). The importance of further research examining the executive functions and continuous performance of children with ADHD is thus underscored.

2.8 TREATMENT OF ADHD IN CHILDREN

The American Academy of Pediatrics (2001) recommends the use of stimulant medication and/or behavioral therapy in the treatment of ADHD in children. For most children, stimulant medication is highly effective. For many children, behavioral interventions are valuable as the primary treatment or as an adjunct to stimulant medication (American Academy of Pediatrics, 2001).

Stimulant medication, currently available, includes short-, intermediate-, and long-acting methelphenidate, and short-, intermediate-, and long-acting dextroamphetamine (not available in South Africa). Volkow et al (2001) hypothesize that stimulant medication exerts a therapeutic effect by enhancing executive function by facilitating dopamine transmission in the prefrontal cortex. The different types of medication and their doses are presented in Table 2.2. The McMaster report (in American Academy of Pediatrics, 2000) reviewed 22 studies and found no significant differences in the effectiveness of methelphenidate and dextroamphetamine, or among different forms of these stimulants. Individual children may, however, respond better to one of the stimulants than the other. Antidepressants can be considered as a second line of treatment. Current evidence supports the use of only two types of medication in this category, namely tricyclic antidepressants and bupropion (American Academy of Pediatrics, 2001). Clinicians are advised to consider this second line of treatment only after the failure of 2 or 3 stimulants and only if they are familiar with their use. Despiramine use has, for example, been associated, in rare cases, with sudden death (Biederman, Thisted, Greenhill and Ryan, 1995).

Unlike most other medications, stimulant dosages are not weight dependent and clinicians are advised to begin with a low dose of medication and to titrate upward because of the marked individual variability of the dose-response relationship (American Academy of Pediatrics, 2001). The dosing schedules should be determined by the required outcomes for the child. Stimulants are generally considered safe medications with few contra-indications to their use. The most common side effects such as decreased appetite, stomach ache or headache, delayed sleep onset, jitteriness or social withdrawal can successfully be managed through adjustments to the dosage or schedule of the medication (American Academy of Pediatrics, 2001).

Table 2.2: Medication used in the treatment of ADHD (From: American Academy of Pediatrics, 2001)

Generic class (Brand name)	Daily dosage schedule	Duration	Prescribing schedule
Stimulants (First-Line Treatment)			
Methylphenidate			
Short-acting (Ritalin, Methylin)	Twice a day (BID) to 3 times a say (TID)	3-5 hr	5-20mg BID to TID
Intermediate-acting (Ritalin SR, Metadate ER, Methylin ER)	Once a day (QD) to BID	3-8 hr	20-40mg QD or 40mg in morning and 20 early afternoon
Long-acting (Concerta, Metadate CD, Ritalin LA[1])	QD	8-12 hr	18-72mg QD
Amphetamine			
Short-acting (Dexedrine, Dextrostat)	BID to TID	4-6 hr	5-15mg BID or 5-10mg TID
Intermediate-acting (Adderall, Dexedrine spansule)	QD to BID	6-8 hr	5-30mg QD or 5-15mg BID
Long-acting (Adderall-XR[1])	QD		10-30mg QD
Antideressants (Second-Line Treatment)			
Tricyclics (Imipramine, Desipramine)	BID to TID		2-5mg/kg/day[2]
Bupropion			
(Wellbutrin)	QD to TID		50-100mg TID
(Wellbutrin SR)	BID		100-150mg BID

KEY:
[1] Not FD approved at time of publication
[2] Prescribing and monitoring information in *Physicians' Desk Reference*

Behavior therapy represents a broad set of specific interventions that have a common goal of modifying the physical and social environment to alter or change behavior, including more structure, closer attention, and limitations of distractions (American Academy of Pediatrics, 2001). Behavior therapy is then implemented by training parents and teachers in specific techniques, as presented in Table 2.3, for improving behavior. Behavior therapy should be differentiated from psychological interventions (such as play therapy) that are directed at changing the child's emotional status.

Table 2.3: Behavioral techniques for children with ADHD (From: American Academy of Pediatrics, 2001)

Technique	Description
Positive reinforcement	Providing rewards or privileges contingent on the child's performance
Time-out	Removing access to positive reinforcement contingent on performance of unwanted or problem behavior
Response cost	Withdrawing rewards or privileges contingent on the performance of unwanted or problem behavior
Token economy	Combining positive reinforcement and response cost. The child earns rewards and privileges contingent on performing desired behaviors and loses the rewards and privileges based on undesirable behavior

In a 14-month randomized clinical trial of treatment strategies for children with ADHD (The MTA Cooperative Group, 1999), a group of 579 children with the combined type of ADHD were assigned to 4 research groups, respectively receiving 14 months of medication management, intensive behavioral treatment, the two types of management combined, or standard community care. The results showed that children in the combined treatment and medication management groups showed significantly greater improvement than those given intensive behavioral treatment and community care. Combined and medication treatments did not differ significantly on any direct comparisons, but in several instances (oppositional/aggressive symptoms, internalizing symptoms, teacher-rated social skills, parent-child relations, and reading achievement) combined treatment proved superior to intensive behavioral treatment and/or community care while medical management alone did not. The medical management of ADHD or combined management of stimulants together with behavior therapy are thus the preferred and recommended management regime at this time (The MTA Cooperative Group, 1999, American Academy of Pediatrics, 2001).

In the study of The MTA Cooperative Group (1999) only children with the combined type of ADHD were used. Further research using children with the inattentive and hyperactive-impulsive types of ADHD would be of value in determining the most effective treatment for these two groups of children.

2.9 DIRECTIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Much of the controversy surrounding research in the field of ADHD appears to have arisen from poorly defined participant selection criteria and, in particular, the diagnostic criteria used. The controversy surrounding ADHD and Hyperkinetic disorders bears testimony to this (McConnell, 1997). The intensive debate surrounding the use of the DSM-IV or the ICD-10 proves to be futile when it is recognized that Hyperkinetic disorder, as described in the ICD-10 classification, is comparable to one of the three ADHD types of the DSM-IV classification, namely the combined type of ADHD (Taylor and Hemsley, 1995). It is pertinent that future studies examining ADHD in children clearly define (and thereby validate) the type/s of ADHD being examined as well as the specific diagnostic criteria and diagnostic tools used in making the diagnosis of ADHD. Recognition of the different ADHD types is crucial when researching the etiology and prevalence rates of ADHD as well as the value of different diagnostic tools and treatment options. The validation of ADHD as a disorder will also facilitate comparisons between studies that, in turn, will enhance both researchers' and clinicians' understanding of ADHD.

Recent developments in the conceptualization of and assessment procedures used in diagnosing ADHD and CAPD, are predicted to provide new insights into the probable linkages and distinctions between these two disorders (Bellis and Ferre, 1999, Bellis, 2003a). Although the American Academy of Pediatrics (2000) does not endorse the routine clinical use of tests of continuous performance, their use for research purposes may facilitate the development of new insights into the nature of the attention deficits associated with the three different types of ADHD. Bellis and Ferre (1999) and Bellis (2003a) also propose that tests of CAPD may be helpful in differentiating between CAPD and ADHD and suggest that children with ADHD either perform normally or poorly across all measures of CAPD, with no clear error pattem emerging in the test results. Further research examining the continuous performance and central auditory processing abilities of children with the three different types of ADHD, namely the combined type, the inattentive type and the hyperactive-impulsive, type is warranted and will be discussed in greater depth in Chapter 3.

2.10 SUMMARY OF CHAPTER 2

Chapter 2 provides a critical review of the etiology of ADHD, the different diagnostic criteria and ensuing controversy, additional diagnostic tools, the prevalence rates of ADHD and the different types of ADHD, co-existing disorders and differentiating ADHD from CAPD, recent developments in the conceptualization of ADHD, the treatment of ADHD and finally, directions for further research.

The debate surrounding the DSM-IV and ICD-10 criteria is addressed, and the similarity between the Hyperkinetic disorder of the ICD-10 and the Combined ADHD type of the DSM-IV criteria is highlighted. The use of additional diagnostic tools, including questionnaires and rating scales, brain imaging and continuous performance is discussed. Further research investigating the value of these measures against the background of clearly defined ADHD types and criteria is recommended. The uncertainty of the prevalence of ADHD and the ADHD types is ascribed to the lack of validation of ADHD as a disorder, different diagnostic criteria as well as variations in the diagnostic tools used. The validation of ADHD as a disorder and the recognition of the different ADHD types are seen to be crucial, not only to research investigating the etiology and prevalence of ADHD, but also research investigating the value of different diagnostic tools and options.

The variety of other psychological and developmental disorders (such as conduct and oppositional defiant disorders, mood disorders/depression, anxiety disorder and speech and language disorders) that frequently co-exist in children with ADHD are addressed in Chapter 2. It is concluded that consideration of these co-existing disorders should form an integral part of the evaluation and diagnostic process.

Finally, the importance of differentiating between ADHD and CAPD in children and the recent conceptualization of ADHD as an executive function disorder is presented and serves as an introduction to Chapter 3 (where the theoretical models differentiating between ADHD and CAPD and value of tests of continuous performance and CAPD are discussed).

CHAPTER 3: THE VALUE OF TESTS OF CONTINUOUS PERFORMANCE AND CAPD IN DIFFERENTIATING BETWEEN ADHD AND CAPD IN CHILDREN

3.1 INTRODUCTION

> *Differentiating Attention Deficit Disorder and Central Auditory Processing Disorder hinges on the accurate diagnosis of these conditions (Chermak et al, 1999).*

As discussed in Chapter 2, differentiating between ADHD and CAPD is a challenge for professionals as both groups of children are heterogeneous in nature and yet present with many similar characteristics (Keller, 1998). Children diagnosed with ADHD are frequently reported to present with difficulties on tasks that challenge the central auditory nervous system (Chermak et al, 1999, Copeland, 2002). It has even been proposed that CAPD and ADHD may reflect a singular disorder (Gason et al, 1986, Keller, 1998). As ADHD is a medical diagnosis, while CAPD is an audiological diagnosis (Chermak et al, 1998), some researchers have suggested that the diagnosis of these two disorders may be a function of the professional making the diagnosis (Riccio and Hynd, 1996). The observed comorbidity of CAPD and ADHD most likely also reflects a shortcoming in the diagnostic criteria as well as the procedures used in differentiating ADHD and CAPD, and is an area warranting further research (Riccio and Hynd, 1996).

In the literature there are three opposing theoretical schools of thought regarding the conceptualization of ADHD and CAPD as outlined in figure 3.1. In the first school of thought, CAPD is considered to be a specific disorder of the auditory modality while deficits in attention are suspected to be supramodal in nature. Included in this school of thought is the model of McFarland and Cacace (1995) who view auditory modality specificity as a criterion for diagnosing CAPD, and recommend using similar tasks in multiple (auditory and visual) sensory modalities to differentiate between auditory specific and supramodal disorders.

In the second school of thought, CAPD is viewed an auditory specific deficit (though the possible existence of co-existing multimodality symptoms based on shared neurophysiological site of dysfunction is recognized) while ADHD is seen to be supramodal in nature (Bellis, 2003b). Included in this school of thought there are three different models. In the first model, Chermak et al (1999) postulate that ADHD is a behavior regulation disorder or executive function disorder, and that the attention deficits associated with ADHD are supramodal in nature, whilst the attention deficits linked to CAPD are primarily associated with the auditory modality but may co-exist with more global dysfunction reflecting other modalities. The second model, namely the Bellis/Ferre Model (Bellis, 2003a), is similar to the model of Chermak et al (1999) with the primary difference between these models relating to the use of subprofiles of CAPD as seen in the Bellis/Ferre Model (Bellis, 2003a) model. In the third model, Barkley (1998) attributes the underlying cause of ADHD to deficiencies in executive dysfunction, most likely due to the underproduction of dopamine in the prefrontal cortex.

In the third school of thought, CAPD is not viewed as an auditory modality specific disorder but rather as a multimodal disorder. Included in this school of thought is the Buffalo model of Katz et al (1992).

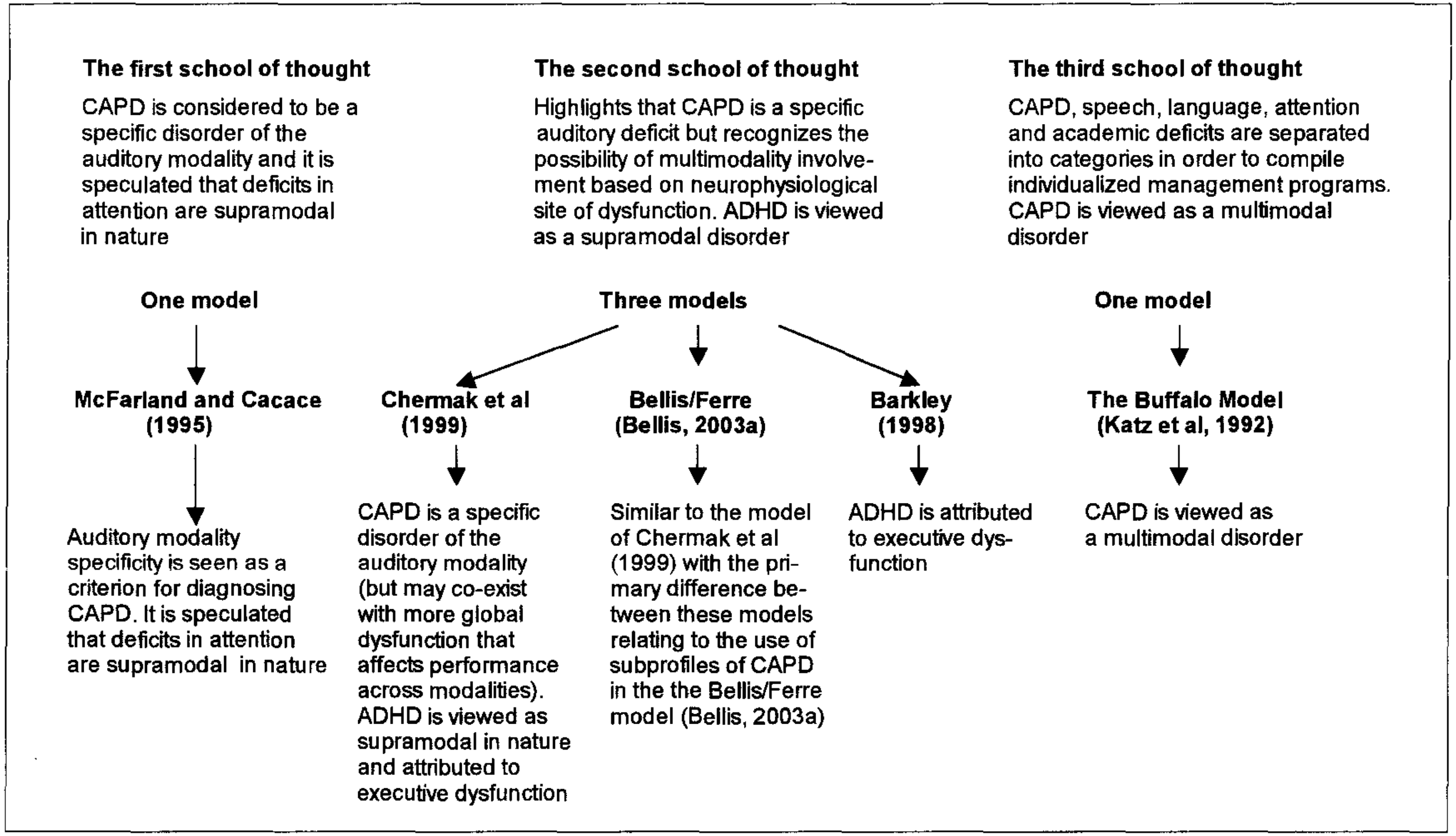

Figure 3.1: The three opposing theoretical schools of thought regarding the conceptualization of ADHD and CAPD.

The above three opposing theoretical schools of thought on the conceptualization of ADHD and CAPD will be critically reviewed in Chapter 3. Against this background, the value of tests of continuous performance and CAPD in assessing ADHD in children will be discussed.

3.2 THE FIRST SCHOOL OF THOUGHT: THE MODEL OF McFARLAND AND CACACE (1995)

In the model of McFarland and Cacace (1995) central "auditory" processing disorders are viewed as modality specific in nature. McFarland and Cacace (1995) reason that the concept of CAPD as a disorder has not been completely validated. They suggest that audiologists diagnose CAPD based on its auditory modality specificity nature. The deficit should thus occur primarily when the individual deals with acoustic information and not when similar information is presented in other sensory modalities (visual, tactile and olfactory). In contrast McFarland and Cacace (1995) view ADHD to be supramodal in nature.

In diagnosing CAPD, McFarland and Cacace (1995) suggest that similar tasks be compared in at least two separate modalities and recommend using the auditory and visual modalities, as these are the major channels of information exchange for the purposes of communication. A deficit in attention could thus be seen as a CAPD if it is established that it is auditory modality specific. If, however, an attention deficit is supramodal in nature (with both auditory and visual deficits) the diagnosis of ADHD is more appropriate. McFarland and Cacace (1995) conclude that further research is required to confirm the proposed auditory specific nature of CAPD and the supramodal nature of ADHD.

Stecker (1998) recommends that the Auditory Continuous Performance Test (Keith, 1984) be administered during CAPD assessment when ADHD is suspected. Stecker (1998) reasons that the Auditory Continuous Performance Test (Keith, 1984) screens for attention disorders and can be used as part of the CAPD test battery to aid in the differential diagnosis of ADHD and CAPD. Based on the model of McFarland and Cacace (1995) the inclusion of only an auditory continuous performance test is questionable practice, as the visual modality is not considered. To address the visual modality, the inclusion of a visual continuous performance test should, therefore, also be considered.

The Integrated Visual and Auditory Continuous Performance Test (IVA CPT) (Sandford and Tumer, 2001) combines both auditory and visual stimuli in a counterbalanced design together with attention and vigilance. As discussed in Chapter 2, 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) with an advantage over other continuous performance tests.

In some preliminary research using an earlier version of the IVA CPT, Sandford et al (1995) reported that children diagnosed with ADHD assessed using the IVA CPT made more errors for auditory than for visual stimuli and were more likely to present with auditory modality impulsivity than their peers. A weakness in the study of Sandford et al (1995) is that the ADHD diagnostic criteria and methods used in their study are not described and subjects are simply described as having the diagnosis of ADHD. There is, also, no acknowledgement of the different types of ADHD. Further research investigating the multi-dimensionality of the attention deficits associated with the different types of ADHD is thus warranted. The use of the IVA CPT (Sandford and Turner, 2001) that includes similar tasks using auditory and visual stimuli could thus provide valuable insights into the nature of the attention deficits associated with ADHD.

3.3 THE SECOND SCHOOL OF THOUGHT: THE MODEL OF CHERMAK ET AL (1999), THE BELLIS/FERRE MODEL (BELLIS, 2003a) AND THE MODEL OF BARKLEY (1998)

In the second school of thought, CAPD is viewed an auditory modality specific deficit (though the possible existence of co-existing multimodality symptoms based on shared neurophysiological site of dysfunction is recognized) while ADHD is seen to be supramodal in nature (Bellis, 2003b). There are three models within the second school of thought, namely the model of Chermak et al (1999), the Bellis/Ferre Model (Bellis, 2003a) and the model of Barkley (1998).

3.3.1 The model of Chermak et al (1999)

In the first model, Chermak et al (1999) view CAPD and ADHD as two distinct clinical disorders, not withstanding some overlap in their behavioral profiles as discussed in Chapter 2. The differences between CAPD and ADHD, as perceived by Chermak et al (1999), are summarized in Table 3.1.

According to Chermak et al (1999) there are distinctions that can be drawn regarding the modality of the inattention observed in CAPD and ADHD. The attention deficits seen in ADHD are pervasive and supramodal, impacting more than one sensory modality (American Psychiatric Association, 1994). In contrast, individuals with CAPD experience attention deficits that may be restricted to the auditory modality (Chermak and Musiek, 1997). As noted by Chermak and Musiek (1997), the commonly observed left-ear deficit on dichotic speech tasks in individuals with CAPD, as well as their depressed auditory performance under conditions of either contralateral or ipsilateral competition as a function of the level of brain dysfunction, argues against a pervasive attention deficit in CAPD and helps distinguish CAPD from ADHD. Although CAPD is seen to be the result of processes dedicated to audition, Chermak et al (1999) recognize that CAPD may also co-exist with more global dysfunction that affects performance across modalities.

Table 3.1: The differences between ADHD and CAPD (based on Chermak et al, 1999).

	ADHD combined and predominantly hyperactive-impulsive types	**ADHD predominantly inattentive type**	**Central auditory processing disorder**
Modality / modalities affected by the attention deficit	Attention deficits are supramodal (global)	Attention deficits are supramodal (global)	Attention deficits may be restricted to the *auditory modality*
Nature of the attention deficit, e.g.: sustained attention, selective attention, or divided attention deficit	Attention is restricted to sustained attention (multimodal)	Selective (multimodal) attention and speed of processing deficits	Selective (focussed) and divided auditory attention deficits
An output (behavior regulation) disorder or an input (processing) disorder	Output disorder	Input disorder	Input disorder
Executive dysfunction: primary or secondary feature of the disorder	Executive function is the primary source of dysfunction	Reduced rate of information processing is the primary source of dysfunction, with executive dysfunction as a secondary feature	Executive dysfunction is a secondary feature, not a primary cause, of listening difficulties

It is further argued that different types of attention deficit may be seen in ADHD and CAPD (Chermak et al, 1999). Although the neural mechanisms underlying the different behaviors associated with various attention tasks are unknown, research suggests that the attention deficits associated with the combined and predominantly hyperactive-impulsive ADHD types may be restricted to sustained attention, albeit in multiple modalities (Barkley, 1997a,b). Selective (multimodal) attention and speed of information processing deficits are thought to characterize the predominantly inattentive ADHD type (Barkley, 1997a). In contrast, both selective (focussed) and divided auditory attention deficits are thought to characterize CAPD (Chermak et al, 1999).

Chermak et al (1999) speculate that the inattentiveness seen in CAPD is a primary deficit resulting from an input or information processing deficit. In contrast, the hyperactive-impulsive and combined ADHD types are characterized as output or response programming and execution disorders (Barkley, 1997a,b). Differentiating the predominantly inattentive ADHD type from CAPD is more challenging since the inattention in both disorders is considered to be a primary input or information processing deficit.

This recent shift in conceptualizing ADHD as a behavioral or executive function disorder, as discussed in Chapter 2, may explain the self-control problems, social skills deficits, and language disorders (for example, difficulty in topic switching, tum taking and sustaining dialogue) so frequently observed in the combined and hyperactive-impulsive types of ADHD (Chermak and Musiek, 1997). Chermak et al (1999) speculate that executive dysfunction may be the source of the behavioral and inattention problems manifested in ADHD. Executive control is a component of metacognition that refers to a set of general control processes that ensure that an individual's behavior is adaptive, consistent with an appropriate goal and beneficial to the individual (Torgesen, 1996). Executive control is necessary for the execution of behavioral sequences, learning and problem solving, psychosocial function (including self-image, self-regulation of emotion and motivation), and goal-directed behaviors, including listening (Chermak et al, 1999).

In contrast with the combined and hyperactive-impulsive types of ADHD, the executive dysfunction observed individuals with the predominantly inattentive ADHD type and CAPD are considered a secondary feature, not a primary cause, of listening difficulties (Chermak et al, 1999).

The above reconceptualization of the predominantly hyperactive-impulsive and combined types of ADHD as an output and executive control disorder supports the use of pharmacological management in managing these types of ADHD (Chermak et al, 1999). Pharmacological management may however not be the most effective treatment in children with the inattentive type of ADHD (Chermak et al, 1999) and further research into the most effective management of the inattentive type of ADHD is thus indicated.

Assessing children with the three different types of ADHD with and without medication, using a continuous performance such as the IVA CPT (Sandford and Turner, 2001), will provide information about the value of using medication in the management of the different types of ADHD. These results could also yield information about the nature of the attention deficits associated with the three types of ADHD as the IVA CPT (Sandford and Turner, 2001) assesses similar tasks using both auditory and visual stimuli.

While Chermak et al (1999) recognize the heterogeneous nature of ADHD and the existence of different types of ADHD, they do not differentiate between different types or subprofiles of CAPD as seen in the discussion of the next model, namely the Bellis/Ferre Model (Bellis, 2003a).

3.3.2 The Bellis/Ferre Model (Bellis, 2003a)

In the second model, namely the Bellis/Ferre Model (Bellis, 2003a) CAPD is viewed as a specific auditory modality deficit, though the possible existence of co-existing multimodality symptoms, based on a shared neurophysiological site of dysfunction, is recognised.

The Bellis/Ferre Model (Bellis, 2003a) was developed, based on the need for a method of relating central auditory test findings to both their underlying neurophysiologic bases and their behavioral, cognitive, academic and communicative sequelae. The CAPD test battery is seen to provide a means of assessing the functional integrity of right- and left-hemisphere cortical regions, corpus callosum, and subcortical structures. Additionally the results of central auditory assessment allow the audiologist to determine the child's auditory strengths and weaknesses and relate these back to overall communication and learning difficulties, thereby identifying a possible subprofile/s of CAPD which, in turn, facilitates the development and implementation of individualized and specific management programs (Bellis, 1996, Bellis, 1999, Bellis and Ferre, 1999, Bellis, 2003a).

The choice of the specific test battery, used in central auditory assessment, varies among audiologists as reflected in the different test batteries that are available, for example, Katz et al (1992), the ASHA Task Force on Central Auditory Processing Consensus Development (1996), Bellis and Ferre (1999), Jerger and Musiek (2000) and Bellis (2003a). The question as to which test combinations are most effective in diagnosing CAPD remains an area of continuing debate (Bellis, 2003a).

Bellis and Ferre (1999), based on the guidelines of the ASHA Task Force on Central Auditory Processing Consensus Development (1996), recommend that a behavioral CAPD test battery include at least one test from each of the following categories: dichotic speech tasks (1 linguistically loaded and 1 linguistically non-loaded measure), monaural low redundancy speech tasks, tests of temporal patterning, and binaural fusion tasks.

More recently, in the report of the Bruton consensus conference (Jerger and Musiek, 2000), a minimum CAPD test battery comprising only three behavioral measures (a dichotic task, a temporal patterning task and a gap detection task) along with physiological measures such as immittance, oto-acoustic emissions and auditory evoked potential measurements was proposed. Bellis (2003a: 237) has challenged the above minimum CAPD test battery (Jerger and Musiek, 2000) arguing that this test battery is "too minimal" when reviewed against the background of the ASHA Task Force on Central Auditory Processing Consensus Development (1996) guidelines and the Schow, Seikel, Chermak and Berent (2000) update of the above ASHA Task Force guidelines.

Recently, Bellis (2003a) has recommended that the components of a comprehensive CAPD test battery be selected from the following general areas:

- A dichotic listening task that involves directed attention (Binaural separation)
- A dichotic listening task that involves report of both ears (Binaural integration)
- A temporal patterning test such as Frequency or Duration Patterns (Auditory Pattern Temporal Ordering)
- A test of monaural low-redundancy speech, such as the Low pass filtered speech test, Compressed speech with or without reverberation (Monaural separation or closure)
- A temporal gap detection test, such as the Random gap detection test (Other temporal processes)

- A binaural interaction test such as Binaural fusion or the more sensitive Masking level difference test (Binaural interaction)
- An auditory discrimination task such as the Northwestern parameter estimation by sequential tracking paradigm (requires additional equipment, not typically available in audiology clinics)
- Physiological measures of auditory function, such Auditory Brainstem Response, Middle Latency Response, and late event-related potentials.

Although the decision regarding how many and precisely which CAPD tests to utilize should be determined by each individual case, Bellis (2003a) suggests that it is prudent to include at least one test from each of the above categories with the exception of the electrophysiological measures that should be included when warranted for a particular case. In addition, Bellis (2003a) recommends including two dichotic tests, namely one with a low linguistic load and one with a high linguistic load.

As seen above, the Bellis/Ferre Model (Bellis, 2003a) is a dynamic and changing one that is continually revised as new insights are acquired and new assessment materials become available in the field of CAPD. The initial version of the Bellis/Ferre Model (Bellis, 1996) included four primary subprofiles and after many revisions (Bellis, 1999, Bellis and Ferre, 1999) now consists of three primary and two secondary subprofiles (Bellis, 2003a). The three primary subprofiles, representing primary auditory (left) cortex, nonprimary (right) cortex, and interhemispheric (corpus callosum) dysfunction are described in Table 3.2. The two secondary subprofiles, outlined in Table 3.3, describe dysfunction in associative (left) cortex and efferent and/or temporal-to-frontal cortex. Each CAPD subprofile, as described in Tables 3.2 and 3.3, is linked to its underlying neurophysiologic region of dysfunction in the brain as well as its higher-level

Table 3.2: Primary CAPD subprofiles of the Bellis/Ferre Model (Bellis, 1999, Bellis, 2003a). *The new additions to the central test findings as presented in the most recent version of the Bellis/Ferre Model (Bellis, 2003a) are presented in italics.*

Auditory Decoding Deficit	Prosodic Deficit	Integration Deficit
Region of dysfunction Primary auditory cortex in the language-dominant (usually left) hemisphere **Auditory processes likely to be impacted** • Auditory closure • Temporal processing • Auditory discrimination • Binaural separation and/or integration **Central auditory test findings** • Bilateral deficit on dichotic speech tests, right ear often worse than left • Bilateral deficit on monaural low redundancy speech tasks, right ear often worse than left and errors phonemically similar to target • *Elevated temporal gap detection thresholds and other temporal processing deficits* • *Elevated just noticeable differences for speech sound discrimination* • *Electrophysiology may show decreased responses over left hemisphere and/or absent Mismatch negativity* • *Performance on tests of temporal patterning, binaural interaction, and discrimination for slowly changing speech sounds (vowels, glides, liquids) is typically normal*	**Region of dysfunction** Nonprimary (usually right) hemisphere **Auditory processes likely to be impacted** • Temporal patterning • Auditory discrimination of nonspeech stimuli (e.g., frequency, intensity or duration discrimination); vowel discrimination difficulties are possible • Binaural separation and/or integration **Central auditory test findings** • Left ear deficit on dichotic speech tasks • Deficit in both temporal patterning tasks in both labeling and humming conditions, indicating difficulty with perception of acoustic contour itself • *Electrophysiology may show decreased responses over right hemisphere. Mismatch negativity (MMN) are typically present to consonant-vowel contrasts, but may be absent to tonal stimuli* • *Performance on tests of binaural interaction, temporal processing, monaural low-redundancy speech, and speech sound (especially consonant) discrimination is typically normal; however some difficulty with vowel discrimination may be present*	**Region of dysfunction** Corpus Callosum **Auditory processes likely to be impacted** • Temporal patterning • Binaural separation and/or integration **Central auditory test findings** • Left ear deficit on dichotic speech tasks, which may be more pronounced with linguistically loaded material • Deficit on temporal patterning tasks in linguistic labeling condition only, indicating intact perception of the acoustic contour itself but inefficient transfer to the left hemisphere for verbal output • *Electrophysiology may show a lack of typical hemispheric asymmetry patterns to speech stimuli* • *Performance on tests of binaural interaction, temporal processing, monaural low-redundancy speech, and auditory discrimination is typically normal*

Table 3.2 continued

Auditory Decoding Deficit	Prosodic Deficit	Integration Deficit
Primary auditory complaints • Difficulty hearing in noise or if speaker does not enunciate clearly • Frequent mishearing and misunderstanding • Feeling as if hearing loss is present even if hearing is normal • Auditory fatigue or overload • Fares better in quieter listening environments or when visual or multimodality cues are added	**Primary auditory complaints** • Difficulty comprehending the intent (rather than the content) of communications • Frequent misunderstandings, complaints of hurt feelings, and perceptions of others' communications as abrupt, rude, sarcastic, or negative in some or other way • Difficulty perceiving jokes, sarcasm, and other messages that rely on subtle prosodic cues • Possible difficulty understanding messages in which subtle changes in stress alter the meaning • Difficulty in comprehending overly abstract communicative exchanges or topics • Auditory complaints are typically not dependent on acoustic environment	**Primary auditory complaints** • Significant difficulty hearing in noise • Difficulty linking linguistic content with prosodic intent, leading to possible misunderstandings • Difficulty with localizing and tracking a moving sound source, especially if it crosses the midline • Feeling as if the right ear is "better", or preference for monaural (right ear amplification) over binaural hearing aids
Related sequelae • Poor phonological awareness abilities • Possible phonological production errors • Vocabulary and syntax may be affected • Good pragmatic communication skills • Poor word attack abilities during reading and spelling, combined with good sight word abilities • Verbal IQ lower than performance IQ • Good performance in nonverbal tasks such as mathematics, art and music	**Related sequelae** • Poor pragmatic and social communication abilities • Poor sight-word reading and spelling abilities, combined with good word-attack or phonological decoding skills • Performance IQ often lower than verbal IQ • Significant difficulty with nonverbal tasks such as mathematics, art and music • Poor visual-spatial abilities • Poor gestalt patterning abilities • May be at risk for depressive disorder secondary to right-hemisphere dysfunction • May meet diagnostic criteria for nonverbal learning disabilities; alternatively, presentation may be very subtle and	**Related sequelae** • Difficulty with any task in which interaction between the two hemispheres of the brain is required • Difficulty associating the visual symbol on the page with the sound, affecting both sight-word and word-attack skills, reading speed, and reading fluency • Performance IQ and Verbal IQ usually relatively evenly developed, with scatter within scales depending on the task demands • Poor bimanual or bipedal coordination abilities • Musical difficulties such as playing an instrument that requires significant

Table 3.2 continued

Auditory Decoding Deficit	Prosodic Deficit	Integration Deficit
	performance across academic areas may be loosely within the normal range • Performs better with concrete than abstract information • May have difficulty with topic maintenance • Phonological awareness abilities, vocabulary, and syntax are usually intact	bimanual coordination (e.g., piano), hearing the lyrics of sounds, or singing in time to melody • Greater difficulty when multimodality cues are added • Significant difficulty in taking dictation or notes • Difficulty drawing a picture from verbal or written descriptions or instructions • Auditory and related symptoms vary widely
Management and intervention strategies • Improvement acoustic access to information • Preteach new vocabulary and concepts • Augment with visual and/or multimodality cues • Repeat, rather than rephrase, messages • Phoneme training, focusing on discrimination of minimal contrast pairs and speech-to-print skills • Compensatory strategies training to include principles of active listening, auditory closure skills, and vocabulary enhancement activities • Speech and language therapy may be indicated to address phonological and language deficits	**Management and intervention strategies** • Placement with an "animated" teacher who makes generous use of prosodic cues and multimodality augmentation • Avoid hints; spell out precisely what is meant • Temporal patterning and prosody training • Reading aloud with exaggerated prosodic features • Compensatory strategies training to include social communication and judgment, role-playing, comprehension of underlying intent, topic maintenance, and communication repair strategies • Psychological counseling often critical in addressing social concerns and depressive symptoms • Intervention by other professionals (e.g., vision therapy, mathematics tutoring, pragmatic therapy) may be indicated	**Management strategies** • Improve acoustic access to information in the classroom • Avoid multimodality cues; present information via one modality at a time • Some aspects of prosody training may be indicated to assist in integrating content with intent, including reading of body language cues • Directed therapy to target interhemispheric activities and binaural separation/integration training • Compensatory training to include principles of active listening, and recruitment of stronger, top-down language and cognitive functions • Occupational therapy and tutoring in specific academic areas as indicated

Table 3.3: Secondary CAPD profiles of the Bellis and Ferre Model (Bellis, 1999, Bellis, 2003a). *The new additions to the central test findings as presented in the most recent version of the Bellis/Ferre Model (Bellis, 2003a) are presented in italics.*

Associative Deficit	Output-organizational Deficit
Region of dysfunction Auditory association cortical areas (in the dominant hemisphere – usually left hemisphere) **Central test findings** • Bilateral deficit on dichotic speech tests, often with the right ear worse than the left • *Performance on tests of monaural low redundancy speech (using appropriate vocabulary), temporal processing, temporal patterning, and binaural interaction is often good, indicating intact function of the primary auditory cortex, corpus callosum and right hemisphere* • *Speech sound discrimination is typically good; however word recognition may be poor depending on the child's receptive language* • *Electrophysiology may show decreased amplitudes over the left hemisphere*	**Region of dysfunction** Temporal-to-frontal and/or efferent system **Central test findings** • Deficit on any task requiring report of more than 2 elements (Frequency and duration patterns, Dichotic digits, Competing sentences, Staggered spondaic word test) • May have elevated or absent contralateral acoustic reflexes • *Performance on low-pass filtered or time compressed speech tasks usually within normal range (child is only required to repeat one word at a time)* • *Performance on speech in noise tests may be impacted due to auditory figure/ground difficulties* • *Absence of contralateral suppression during otoacoustic emission testing*
Primary auditory complaints Difficulty in applying the rules of language to incoming acoustic information, for example: experiences difficulty with sentences presented in passive voice, compound sentences, and other linguistically complex messages	**Primary auditory complaints** Inability to sequence, plan, and organize appropriate responses to novel auditory information and instructions.
Related sequelae • Receptive language deficits in vocabulary, semantics and syntax • Early academic achievement appropriate but, as the	**Related sequelae** • Difficulty hearing in noise • Poor organizational skills • Difficulty following directions

Table 3.3 continued

Associative Deficit	Output-organizational Deficit
linguistic demands in the class start to increase(3rd grade), general academic difficulties may start to become apparent	• Reversals • Poor recall and word retrieval abilities • Expressive speech errors (consisting of perseverative responses in which the target is substituted by a previously heard word) • Sequencing errors and sound blending difficulties are not uncommon • Generally good reading comprehension though spelling and writing skills may be poor
Management and intevention strategies • Language intervention for receptive language • Metacognitive techniques (verbal rehearsal, chunking, tag words, and organizational aids • Classroom management strategies (pre-teaching new information and imposition of external organization within the classroom) • Instructions and information should be rephrased rather than simply repeated	**Management and intervention strategies** • Imposition of external organization (written reminders and checklists) • Metacognitive techniques • Speech-language therapy • Repetition and rephrasing (with the message or response broken down into smaller linguistic units of no more than 2 critical elements

language and learning implications and sequelae. The new additions to the central auditory test findings, as represented in the most recent version of the Bellis/Ferre Model (Bellis, 2003a), are presented in italics in Tables 3.2 and 3.3. This distinction is made as the data collection for the study took place prior to the publication of the most recent version of Bellis/Ferre Model (Bellis, 2003a). The discussion of the results of the study takes place against the backdrop of the penultimate version of the Bellis/Ferre Model (Bellis, 1999) but the recommendations of the most recent version (Bellis, 2003a) are considered and discussed in Chapter 6.

In the past, the two secondary subprofiles were seen to represent the gray area between audition, language and executive function, but included in Bellis/Ferre model (Bellis, 1999) as they yield definitive findings on central auditory assessment. Recently, Bellis (2003a: 289) again questioned the inclusion of the secondary subprofiles in the latest version of the Bellis/Ferre model describing the secondary subprofiles as "riding the fine, gray line between audition and higher-order abilities such as receptive language and executive function". It is possible that future revisions of the Bellis/Ferre Model (Bellis, 2003a) may not include one or possibly both of the current secondary subprofiles (Bellis, 2003b). Bellis (2003b) has suggested for example that the Output-organization subprofile more likely reflects an attention disorder than a CAPD. Further research examining the nature of the relationships between the secondary subprofiles, language, executive function and attention is thus warranted.

In an interesting article differentiating between ADHD and CAPD, Bellis and Ferre (1999) have suggested that tests of CAPD may be helpful in differentiating between CAPD and ADHD in children. Four case studies are presented in their article, namely; case 1: a child with an auditory decoding deficit CAPD subprofile, case 2: a child with an integration deficit CAPD subprofile, case 3: a child with a prosodic CAPD subprofile, and case 4: a child with ADHD. A CAPD test battery comprising dichotic speech tasks, monaural low-redundancy speech tasks, tests of temporal patterning and binaural interaction tasks, was used to assess the children. The CAPD results of the first three children yielded patterns that can be linked to specific CAPD subprofiles. In case 4, the child with ADHD, the CAPD test results were found to be within the normal range despite, initially presenting with both behavioral and academic difficulties suggestive of auditory dysfunction. Bellis and Ferre (1999) and Bellis (2003a) report (based on clinical experience) that children with ADHD are either expected to perform normally or poorly across all measures of CAPD, with no clear error pattern emerging in the test results. Further research examining the central auditory processing of children with the three different types of ADHD, namely the combined type, the inattentive type and the hyperactive-impulsive type, is indicated. Additionally, the issue of whether CAPD testing in these children should be done in the medicated or non-medicated state warrants further investigation and will be discussed under 3.6.

3.3.3 The model of Barkley (1998)

Although the model of Barkley (1998) does not refer directly to CAPD, the similarities between the models of Barkley (1998) and Chermak et al (1999) regarding the conceptualization of ADHD as an executive disorder necessitate their inclusion as part of the second school of thought. Much of the pioneering work in conceptualizing ADHD, as an executive dysfunction, can be attributed to the work of Barkley (Barkley, 1990, Barkley, 1996, Barkley 1997a, Barkley, 1997b). It is noted that Chermak et al (1999) refer to Barkley's work in their model. Additionally, the uncertainty over the inattentive type of ADHD, reflected in both the models of Barkley (1998) and Chermak et al (1999), and the possible links between the inattentive type of ADHD and CAPD, support the ensuing discussion of the model of Barkley (1998) and its inclusion as part the second school of thought.

As seen in figure 3.2, Barkley (1997b, 1998) proposes that behavioral inhibition is the fundamental attribute linked to the performance of the other executive functions in children with ADHD, namely prolongation, separation and regulation of affect, internalization of language, reconstitution and motor control and fluency.

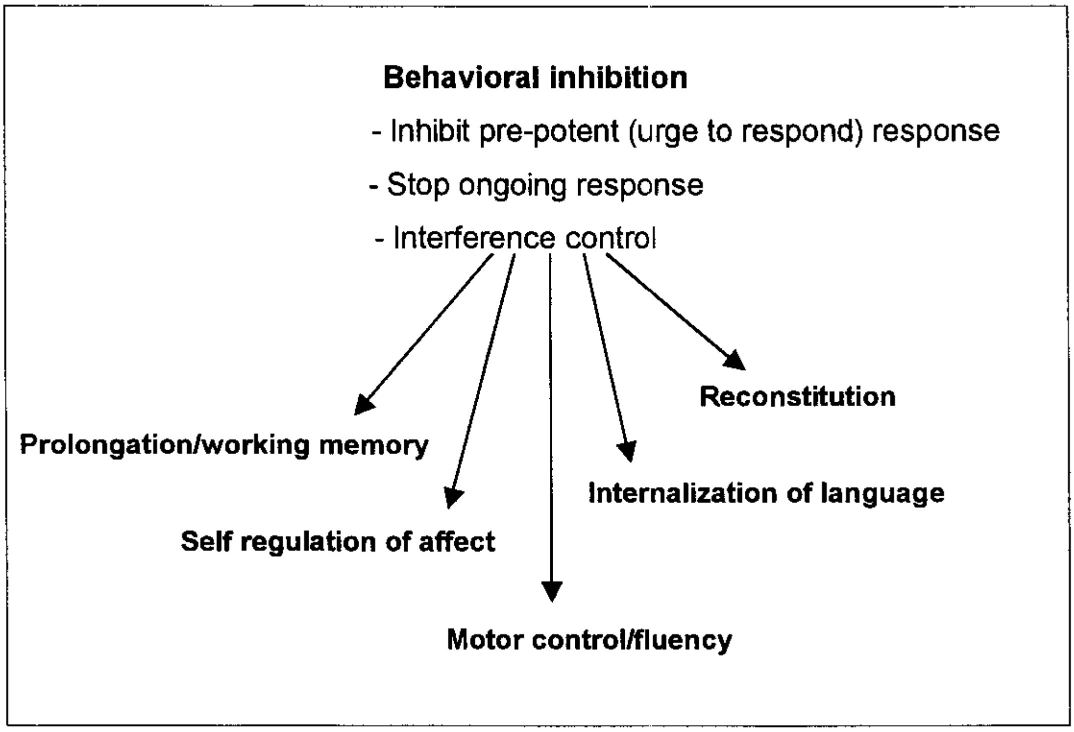

Figure 3.2: Barkley's (1997b, 1998) conceptualization of ADHD

There are three types of behavioral inhibition: firstly, the ability to inhibit a pre-potent response (urge to act) before it happens; secondly, the ability to stop an ongoing response that is ineffective, maladaptive or detrimental and change it to another response; and thirdly, the ability to protect the delay in response from outside interference. Acts of self-control occur in the brain between the time the event occurs and the time it takes to respond. During this time interval the brain regulates action. Behavioral inhibition is thus the key to these executive dysfunctions. Barkley (1997b, 1998) describes the attention deficits associated with ADHD as a mismatch between demands and resources and ascribes the disorder to behavioral inhibition which creates secondary impairments in the executive functions which lead to deficient self-regulation as well as impairment in the organization of behavior over time which, in turn, results in deficits in social/adaptive behavior.

Barkley (1998) has proposed that individuals with the *inattentive type of ADHD* differ from the combined and hyperactive-impulsive types of ADHD and suggests that individuals with the inattentive type of ADHD will receive no greater benefit from stimulants (such as Ritalin) than do normally functioning children. Similarly to Chermak et al (1999), Barkley (1998) suggests that the inattentive type of ADHD is a processing disorder rather than a dysfunction of executive dysfunction. The relationship between the inattentive type of ADHD and CAPD and the effects of medication thus warrants further investigation.

Executive functions can be assessed using a variety of neuropsychological assessments such as the Wisconsin Card Sort, the Cambridge Neuropsychological Tests Automated Battery, Category test, and Trailmaking (Packer, 2002). There is currently no agreed on test battery for assessing executive dysfunction in children (Packer, 2002). Computerized tests of continuous performance have also been reported to tap into executive function (Packer, 2002). Welsh (1994) reasons that although tests of continuous performance were originally designed to measure the global construct of attention, it is evident that sub-processes, including effortful information processing over time and inhibition of irrelevant and impulsive responding, are also tapped. Thus the performance measures observed in these attention tasks may also reflect executive function deficits (Welsh, 1994, Packer, 2002). In selecting a test such as the IVA CPT, not only the nature of the attention deficits associated with the three types of ADHD can be determined, but executive functions can also possibly be tapped.

3.4 THE THIRD SCHOOL OF THOUGHT: THE BUFFALO MODEL (KATZ ET AL, 1992)

In the third school of thought, CAPD is not viewed as an auditory modality specific disorder but rather as a multimodal disorder. The Buffalo Model (Katz et al, 1992) describes four categories of CAPD, namely Decoding, Tolerance-fading memory, Integration and Organization. A summary of the CAPD categories is provided in Table 3.4.

The different types or categories were initially based solely on the results of the Staggered spondaic word test (Katz, 1992). The Staggered spondaic word test was originally employed to study site-of-lesion in adults with tumors and strokes and later "...when interest turned to CAPD in learning-disabled children, the test was pressed into service to identify auditory processing disorder" (Katz, 1992: 81). Subsequently, even though a CAPD test battery (comprising the Staggered spondaic word test (Katz, 1986), the Phonemic synthesis test (Katz, 1983), a speech-in-noise test (Stecker, 1992), and the Masking level difference test at 500Hz) has been recommended (Stecker, 1998), the categorization of CAPD continues to be based primarily on the Staggered spondaic word test results.

Additionally, the Buffalo Model (Katz et al, 1992) describes not only clusters in Staggered spondaic word test results but also the behavioral characteristic of the children during CAPD evaluation (Stecker, 1998). These behaviors include aspects such as "impulsive responses", "long response delays" and "confused responses" (Stecker, 1998). Clear distinctions are not made in the Buffalo Model (Katz et al, 1992) between aspects such as memory, attention and CAPD, thus suggesting that CAPD is a multimodal disorder.

Table 3.4: The CAPD categories of the Buffalo Model (based on Katz et al, 1992)

	CAPD categories			
	Decoding	**Tolerance-fading memory**	**Integration**	**Organization**
Description of the category	Difficulty in accurately and quickly processing what is heard	Difficulty in understanding speech under adverse circumstances and/or short-term memory weaknesses	Difficulty in integrating auditory information with other functions, such as visual and non-verbal aspects of speech. There are two types, namely Type 1, which is similar to the decoding deficit and Type 2, which is similar to the tolerance-fading memory deficit	Characterized by reversals, sequencing errors and disorganization. This category is usually secondary to another CAPD category and rarely occurs in isolation *Category seldom occurs in isolation – seems to be some overlap with Tolerance-fading memory and Decoding categories*
Site-of-lesion	Posterior temporal region	Anterior temporal region and frontal lobes	Type 1: Corpus callosum and the angular gyrus Type 2: Anterior region of the brain and anterior portion of the corpus callosum	Frontal lobe and adjacent to posterior temporal region
Behavioral characteristics	Difficulty in keeping up with the flow of conversation, poor phonemic skills, slow responders, often have articulation errors, difficulty following directions, weak oral reading and spelling skills	Impulsive responders, easily overstimulated, may be hyperacusic, poor reading comprehension and handwriting due to poor motor planning, have short attention spans, easily distracted	Learning disabled, poor readers, often labeled as dyslexic. The type 1 profile also included poor spelling skills, poor sound-symbol relationships, excessively slow rate and poor handwriting	Characterized by reversals, sequencing errors and disorganization.
CAPD test results	History of conductive hearing loss, Staggered spondaic word test – weakness in right competing and/or left non-competing conditions, long response delays, more errors on items presented to the right ear first, more errors	Staggered spondaic word test – peak in left competing condition, more errors on the first spondee, tend to err on items presented to the left ear first, Phonemic synthesis test – omission of initial sounds and quick impulsive	Type 1 and 2: Type A pattern on the Staggered spondaic word test. Phonemic synthesis test – Type 1 has scores below grade level with long delays and confused responses and quiet rehearsals.	Staggered spondaic word test – reversals, Phonemic synthesis test - reversals

Table 3.4 continued

	CAPD categories			
	Decoding	**Tolerance-fading memory**	**Integration**	**Organization**
	on second than on first spondee, Phonemic synthesis test – scores outside normal limits, a Speech-in-noise deficit is sometimes present	responses, Speech-in-noise tests – poor scores	Speech-in-noise tests – poor score for Type 2, sometimes with a large discrepancy between the two ears	
Speech-language findings	Difficulties with receptive language (morphology), word-finding, prosody, oral and written discourse and articulation errors	Expressive language weakness: cluttering, inconsistent articulation, receptive language weakness: elaborated syntax, discourse errors: oral and written	Word finding problems, receptive language errors (morphology and syntax), expressive language errors (oral and written)	Discourse errors (oral and written sequencing), disorganized in work
Academic implications	Slow responder, phonics problems, poor understanding of directions, weak on written tests, minimal, oral discussions, difficulty with group listening	Poor attention span, distractible, reading weakness, weak short term memory, difficulty following directions, poor handwriting, impulsive behavior, poor motor planning	Slow responders, poor phonetic skills, poor-sound symbol relationships, severe spelling and reading problems, poor handwriting, difficulty with multi-modal tasks	Sequencing errors, disorganized in work
Management strategies	Improve phonemic and metaphonological skills, use phonic approach in reading, use clear and concise directions, allow for testing modifications, provide outlines, rephrase and restate, pretutor, provide written instructions	Improve signal to noise ratio, noise desensitization practice, compensatory strategies for auditory memory, preferential seating, earplugs, strategies to gain attention, take notes and outline in class, tape record classes, quiet study area	Improve phonemic and metaphonological skills, improve signal-to-noise ratios, use note-takers, tape record classes, reader-writer for tests, texts on tape, word processor with audio spell-check	Discourse therapy (sequence, information), consistent routines, checklists, calender

Interestingly, Stecker (1998) has reported that children with the Tolerance-fading memory deficit often exhibit similar characteristics to those with ADHD. Stecker (1998) recommends that the Auditory Continuous Performance Test (ACPT) (Keith, 1994) be administered if ADHD is suspected as this test screens for attention disorders. Stecker (1998) reasons that the inclusion of the Auditory Continuous Performance Test (Keith, 1984) in the CAPD test battery will aid in the differential diagnosis of ADHD and CAPD and thus facilitate appropriate intervention. Overlooked, however, in the reasoning of Stecker (1998) is the importance of considering not only auditory but also visual continuous performance. In selecting a test such as the IVA CPT, which combines both the auditory and visual continuous performance, the nature of the attention deficits associated with ADHD can possibly be determined.

Medwetsky (2002) also speculates that the Tolerance-fading memory deficit is the consequence of an attention deficit. Individuals with the Tolerance-Fading Memory deficit experience difficulty in retaining information presented and have difficulties in the presence of background noise. Medwetsky (2002) reasons that the latter is likely due to two causes. Firstly, if the underlying cause is related to attention, the individual is less capable of focusing on target stimuli while blocking out competing stimuli. Secondly, since individuals with this deficit are less capable of retaining information in their short term memory then any factor that increases the amount of time that stimuli will need to be processed will, in turn, affect the amount of information that can be retained. Should the Tolerance-fading memory deficit prove to be the consequence of an attention deficit, then management strategies should include metacognitive strategies to improve the individual's attention, and stimulant medication warrants consideration (Medwetsky, 2002).

3.5 THE VALUE OF TESTS OF CONTINUOUS PERFORMANCE AND CAPD IN DIFFERENTIATING BETWEEN ADHD AND CAPD IN CHILDREN

In summarizing the above discussion of the three opposing schools of thought regarding the conceptualization of ADHD and CAPD the following insights are developed:

The first school of thought:

- McFarland and Cacace (1995) propose that CAPD is an auditory modality specific disorder whereas the attention deficits associated with ADHD are suspected to be supramodal in nature, i.e. associated with both the auditory and visual modalities. Research examining the nature of the attention deficits associated with ADHD is thus warranted. McFarland and Cacace (1995) recommend using similar tasks in assessing the auditory and visual modalities. The IVA CPT that combines both auditory and visual stimuli with tasks of attention and vigilance in a counterbalanced design may be a useful tool in determining the nature of the attention deficits associated with ADHD.

The second school of thought:

- Chermak et al (1999) support McFarland and Cacace's (1995) view of the supramodal nature of the attention deficits associated with ADHD, and additionally ascribe the combined and hyperactive-impulsive types of ADHD to an executive dysfunction. The inattentive type of ADHD is seen as a processing disorder with executive dysfunction as a secondary disorder. Differentiating between the inattentive type of ADHD and CAPD thus becomes a challenge as CAPD is also considered to be a processing disorder though the attention deficits associated with CAPD are primarily considered to be auditory modality specific in nature. Although CAPD is seen to result from dysfunction of the processes dedicated to audition, it is recognized that CAPD may co-exist with more global dysfunction that affects performance across modalities (Chermak et al, 1999).

Chermak et al (1999) report that children with the inattentive type of ADHD appear to receive limited if any benefit from stimulants, in contrast to the combined and hyperactive-impulsive types of ADHD that are linked to executive dysfunction. Further research investigating the nature of the attention deficits associated with ADHD and the effects of stimulants on the functioning of children with the three different types of ADHD is thus indicated. Tests of auditory and visual continuous performance and tests of CAPD may be useful in determining the nature of these attention deficits and the effects of medication.

- In the Bellis/Ferre Model (Bellis, 2003a), CAPD is viewed as a specific auditory deficit, but the existence of co-existing multimodality symptoms based on shared neurophysiological site of dysfunction is acknowledged. This model is a dynamic and changing one. The initial version of the Bellis/Ferre Model (Bellis, 1996) included four primary subprofiles and now, after many revisions, consists of three primary and two secondary subprofiles. The most recent Bellis/Ferre Model (Bellis, 2003a) includes three primary and two secondary subprofiles. Bellis (2003b) currently questions the inclusion of the secondary subprofiles in their most recent model, arguing that these subprofiles appear to represent language, executive function and attention rather than central auditory processing. Bellis (2003b) has suggested, for example, that the Output-organization subprofile more likely reflects an attention disorder than a CAPD. Further research examining the relationships between the secondary subprofiles, language, executive dysfunction and attention is thus warranted.

  Bellis and Ferre (1999) propose that tests of CAPD may be helpful in differentiating between ADHD and CAPD in children and use four case studies in their article to illustrate this. Based on clinical experience, Bellis and Ferre (1999) and Bellis (2003a) suggest that children with ADHD are expected to perform normally or poorly across all measures of CAPD, with no clear pattern emerging on the test results. Further research examining the central auditory processing of children diagnosed with the three different types of CAPD is thus warranted.

The choice of the specific tests used in a behavioral test battery for assessing central auditory processing varies amongst audiologists. Bellis and Ferre (1999) have recommended that a behavioral CAPD test battery should include at least the following: dichotic speech tasks (1 linguistically loaded and 1 linguistically non-loaded measure), monaural low redundancy speech tasks, tests of temporal patterning, and binaural fusion tasks. Recently, in the Bruton conference consensus report, Jerger and Musiek (2000) have recommended a minimum behavioral CAPD test battery including puretone audiometry, performance-intensity functions for word recognition, a dichotic task, a frequency or duration pattern sequence test and a temporal gap detection test. Jerger and Musiek (2000) have, however, not as yet reported on the possible value of their test battery in differentiating between ADHD and CAPD. The CAPD test battery recommended by Bellis and Ferre (1999) in examining the value of behavioral tests of CAPD in differentiating between ADHD and CAPD in children warrants further research after which the value of other test batteries such as the one proposed by Jerger and Musiek (2000) could be investigated.

Finally, it is recognized that Bellis (2003a) recently published an update for recommendations regarding the components of a comprehensive CAPD test battery. The value of this updated comprehensive CAPD test battery in differentiating between ADHD and CAPD warrants further investigation but is beyond the scope of this study as the data collection phase had been completed prior to the publication of these recommendations.

- Barkley (1998) also contributes the combined and hyperactive-impulsive types of ADHD to an executive dysfunction and furthermore suggests the inattentive type of ADHD is likely a processing disorder. Barkley (1998) supports Chermak et al's (1999) view that children with the inattentive type of ADHD will receive no greater benefit from stimulants such as Ritalin than do normally functioning children. The relationship between the different types of ADHD and the effects of medication thus warrants further investigation. Again, tests of auditory and visual continuous performance and tests of CAPD may be useful in determining the nature of these attention deficits and the effects of medication.

The third school of thought:

- Based on the Buffalo Model of Katz et al (1992), both Stecker (1998) and Medwetsky (2002) have reported that children with the Tolerance-fading memory deficit often exhibit similar characteristics as those with ADHD and thus recommends including the Auditory Continuous Performance Test (Keith, 1994) during CAPD testing, when ADHD is suspected. The inclusion of a visual continuous performance test, in addition to the above test of auditory continuous performance, is likely to yield more information on the nature of the attention deficit associated with ADHD. The IVA CPT (Sandford and Turner, 2001) that combines both auditory and visual stimuli with tasks of attention and vigilance in a counterbalanced design may be a useful tool in determining the nature of the attention deficits associated with ADHD. The inclusion of a CAPD test battery would be useful in determining whether patterns exist in the test results that can be linked to the different categories of CAPD.

3.6 CONCLUSIONS

The value of assessing the auditory and visual continuous performance and central auditory processing of children with the three different types of ADHD (combined, inattentive and hyperactive-impulsive) is thus as follows:

- Tests of auditory and visual performance will yield information on the nature of the attention deficits associated with each type of ADHD, i.e. supramodal (visual and auditory modalities) or modality specific.

- A CAPD test battery will yield information about whether patterns exist in the results of children with the three different types of ADHD, and whether these results can be matched with specific categories or subprofiles of CAPD.

By incorporating the above measures of auditory and visual continuous performance, and central auditory processing a "specific multi-dimensional test battery" can be created. The term "specific multi-dimensional test battery" as used here encompasses two concepts (as discussed in Chapter 1), namely "specific" and "multi-dimensional". The term "specific" refers to specific measures of both central auditory processing and continuous performance. The concept "multi-dimensional" refers to the diversity and complexity of the factors being considered; namely the central auditory processing, and (auditory and visual) continuous performance of the participants in both the medicated and non-medicated state.

An important consideration in administering the above procedures to children with ADHD is whether these children should be assessed in the medicated and non-medicated state.

Chermak et al (1999) and Bellis (2001, 2003a) suggest that tests of CAPD be administered to children with ADHD in the medicated state as this will control attention deficits and enable the audiologist to obtain a more accurate representation of the child's actual central auditory processing abilities. Others may argue that audiological assessment should be conducted in the child's natural state (without medication) and/or express concerns about the possible confounding effects of medication on the test performance (Chermak et al, 1999). Tests of auditory and visual continuous performance provide information about the child's attention and vigilance and the purpose of the testing should dictate whether the child is tested in the medicated or not-medicated state. For example, if the purpose of the testing is to determine the attention and vigilance of the child, it would probably be best to test the child in the non-medicated state. If, however, the purpose of the testing is to determine the effect of the medication on the child's functioning, then testing in the medicated state or at least a comparison of functioning in both the medicated and non-medicated state would be more appropriate.

Based on the suggestions made by both Chermak et al (1999) and Barkley (1998) that children with the inattentive type of ADHD are unlikely to benefit from medication, it may be of interest to assess the continuous performance and central auditory processing of children with the three different types of ADHD in both the medicated and non-medicated state.

3.7 SUMMARY OF CHAPTER 3

The three opposing theoretical schools of thought regarding the conceptualization of ADHD and CAPD in children are discussed. In the first school of thought, CAPD is considered to be a disorder of the auditory modality while ADHD is suspected to be supramodal in nature. In the second school of thought, the auditory specific nature of CAPD is highlighted (while simultaneously recognizing that multimodality involvement may co-exist with CAPD due to the interconnectedness of the central nervous system) and ADHD is seen to be supramodal in nature. The value of tests of CAPD in differentiating between CAPD and ADHD, as suggested by Bellis and Ferre (1999), is highlighted in the discussion. In the third school of thought, the Buffalo Model (Katz et al, 1992) and the multimodal nature of CAPD is discussed. The possible link between Tolerance-fading memory deficit (one of the CAPD categories of the Buffalo Model (Katz et al (1992)) and ADHD, as reported by Stecker (1998) and Medwetsky (2002), is highlighted. Thereafter, the value of tests of auditory and visual continuous performance in investigating the nature of the attention deficits associated with the three different types of ADHD is discussed. Finally, the issues surrounding the administration of the above measures in the medicated and/or non-medicated state are addressed.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 INTRODUCTION

The review of the literature presented in Chapters 1, 2 and 3 highlights the lack of congruity in defining ADHD as a disorder. In many previous research studies the defining characteristics of children with ADHD have been subjective, poorly defined, frequently changing and disconnected from any theoretical construct or empirical base (Chermak and Musiek, 1997). This has lead to controversy concerning the etiology and prevalence of ADHD (and the different types of ADHD), as well as the value of different assessment methods and treatment options in the management of children with ADHD.

Against this background, the possible value of a specific multi-dimensional test battery (comprising tests of both continuous performance and CAPD) for investigating the nature of the deficits associated with the three different types of ADHD (in both the medicated and non-medicated state) is presented.

Chapter 4 presents the research methodology of the study, and entails a description and discussion of the aims, research design, participant selection criteria and procedures, as well as a description of the participants, apparatus and material, data collection procedures and, finally, the data analysis procedures used in the study.

4.2 AIMS

The main aim of the research is to determine the central auditory processing and continuous performance patterns of children with ADHD in the medicated and non-medicated state.

A specific multi-dimensional test battery was compiled for assessing the central auditory processing and auditory and visual continuous performance of the participants.

The sub-aims of the study are:

4.2.1 To assess the participants in 3 research groups (combined type, predominantly inattentive type, and the predominantly hyperactive-impulsive type of ADHD) in the medicated and non-medicated state using the specific multi-dimensional test battery.

4.2.2 To compare the inter- and intra-group tendencies of central auditory processing for the 3 research groups in the medicated and non-medicated state.

4.2.3 To compare the inter- and intra-group tendencies of auditory and visual continuous performance for the 3 research groups in the medicated and non-medicated state.

4.2.4 To analyze the specific multi-dimensional test battery results in relation to the different types of ADHD and subprofiles of CAPD.

4.3 RESEARCH DESIGN

A Between group (combined ADHD group, inattentive ADHD group and hyperactive-impulsive ADHD group) within-subjects design was used for two test conditions (with and without medication).

The test conditions were counterbalanced to control for order effect of the test conditions, as illustrated in Table 4.1. Half the participants in research groups 1 and 2, were tested, first in the medicated state and then the non-medicated state, while the remaining half of the participants in research groups 1 and 2 were

Table 4.1: The test conditions were counterbalanced to control for the order effect of the two test conditions (with and without medication).

	Research group 1: Combined group		**Research group 2: Inattentive group**		**Research group 3: Hyperactive-impulsive group**	
Test condition A: With medication	P1: 8yrs P2: 9yrs P3: 10yrs P4: 11 yrs P5: 12 yrs	P6: 8yrs P7: 9yrs P8: 10yrs P9: 11yrs P10: 12 yrs	P11: 8yrs P12: 9yrs P13: 10yrs P14: 11yrs P15: 12 yrs	P16: 8yrs P17: 9yrs P18: 10yrs P19: 11yrs P20: 12yrs	P21:11yrs	
Test condition B: Without medication	P6: 8yrs P7: 9yrs P8: 10yrs P9: 11yrs P10: 12yrs	P1: 8yrs P2: 9yrs P3: 10yrs P4: 11yrs P5: 12yrs	P16: 8yrs P17: 9yrs P18: 10yrs P19: 11yrs P20: 12yrs	P11: 8yrs P12: 9yrs P13: 10yrs P14: 11yrs P15: 12yrs		P21:11yrs

Key	
P	Participant
Yrs	Years (age of the participant)

first tested in the non-medicated state and then in the medicated state. Research group 3 consisted of only one participant and the test conditions could thus not be counterbalanced.

4.4 PARTICIPANTS

The participants, used in the study, were drawn from a school for children with learning disability. The decision to select participants from a school for children with learning disability was twofold. Firstly, children in schools for learning disability are reported to have a higher incidence of ADHD (Keller, 1998). Secondly, by using one school and doing the testing at the school the reliability and validity of the data collection procedures could be controlled in terms of environmental noise, participants' fatigue and medication state and levels, as discussed later in this chapter under 4.4.2.

Three research groups were used in this study. Research group 1 consisted of 10 children with the combined type of ADHD, research group 2 consisted of 10 children with the predominantly inattentive type of ADHD, and research group 3 consisted of a child with the predominantly hyperactive-impulsive type of ADHD. The inclusion of only one participant in research group 3 was due to a lower incidence of the hyperactive-impulsive type of ADHD compared to the combined and inattentive types of ADHD, as discussed in greater depth under 4.4.2.

4.4.1 Participant criteria

The participants included in the study were required to meet the criteria discussed below. This information was obtained from the school files as well as the principal of the school.

4.4.1.1 Diagnosis of ADHD

Participants were required to have been diagnosed by a medical practitioner as having ADHD and were required to be taking medication for ADHD, as prescribed by their medical practitioner. As the type of ADHD was not consistently listed in the school files the researcher consulted the five medical practitioners (four pediatricians and a psychiatrist) primarily used by the school in the management of children with ADHD. The telephonic consultations yielded that there are differences in the diagnostic criteria and materials used by the different medical practitioners in the diagnosis of ADHD. The diagnostic criteria and materials used by these medical practitioners included the DSM-IV criteria (American Psychiatric Association, 1994), the ICD-10 criteria (World Health Organization, 1992), the Connors rating scales (Conners, 1972, 1989) as well as checklists compiled by the individual practitioners. This finding is consistent with literature (American Academy of Pediatrics, 2000) reporting the varied and diverse measures currently used in the diagnosis of ADHD. The above measures, however, do not all allow for accurate differentiation between the different types of ADHD, and in the case of the DSM-IV (American Psychiatric Association, 1994) and the ICD-10 criteria (World Health Organization, 1992), different classifications of ADHD are provided.

A double criterion was thus set for potential participants. Participants were not only required to have been diagnosed with ADHD by a medical practitioner but were also required to meet the DSM-IV criteria (as outlined in Table 1.1) for a specific type of ADHD. This information was obtained from checklists completed by parents and teachers (Appendices I and II). The checklists were based on the criteria of the DSM-IV and each participant was required to meet the criteria for the specific type of ADHD by both the teacher and the parents in order to be placed in a particular research group. The DSM-IV criteria (American Psychiatric Association, 1994) for the diagnosis of the different types of ADHD require the presence of six or more symptoms of inattention and/or hyperactivity-impulsivity persisting 6 or more months. As discussed in Chapter 1, the combined type of ADHD meets criteria A and B (as listed in Table 1.1), the predominantly inattentive type of ADHD meets criteria A, but not B (as listed in Table 1.1), and the predominantly hyperactive-impulsive type of ADHD meets criterion B, but not all A (as listed in Table 1.1).

4.4.1.2 Age

Participants were required to be between 8 and 12 years of age. The motivation for this criterion is that the diagnostic CAPD test material available for children, younger than 8 years of age, is limited. Younger children can therefore not be assessed using a comprehensive diagnostic battery of CAPD tests (Chermak and Musiek, 1997, DeConde Johnson, Benson and Seaton, 1997).

4.4.1.3 Home language and medium of formal education

English, as home language and medium of formal education, was included as a criterion as the test materials currently available for assessing CAPD are only available in English. Individuals assessed in a language in which they have competence but which is not their home language have been documented to perform less favorably on CAPD and vigilance tests than when assessed in their home language (Bellis, 1996, Chermak and Musiek, 1997, DeConde Johnson et al 1997).

4.4.1.4 Cognitive abilities

Participants were required to have average to above-average intellectual abilities as documented in the school files. Average to above-average intellectual ability is a condition for acceptance into the school. A team comprising psychologists, speech-language pathologists and remedial teachers do the initial admission assessment at the school.

Below-average intellectual abilities have been shown to negatively influence CAPD test results (Bellis, 1996, Chermak and Musiek, 1997, DeConde Johnson et al, 1997) as well as tests of visual and auditory continuous performance. Children with below average intellectual abilities were thus excluded from the study.

4.4.1.5 Medical history

Participants were required to have no history of neurological dysfunction due to medical conditions such as epilepsy and cerebral palsy or head trauma. Neurological dysfunction of this nature may influence the individual's ability to respond appropriately in the test situation and may impact negatively on CAPD test scores (Bellis, 1996, Chermak and Musiek, 1997) and tests of visual and auditory vigilance (Tillery, 1998).

Children with medical conditions and syndromes such as visual disorders, Tourette Syndrome and Asperger's Syndrome as well as other conditions such as Oppositional defiant disorder, Conduct disorder, and Obsessive compulsive disorder were also excluded as possible participants for the study in order to control for additional variables that could influence the results of the study. This information was obtained from the school files.

4.4.1.6 Medication

Each participant included in the study was assessed using the specific multi-dimensional test battery under two test conditions, namely the medicated and non-medicated state. The participants were children diagnosed by medical practitioners as having ADHD and had been prescribed medication for ADHD. Each child was assessed in the medicated state at the optimal levels of the medication following the onset of action period, and in the non-medicated state after a period of withdrawal, when the medication was no longer present in the participant's system. The onset of action for Ritalin and Ritaphen (a generic of Ritalin) is 10-20 minutes after ingestion with a clinical effect lasting 3-5 hours (Copps, 2002). The onset of action for slow release Ritalin (Ritalin SR) is 1 hour with a clinical effect lasting 4-6 hours and occasionally as long as 8 hours (Copps, 2002). When testing in the non-medicated state, an extended withdrawal period of at least 12 hours was required for children taking Ritalin/Ritaphen, and a 24 hour period for children using slow release Ritalin.

4.4.1.7 Peripheral hearing and middle ear functioning

Normal peripheral hearing and middle ear functioning at the time of the data collection were included as criteria as both elevated hearing thresholds and abnormal middle ear functioning impact negatively on a participant's ability to understand test instructions correctly. Furthermore, abnormal peripheral hearing and middle ear functioning impacts negatively on CAPD test scores as well as measures of auditory continuous performance (Bellis, 1996, Chermak and Musiek, 1997, DeConde Johnson et al, 1997).

Normal peripheral hearing is defined as normal puretone thresholds between 0 and 15dBHL (for the frequency range 125-8000Hz) and normal middle ear functioning as a type A tympanogram with a middle ear pressure of between –100 and +50dB, and a static compliance between 0,3 and 1,75cm^3. The normative data used is based on the recommendations of Musiek and Rintelmann (1999).

Ipsi- and contra-lateral stapedial reflex measurements were included as part of the immittance measurements but formed part of and are discussed under the data collection procedures.

4.4.1.8 Motivation

The participants included in the study were required to be motivated to participate in the study. The researcher explained what the testing would entail to the participants, namely "a computer game and some listening games". The children were also given a sticker of a cartoon character at the end of each session. Only those children who wished to partake in the study were included. Motivation or the willingness to partake and cooperate during behavioral CAPD assessments (Jerger and Musiek, 2000) and tests of continuous performance (Sandford and Turner, 2001) are important variables to consider as a lack of motivation may impact on the validity of the test results.

4.4.2 Participant selection procedures

An appointment was made with the principal of a school for children with learning disabilities to discuss the proposed study and to obtain permission to use children from the school in the study.

The principal agreed to participate in the study but asked that arrangements be made for the data collection to be done at the school rather than at the Department of Communication Pathology at the University of Pretoria, as originally proposed by the researcher. This request was made by the principal for the following reasons:

- Firstly, the testing needed to be done in the morning to control for participants' fatigue and this had implications for the school program. The principal felt that by doing the data collection at the school, the amount of time that each child missed would be reduced by eliminating traveling time.

- Secondly, the principal was concerned that the parents would not be able or willing to take time off work to bring children for the testing.

- Thirdly, although willing to arrange for the school to bring the children for the testing, the principal for safety reasons was concerned about transporting the children for safety reasons.

- Fourthly, the principal felt that the children would respond more appropriately within a familiar environment.

- Fifthly and finally, it was noted that the teachers usually administer the medication at the school (with the permission of the parents). The principal felt that the medication could be better controlled if the testing took place at the school.

Possible participants for the study, namely children diagnosed with ADHD by a medical practitioner and meeting the participant criteria stipulated above, were identified by the researcher and the principal using the school files. There were 157 children enrolled at the school with 64 (40,76%) children diagnosed with ADHD by a medical practitioner. Of the 64 children diagnosed with ADHD by a medical practitioner, 41 (64,06%) of the children also met the participant selection criteria stipulated for age, home language and medium of formal education, cognitive abilities, motivation, medical history, medication as well as peripheral hearing and middle ear functioning.

A letter outlining the study, and requesting permission for their child to participate in the study (included as part of Appendix I) was sent to the parents of the 41 children that met the criteria for the study. Thirty five (85,37%) of the 41 letters were returned providing written permission for their children to participate in the study.

A checklist of the child's behavior based on the DSM-IV (as discussed under 4.4.1) was sent, together with above letter of permission (as part of Appendix I), for the parents to complete. A similar checklist (Appendix II) was adapted for the teachers and given by the principal to each child's teacher to complete. The information obtained from the checklists was used to allocate the participants to the three research groups (the combined type, the hyperactive-impulsive type and the inattentive type of ADHD) as discussed under 4.4.1. Each participant was required to meet the specific ADHD type criteria by both the teacher and the parents in order to be placed in a particular research group.

The number of potential participants meeting the specific ADHD criteria, as assessed by both the parents and the teachers for each age interval (8, 9, 10, 11 and 12 years), is presented in Table 4.2. The Frequency Procedure of the SAS Program (SAS Institute Inc., 1999) was used to determine the number of children meeting the specific ADHD criteria, as assessed by both the teachers and parents. In the selection of the participants, it was hoped to identify two participants at each age interval for each research group. Only one participant who met the criteria for the hyperactive-impulsive type of ADHD was identified. This finding is supported by the literature (Wilens et al, 2002) that reports a lower incidence of the hyperactive-impulsive type of ADHD than the combined or inattentive types of ADHD.

Table 4.2: The number of potential participants meeting the specific ADHD criteria as assessed by both the parents and the teachers for each age interval.

Age interval	Combined type of ADHD	Inattentive type of ADHD	Hyperactive-impulsive type of ADHD	Did not meet the criteria	TOTAL
8 years	3	2	0	2	**7**
9 years	2	3	0	1	**6**
10 years	2	2	0	2	**6**
11 years	3	3	1	3	**10**
12 years	2	2	0	2	**6**
TOTAL	**12**	**12**	**1**	**10**	**35**

4.4.3 Description of the participants

Ten participants (2 participants representing each age interval) were randomly selected for the research group 1 (combined type of ADHD) and research group 2 (inattentive type of ADHD). Only one participant who met the criteria for the hyperactive-impulsive type of ADHD, as discussed under 4.4.2 was identified. Table 4.3 provides a summary of the participants included in the study.

4.5 APPARATUS AND MATERIAL

The apparatus and material used in the selection of the participants and during data collection will be discussed separately.

4.5.1 Material and apparatus used to identify possible participants for the study

The following material and apparatus was used to identify possible participants for the study:

Table 4.3: Description of the participants included in the study

Research group	Participant number	Age (in years)	Gender	Hand dominance	Medication
Research group 1: Combined type	1	8	Male	Left	Ritaphen
	2	9	Male	Right	Ritalin
	3	10	Female	Right	Ritalin
	4	11	Male	Right	Ritalin
	5	12	Male	Right	Ritaphen
	6	8	Male	Right	Ritalin
	7	9	Male	Right	Ritalin
	8	10	Male	Right	Ritalin
	9	11	Male	Right	Ritalin SR
	10	12	Female	Right	Ritalin SR
Research group 2: Inattentive type	11	8	Male	Right	Ritalin
	12	9	Male	Right	Ritalin SR
	13	10	Male	Right	Ritalin
	14	11	Female	Left	Ritalin
	15	12	Male	Right	Ritalin
	16	8	Male	Right	Ritalin
	17	9	Male	Right	Ritalin
	18	10	Male	Left	Ritalin SR
	19	11	Male	Right	Ritalin
	20	12	Female	Left	Ritalin
Research group 3: Hyperactive-impulsive type	21	11	Female	Right	Ritalin

4.5.1.1 School files

Permission was obtained from the school principal to use the school files to identify possible candidates for the study.

4.5.1.2 Letter of consent (Appendix I)

A letter of consent (Appendix I) to gain written permission for their children to participate in the study was compiled by the researcher and completed by the parents. This letter of consent outlined the study, guaranteed confidentiality, and provided practical information such as the nature of testing, venue and the period of time that would be necessary for completing the testing.

4.5.1.3 Behavioral checklists (included as part of Appendix I and Appendix II)

A checklist of behaviors based on the criteria of the DSM-IV (included as part of Appendix I) was given to the parents to complete and a similar checklist (Appendix II) was given to the teacher of each child to complete. The information obtained from the checklists was used to allocate participants to the three research groups. Each participant was required to meet the specific ADHD type criteria by both the teacher and the parents in order to be placed in a particular research group.

4.5.1.4 Audiometric equipment and audiogram (Appendix III)

A GSI 68 Diagnostic Audiometer with Telephonic TDH-39P earphones and a GSI 28A Middle Ear Analyzer was used to assess the peripheral hearing and middle ear functioning of the participants prior to administering the specific multi-dimensional test battery. The audiometer and middle ear analyzer had been calibrated according to the requirements of the South African Bureau of Standards (SABS). The results were recorded on the audiograms (Appendix III) of the Department of Communication Pathology, University of Pretoria.

4.5.2 Material and apparatus to be used during data collection

A specific multi-dimensional test battery was compiled to assess the central auditory processing as well as auditory and visual continuous performance of the participants. The administration of the specific multi-dimensional test battery necessitated the use of an audiometer, a compact disc player and a laptop computer. A sound level meter was used to monitor the noise levels in the room used for the testing.

4.5.2.1 The specific multi-dimensional test battery

The specific multi-dimensional test battery consisting of a comprehensive CAPD test battery as well as The Integrated Visual and Auditory Continuous Performance Test (IVA CPT) and IVA STAR (narrative report writer for the IVA CPT) (Sandford and Turner, 2001) as presented visually in figure 4.1. The term "specific multi-dimensional test battery" is used to refer to the above test battery as it includes "specific" measures of both central auditory processing and continuous performance. The concept "multi-dimensional" as used in this term refers to the complexity and diversity of factors being considered; namely the central auditory processing, and auditory and visual performance of the participants in both the medicated and non-medicated state. The rationale for the test material included in the specific multi-dimensional test battery, as discussed in Chapter 3, is summarized in Table 4.4.

4.5.2.1.1 <u>The CAPD test battery</u>

In the Bruton conference consensus report, Jerger and Musiek (2000) identify three possible approaches to the construction of a CAPD test battery, namely behavioral tests, electrophysiological and electroacoustic tests, and finally, neuroimaging studies. Behavioral measures are seen to hold the greatest promise in routinely used test batteries as electrophysiological and electroacoustic tests, as well as neuroimaging are more expensive and time consuming with limited availability (Jerger and Musiek, 2000).

As discussed in Chapter 3, the choice of specific tests used in the behavioral assessment of central auditory processing, varies among audiologists (Katz et al, 1992, Bellis and Ferre, 1999, Jerger and Musiek, 2000).

In a relevant article differentiating between ADHD and CAPD, Bellis and Ferre (1999) propose that tests of CAPD may be useful in differentiating between ADHD and CAPD in children. The CAPD test battery used in the study is thus

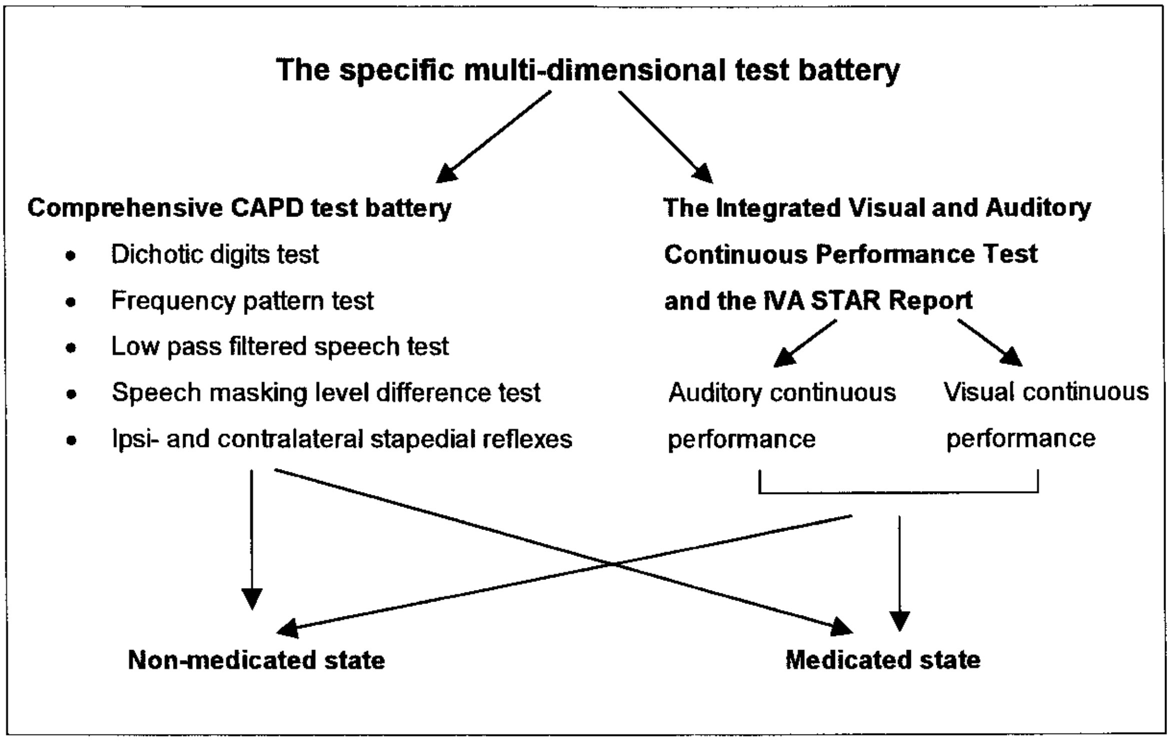

Figure 4.1: The specific multi-dimensional test battery

based on the recommendations of Bellis and Ferre (1999). Bellis and Ferre (1999) recommend that a behavioral CAPD test battery includes at least one test from each of the following categories:

- Dichotic tests (one linguistically loaded test and one test with a lighter linguistic load)
- Temporal ordering
- Monaural low redundancy tests
- Binaural fusion tests

As discussed in Chapter 3, Bellis (2003a) recently provided an update on recommendations for the components of a comprehensive CAPD test battery. The value of this updated comprehensive CAPD test battery in differentiating between ADHD and CAPD warrants further investigation but is beyond the scope

Table 4.4: The rationale behind the components of the specific multi-dimensional test battery.

Components of the specific multi-dimensional test battery	Motivation
The Integrated Visual and Auditory Continuous Performance Test (IVA CPT) and the IVA STAR (Narrative report writer for the IVA CPT) (Sandford and Turner, 2001)	• The inclusion of the IVA CPTand IVA STAR (Sandford and Turner, 2001) consisting of similar tasks in multiple (auditory and visual) sensory modalities assists in determining the modality of attention deficits associated with ADHD. Chermak et al (1999) describe the attention deficits associated with ADHD to be supramodal in nature. McFarland and Cacace (1995) postu late that CAPD are auditory specific in nature and that the use of similar tasks in multiple sensory modalities are thus of value in differentiating between ADHD and CAPD. By including the IVA CPTand IVA STAR (Sandford and Turner, 2001) in the specific mu lti-dimensional test battery the modality or modalities affected by the attention deficit associated with ADHD could be determined for the three different types of ADHD. • The IVA CPT and IVA STAR, were selected in preference to other available tests of co ntinuous performance, as these measures combine *both* auditory and visual stimuli in a counterbalanced design, together with attention and vigilance, thus incorporating two continuous performance tests into one measure (Kane and Whiston, 2001).
Comprehensive CAPD test battery (based on the recommendations of Bellis and Ferre, 1999)	• The comprehensive CAPD test battery (based on the recommendations of Bellis and Ferre, 1999) was included in order to determine whether patterns occur in the CAPD test results for both the medicated and non-medicated conditions. Specific patterns in CAPD test results have been linked to CAPD subprofiles (Bellis and Ferre, 1999). Bellis and Ferre (1999) speculate that children with ADHD should present with intact central auditory processing abilities, or in the case of abnormal CAPD test results, that no clear patterns that can be linked to CAPD subprofiles will be observed. • Bellis (2003a) recently provided an update of their recommendations for the components of a comprehensive CAPD test battery. The value of this updated comprehensive CAPD test battery in differentiating between ADHD and CAPD warrants further investigation but is beyond the scope of this study as the data collection phase of the study had been completed prior to the publication of these recommendations.

of this study as the data collection for the study was completed prior the publication of these recommendations.

The specific behavioral tests used in compiling the CAPD test battery for the study were drawn from the "Tonal & Speech Materials for Auditory Perceptual Assessment Disc 2.0" (Department of Veterans Affairs, 1998). This compact disc has twenty-two recorded tracks that can be used in assessing central auditory processing. The compact disc was compiled and recorded in the USA and the speakers used to record the test stimuli thus have American accents. Normative data is not provided with the compact disc and the audiologist is referred to a series of papers in the July 1994 issue of the Journal of the American Academy of Audiology in which preliminary normative data are provided for some of the test materials (Department of Veterans Affairs, 1998). As with all tests of central auditory processing, it is strongly recommended that clinicians develop appropriate normative data for their own clinics (Bellis, 1996, Department of Veterans Affairs, 1998). As no equivalent tests of CAPD are available in South Africa, phase I of the pilot study was used to compile normative data that could be used during data analysis.

The CAPD test battery used in this study, namely that of Bellis and Ferre (1999) consists of four behavioral measures and one electrophysiological/ electroacoustic measure. The specific tests included in the test battery are presented below, followed by the motivation for the inclusion of the specific test in each test category:

- The Dichotic digits test (Double digits)
- The Frequency pattern test (both the labeling and humming conditions)
- Low pass filtered speech test
- Speech masking level difference test
- Ipsi- and contra-lateral acoustic reflexes (measured during the Immittance testing)

The Dichotic digits test (double digits) from the "Tonal & Speech Materials for Auditory Perceptual Assessment Disc 2.0" (Department of Veterans Affairs, 1998) was selected to represent the dichotic test category. This test has a lighter linguistic load than some of the other dichotic tests such as the Dichotic sentence identification test that is also available on the above compact disc. The Dichotic digits test is available in two versions, namely single and double digits. The double digits version was selected as the task is more challenging, yet simple enough even for young children (Bellis, 1996, Bellis, 2001, Bellis, 2003a). Track 3 on the compact disc was used and consists of 25 test items each consisting of 4 different digits where 2 digits are presented with the other 2 digits being simultaneously presented to the other ear. The first 5 items were used as practice items and the remaining 20 items were used as the test items. The scoring sheet used is presented in Appendix IV.

Although it is recommended in the literature (Bellis, 1996; Bellis and Ferre, 1999, Bellis, 2003a) that a dichotic test with a higher linguistic load also be included in the test battery, this was not done for the following reasons. Firstly, the participants included in the study were drawn from a school for children with learning disability. As discussed above, children with learning disability are reported to have a higher incidence of language disorders (Medwetsky, 2002). The inclusion of measures with a lighter linguistic load thus reduces the effects that possible language impairment may have on CAPD results. Secondly, the Dichotic sentence identification test on the above compact disc requires a level of reading ability that could negatively have affected the results of the younger participants. Finally, time constraints were also taken into account. The complete specific multi-dimensional test battery needed to be administered in a single test session in the medicated and non-medicated state.

The Frequency pattern test from the "Tonal & Speech Materials for Auditory Perceptual Assessment Disc 2.0" (Department of Veterans Affairs, 1998) was selected to represent the temporal ordering test category. This test consists of frequency tone patterns and the participant is requested to repeat the frequency pattern heard, for example: "low, low, high" or "high, low, high". Track 16 on the above compact disc was used and the stimuli were presented first to one ear and then to the other. There are 30 test items. The first 5 items were again used as practice items while the remaining 25 items were used for the actually testing. This test was also administered under two conditions. In the first condition, the participant was asked to label the frequency pattern and in the second test condition, the participant was asked to hum the frequency pattern (thus removing the linguistic labeling component). The comparison of the results obtained under the two conditions provide information about the interhemispheric transfer of information (Bellis, 1996, Bellis, 2003a). The Frequency pattern test rather than the Duration pattern test on the compact disc was selected, as age norms for the test are better defined, and the test is more appropriate for young children (Bellis, 1996, Bellis, 2001, Bellis, 2003a). The scoring sheets used are included in Appendices V (labeling condition) and VI (humming condition).

The Low pass filtered speech test from the "Tonal & Speech Materials for Auditory Perceptual Assessment Disc 2.0" (Department of Veterans Affairs, 1998) was selected to represent the monaural low redundancy test category. This test consists of monosyllabic words from list 3 of the Northwestern University Auditory Test no. 6, spoken by a female. The words are low pass filtered (1500Hz cutoff; 115dB/octave). Track 14 on the above compact disc was used. There are 50 test items. The first 5 items were used as practice items after which test items 6-25 were presented to the left ear. The next 5 items (items 26-30) were again used for training, after which items 31-50 were presented to the right ear. The Filtered speech test rather than other tests such as the 45% or 65% Time compressed speech was selected for inclusion in the CAPD test battery as the validity of the Filtered speech test in both children and adults is better documented. Furthermore the normative data available for the filtered speech test are more comprehensive than for other measures of monaural low redundancy (Bellis, 1996, Bellis, 2003a). The scoring sheet used is presented in Appendix VII.

The Speech masking level difference (MLD) test from the "Tonal & Speech Materials for Auditory Perceptual Assessment Disc 2.0" (Department of Veterans Affairs, 1998) was selected to represent the binaural fusion test category. This test consists of spondaic words embedded in bursts of broadband noise that are presented in the S_oN_o and $S_{\pi}N_o$ paradigm. The MLD threshold is calculated by determining the difference between the thresholds obtained for the above two conditions. The Binaural fusion test using monosyllabic words (with low frequency information presented to the one ear and the high frequency information simultaneously presented to the other ear), was originally considered but rejected based on literature (Bellis, 1996) that questions the utility of the Binaural fusion test, as most children obtain high scores for the test. The Tonal MLD test was then considered but could not be used as the GSI 68 Diagnostic Audiometer that had been loaned to the researcher for the data collection did not have this function. The decision was thus made to use the Speech MLD test from the "Tonal & Speech Materials for Auditory Perceptual Assessment Disc 2.0" (Department of Veterans Affairs, 1998). The scoring sheet used is presented in Appendix VIII.

The ipsi- and contra-lateral stapedial reflex measurements (obtained during the Immittance measurements) were included as the final component of the CAPD test battery. These measurements are routinely used by the researcher during CAPD testing and there is evidence in the literature to suggest that the contra-lateral reflexes may be elevated or absent for some children with CAPD (Bellis, 1996; Bellis, 1999, Bellis, 2003a).

4.5.2.1.2 The Integrated Visual and Auditory Continuous Performance Test IVA CPT (Sandford and Turner, 2001)

As discussed in Chapter 2, there are a number of commercially available tests of continuous performance. For this study, The Integrated Visual and Auditory Continuous Performance Test (IVA CPT) and IVA STAR (narrative report writer for the IV CPT) (Sandford and Turner, 2001) were selected. The Integrated Visual and Auditory Continuous Performance Test (Sandford and Turner, 2001) combines both auditory and visual stimuli in a counterbalanced design, together with attention and vigilance. As discussed in Chapters 2 and 3, 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) with an advantage over other tests of continuous performance. The IVA STAR is an additional feature of the IVA CPT (Sandford and Turner, 2001) that can be purchased. The IVA STAR does not require any additional testing and is an automated report that provides a comparison of the auditory and visual modalities.

The IVA CPT (Sandford and Turner, 2001) is a 20 minute computerized continuous performance test that combines both auditory and visual stimuli. As stated above, by combining the auditory and visual modes in a counterbalanced design together with attention and vigilance, the IVA CPT (Sandford and Turner, 2001) incorporates two continuous tests of performance into one. The main testing segment takes 13 minutes, with the remaining time being used for instructions, the practice period and "warming up" and "cooling down".

As for other tests of continuous performance the IVA CPT (Sandford and Turner, 2001) is designed to be mildly boring and starts with a five-minute warm-up and training session after which the thirteen minute test commences. The test task is simple and requires the individual to click on the mouse only when s/he hears or sees the target (the number "1") and not to click when s/he hears or sees the non-target or foil item (the number "2"). Since the "1's" and "2's" are presented in a pseudo-random combination of visual and auditory stimuli, it is more demanding than other tests of continuous auditory performance as it challenges the individual's ability to change cognitive sets. The administration of the test is automated to standardize the presentation of auditory and visual stimuli. The computer "speaks" all test instructions in order to minimize test variability. The test contains two conditions in two modalities for a total of 200 trials. The first block of 100 trials consists of 50 trials in the auditory modality and 50 trials in the visual modality. This is a measure of impulsivity using a ratio of targets to non-targets of 5,25:1. The second block of 100 trials consists of 50 trials in the auditory modality and 50 trials in the visual modality. This assesses inattention where the number of targets to foils is reduced but the ratio stays the same. This counterbalanced design allows the individual to rest to some degree and controls for practice and fatigue effects during the course of the test. By using a mouse click as a means of response, the IVA CPT (Sandford and Turner, 2001) provides an objective means of determining fine motor hyperactivity by measuring inappropriate mouse clicking activity.

The scores are presented as both raw scores and quotient scores. All quotient scores have a mean of 100 and a standard deviation of 15, the same as those used for most Intelligence Quotient (IQ) tests. The automated normative database (n=1700 normal individuals, aged 5-90+) takes gender and age into account. An example of the scoring sheet is presented in Appendix IX.

The IVA CPT (Sandford and Turner, 2001) consists of 6 composite scores and 22 other scores divided into 5 groups, namely the Fine motor regulation/hyperactivity score, the Response control scores, the Attention scores, the Attribute scores, and the Validity scores. The 2 main global composite quotient scores of the IVA CPT (Sandford and Turner, 2001) (defined in Table 4.5) are the Full scale response control quotient and the Full scale attention quotient scores. The Full scale response quotient is based on 2 composite

Table 4.5: A description of the IVA CPT scores (Sandford and Turner, 2001)

IVA scores	Description of the IVA scores
Full Response Control Quotient - Auditory Response Control Quotient (ARCQ) - Visual Response Control Quotient (VRCQ)	(Based in equal weights on the ARCQ and VRCQ) (Based in equal weights on auditory prudence, consistency and stamina) (Based in equal weights on visual prudence, consistency and stamina)
Full Attention Quotient - Auditory Attention Control Quotient (AACQ) - Visual Attention Control Quotient (VACQ)	(Based in equal weights on the AACQ and VRCQ) (Based in equal weights on auditory vigilance, focus and speed) (Based in equal weights on visual vigilance, focus and speed)
Fine motor regulation / hyperactivity	Off-task behaviors with the mouse (including multiple clicks, spontaneous clicks, anticipatory clicks and trials when the mouse is held down)
Response control - Auditory prudence - Visual prudence - Auditory consistency - Visual consistency - Auditory stamina - Visual stamina	Prudence is a measure of impulsivity and response inhibition Consistency is a measure of general reliability of response times (ability to stay on task) Stamina used to identify problems related to sustaining attention over time
Attention - Auditory vigilance - Visual vigilance - Auditory focus - Visual focus - Auditory speed - Visual speed	Vigilance is a measure of inattention and is determined by the ability to maintain preparedness to an intermittent signal Focus is sensitive to an unusual number of occurrences of slow reaction times Speed refers to the reaction time of all the correct responses
Attribute - Balance - Auditory readiness - Visual readiness	Balance refers to whether the person processes information more quickly visually, aurally or equally Readiness is a subtle measure of attention problems by measuring test performance when demands to respond are less frequent
Validity - Auditory comprehension - Visual comprehension - Auditory persistence - Visual persistence - Auditory sensory motor - Visual sensory motor	Comprehension identifies random responding and help reduce false positives Persistence may reflect a lack of motivation, or in some cases, mental or motor fatigue Sensory/motor provides a measure of reaction times to simple singular test stimuli to screen for slow reaction times

scores, namely the Auditory response control quotient and the Visual response control quotient. These response control quotients are derived from the primary scores of Auditory and Visual prudence, Consistency and Stamina scales as defined in Table 4.5. The Full scale attention quotient is based on 2 composite scores, namely the Auditory attention control quotient and the Visual attention control quotient. These attention control quotients are derived from the primary scores of Auditory and Visual vigilance, Focus and Speed scales as defined in Table 4.5. The Fine motor regulation scale provides additional information by recording off-task behaviors with the mouse, including multiple clicks, spontaneous clicks during the instruction period, anticipatory clicks and holding the mouse button down. The Attribute scores provide information about the individual's learning style. The Attribute scores, namely Balance, Auditory readiness and Visual readiness, are defined in Table 4.5. The Validity scores provide information about the individual's random responses, lack of motivation or fatigue and reaction times. The Validity scores, namely Auditory and Visual comprehension, Persistence and Sensory motor, are defined in Table 4.5.

The IVA STAR (normative report writer for the IVA CPT) consists of primary and combined scales (defined in Table 4.6) and provides additional information about attention. These scales also make use of standard scores (Q scores) to facilitate comparisons between them. An average score is 100, with 15 points representing one standard deviation, similar to IQ scores. An example of the scoring sheet is presented in Appendix X. The four primary scores determined for both the auditory and visual modalities are alertness, steadiness, promptness and constancy. The combined scales integrate the four primary scales and provide an overall impression of the performance of the auditory and visual modalities. The Combined attention quotient score further combines the visual and auditory quotients into one global score in order to provide a measure of overall attention.

Table 4.6: A description of the IVA STAR scores (Sandford and Turner, 2001)

IVA scores	Description of the IVA STAR scores
Primary Scales	
- Auditory alertness - Visual alertness	Alertness measures the percentage of correct responses when the demand to respond is infrequent (reflects problems with inattention)
- Auditory steadiness - Visual steadiness	Steadiness is defined as the percentage of correct responses when targets are frequent (reflects problems in sustaining attention)
- Auditory promptness - Visual promptness	Promptness is defined as the discriminatory reaction time to the targets during sections when the targets are rare (reflects mental processing speed
- Auditory constancy - Visual constancy	Constancy is defined as the variability of an individual's discriminatory reaction time when targets are infrequent (reflects fatigue and distractions by internal or external conditions)
Combined Scales	
- Auditory specific	General attention for the auditory modality
- Visual specific	General attention for the visual modality
- Global (Auditory and Visual)	Overall attention combining the auditory and visual modality

4.5.2.2 Audiometric equipment, compact disc player, notebook computer and sound level meter

A GSI 68 Diagnostic Audiometer with Telephonic TDH-39P earphones was used to administer the CAPD test battery. The CAPD test materials from the compact disc were routed via the Sony CD player through the audiometer to the headphones worn by the participant. The GSI 68 Audiometer had been calibrated according to the SABS Standards.

A Mecer Pentium III Notebook (Series A450) was used to load the IVA CPT software (Sandford and Turner, 2001) purchased from Braintrain. The test stimuli were presented through Digitech CD-3000 stereo headphones to the participants.

The testing was done at the school in the teachers' computer room, where the noise levels were monitored using a Rion Sound Level Meter NA-24 set on function A. The room is situated away from the central noise areas of the school, has a dimension of 3x2m² and is fitted with a carpet and curtains. The noise levels were monitored in the room and noise levels were kept below the 40-45dBSPL marker on the sound level meter. The sound level meter had been calibrated according to SABS standards. Ideally, the testing should have been done in a soundproof booth but for reasons discussed under 4.4.2 this was not possible as the data collection needed to be done at the school. By using a sound level meter and controlling the environmental noise, the researcher was able to assess all the subjects under the same controlled and quiet conditions.

4.6 THE PILOT STUDY

The pilot study consisted of three phases as outlined in Table 4.7.

Table 4.7: The aim, motivation, procedure, results and conclusions/adaptations relating to the three phases of the pilot study.

Phase	Aim	Motivation	Procedure	Results	Conclusions/ adaptations
I	The collection of normative data for the CAPD test battery.	The normative data available have been obtained in the USA and may thus not necessarily be reflective of the SA population. Furthermore, it is strongly recommended that clinicians develop appropriate normative data for their own clinics (Department of Veterans Affairs, 1998, Bellis, 1996).	The researcher and two final year Communication Pathology students at the University of Pretoria assessed 50 children (ten children aged 8, 9, 10, 11, and 12 years) using the training and test procedures presented in Table 4.8 and discussed under 4.7 (Data collection procedures). The children were required to have no history of developmental and/or learning disability or ADHD and were attending mainstream schools.	The results (means and standard deviations) are included in Appendix XI. The results obtained were similar to those reported by Bellis (1996, 2003a) with the exception of the Filtered speech test where the children in this study performed more poorly. This is possibly attributable to the different versions in the test material used by Bellis (1996, 2003a). Bellis (1996, 2003a) obtained normative data for the Ivey filtered word test (male speaker) on tape with a 1000Hz cut-off. The Filtered speech test on the Tonal and Speech Materials for Auditory Perceptual Assessment Disc 2.0. uses the voice of a female speaker and a 1500 low pass cut-off. Scores obtained using the compact disc version have been reported to be lower than for the tape version (Bellis, 1996, 2003a)	Based on the recommendation that clinicians develop appropriate normative data for their own clinics (Bellis,1996, Department of Veterans Affairs, 1998), the normative data collected by the researcher will be used in the study.

Table 4.7 continued

Phase	Aim	Motivation	Procedure	Results	Conclusions/ adaptations
II	To gain experience in administering and interpreting the IVA CPT and IVA STAR.	The IVA CPT and IVA STAR were new assessment measures to the researcher and it was thus necessary for the researcher to gain experience in administering and interpreting the IVA CPT and IVA STAR.	Three adults (aged 36,38 and 57) and thereafter five mainstream children (two of whom were aged 8, two aged 9 and one aged 10) were assessed using the IVA CPT and IVA STAR. Thereafter the researcher interpreted the results according to IVA CPT test manual (Sandford and Turner, 2001).	No difficulties were experienced in administering and interpreting the test results. It was, however, noted that the one child was left-handed but had been taught to use his right hand when working with the computer mouse. The researcher allowed the child to use his right hand as his ability to work with the computer mouse was far superior to that of his left hand. His results using his right hand were within the normal range and similar to those of the other children. The other children and adults were all right handed.	The researcher gained experience in administering and interpreting the IVA CPT and IVA STAR. It was decided to allow left-handed participants in the study to use the hand that they were accustomed to using when manipulating the computer mouse.
III	To determine the length of time required in administering the immittance, puretone (air-conduction) audiometry (part of the selection procedures) and the specific multi-dimensional test battery (the data collection phase).	Information about the length of time required to complete the testing was necessary in order to compile a testing roster than could be accommodated into the school program.	Two children (aged 8) were assessed using the immittance, puretone (air-conduction) audiometry and the specific multi - dimensional test battery. Both children were in the mainstream educational setting. The first child had no history of learning disability while the second child had a history of learning disability. The second child was included to determine whether children with a history of learning disability would require more time to complete the testing	The time required for administering the different tests to the children was similar and as follows: Immittance and puretone testing (10 minutes), IVA CPT / IVA STAR (20 minutes) and the CAPD test battery (30 minutes: 5 minutes for instructions and 25 minutes for the testing). The total testing time was thus approximately 1 hour.	It was decided to use a 1 hour 15 minute test session to allow for any additional time required and to create a relaxed and unrushed atmosphere during the testing.

The first phase consisted of the collection of normative data for the behavioral CAPD test battery using children within the mainstream setting and experiencing no developmental or learning disabilities. The behavioral CAPD test battery comprised of the Dichotic digits test (double digits), the Frequency pattern test, the Low pass filtered speech test and the Speech masking level difference test. The CAPD tests were all administered at an intensity of 50dBSL (re: average puretone threshold at 500, 1000 and 2000Hz). The normative data for CAPD tests provided in the literature were compiled using varying intensity settings (Bellis, 1996). A fixed intensity of 50dBSL (re: average puretone threshold at 500, 1000 and 2000Hz) was used and puretone thresholds rather than speech reception thresholds were used as the data collection was to be done in one room at the participants' school and live voice speech audiometry was thus not possible. The use of recorded USA speech audiometry materials (no equivalent measures are available in South Africa) was considered but decided against, as no normative data are available for the South African population for these measures.

In compiling the normative data, fifty children were assessed (ten children aged 8, 9, 10, 11 and 12 years) respectively. Prior to commencing with the CAPD testing, the children were familiarized with the test material, as outlined and motivated in Table 4.8. The children's attention was also drawn to the fact that the recorded material had been compiled in the USA and that due to the American accent, some words might be pronounced slightly differently. Children in South Africa receive exposure to the American accent through television programs, films and teaching materials and it was thus felt that differences in accent would not be unfamiliar to the children participating in the study.

The results of the fifty children were processed using the Means Procedure of the SAS program (SAS Institute Inc., 1999). The mean, standard deviation, mean – 1 standard deviation and mean - 2 standard deviations were determined

Table 4.8: Training that occurred prior to the CAPD Testing

CAPD Test	Training	Motivation for training
Dichotic digits test	Each child was asked to repeat a sequence with 4 digits.	The Dichotic digits test consists of 4 digits, with 2 digits being presented simultaneously in the different ears. A pre-requisite for this test is that a child is able to repeat a sequence of 4 digits. Each child was required to be able to repeat a sequence of 4 digits.
Frequency pattern test	A low puretone was presented on the audiometer at 500Hz and a high puretone at 4000Hz was used to illustrate the concept of "high" and "low", whereafter the child was asked to say whether the puretone presented was "low" or "high".	The Frequency pattern test consists of patterns that the child must label and later hum, for example "low low high". This requires an underlying understanding of the concepts "low" and 'high". Each child was required to be able to correctly identify the "low" and "high" puretones.
Low pass filtered speech test	The words included as test items were read to each child and the meaning of each word was discussed.	Although the Low pass filtered speech test was compiled for the USA population, an examination of the words included in the test revealed that these words should also be familiar to children in SA. Some of the words included in the test do, however, require a fairly advanced level of vocabulary, for example words such as "seize", "dodge" and "void". The children included in both the pilot and actual study ranged in age from 8 to 12 years of age and thus had different levels of linguistic ability. The children in the actual study also attend a school for children with learning disability. Children with learning disability are reported to have a higher incidence of language impairment (Medwetsky, 2002). It was thus decided to read the list of words to each child and discuss the meaning of the words prior to commencing with the testing. By familiarizing the children with the words the effects of language ability could be reduced in order to obtain a more accurate reflection of each child's central auditory processing.
Speech masking level difference test	The words included as test items were read to each child and the meaning of each word was discussed. The researcher also read through the list of printed words given to each child together with the child to ensure that the child was able to read the words that s/he was required to repeat.	Similarly (as for the Low pass filtered speech test) although the Speech masking level difference test was compiled for the USA population the words included in the test should also be familiar to children in SA. Some of the words included in the test do, however, require a fairly advanced level of vocabulary, for example "inkwell", "oatmeal" and "northwest". The children included in both the pilot and actual study ranged in age from 8 to 12 years of age and thus had different levels of linguistic ability. Additionally, the Speech masking level difference test requires the child to identify and repeat the words they hear (while ignoring competing noise) from a printed list of 10 spondaic words. It was thus decided to read the printed list of words with each child and discuss the meaning of the words prior to commencing with the testing. By familiarizing the children with the printed words (and the meaning of the words) the effects of verbal and written language ability could be reduced in order to obtain a more accurate reflection of each child's central auditory processing.

for each age interval, namely 8, 9, 10, 11, and 12 years of age, for each CAPD test. The average mean, standard deviation, mean – 1 standard deviation and mean - 2 standard deviations for the combined age intervals were also determined. The normative data for the CAPD test battery are included as Appendix XI.

The second phase involved administering the IVA CPT and IVA STAR (Sandford and Turner, 2001) to a group of individuals with no reported history of learning disorder in order for the researcher to gain experience in administering and interpreting the tests. Three adults and 5 mainstream children were assessed. The findings of the second phase did not require statistical analysis and are presented in Table 4.7.

The third phase was to administer the complete test battery to two children; one child with and one child without a history of developmental or learning disability, in order to determine the length of time required to administer the immittance, puretone (air-conduction) audiometry (part of the selection procedures) and the specific multi-dimensional test battery (the data collection phase). The immittance and puretone audiometry required as part of the participant selection procedures was done prior to but during the same session as the data collection, as discussed under 4.7. The findings of the third phase did not require statistical analysis and are presented in Table 4.7.

4.7 DATA COLLECTION PROCEDURES

The researcher assessed the twenty-one subjects at their school. As discussed under 4.5.2.2 the testing was done in the teachers' computer room, where the noise levels were monitored using a Rion Sound Level Meter NA-24 set on function A. The room is situated away from the central noise areas of the school, has a dimension of 3x2m² and is fitted with a carpet and curtains. The noise levels were monitored in the room and noise levels were kept below 40-45dBSPL. Ideally, the testing should have been done in a soundproof booth but for the reasons discussed under 4.4.2 this was not possible as the data collection needed to be done at the school. By using a sound level meter and controlling the environmental noise, the researcher was able to assess all the subjects under the same controlled and quiet conditions.

The test procedure was administered twice to each participant under the two test conditions, namely with and without medication. As discussed under 4.3, the test conditions were counterbalanced to control for the order effect of the two conditions. A minimum period of at least one week (7 days) was required between the two test conditions of each participant. The order of the test conditions for each participant is presented in Table 4.1. The testing time per participant with and without medication was 1 hour to 1 hour 15 minutes.

The immittance (including acoustic reflex measurements) and puretone (air conduction) audiometry that formed part of the participant selection procedures were administered in the first session. The reasons for doing this testing at the same time as the data collection were twofold. Firstly, the middle ear functioning and peripheral hearing of each participant was required to be within the normal range at the time of the data collection and secondly, the puretone thresholds obtained were used to set in the stimulus intensity levels for the CAPD tests. As hearing thresholds had already been established during the first session, only the tympanometry part of the immittance (not the acoustic reflex measurements) was repeated at the beginning of the second session in order to monitor middle ear functioning of the participants. All participants were required to have normal middle ear functioning and peripheral hearing as discussed under 4.4.1.7. The ipsi- and contralateral reflexes measurements were done at 500, 1000 and 2000Hz but were seen to form part of the data collection procedures as discussed under 4.4.1.7. The participants were given the following instructions prior to the immittance testing: "Sit as still as you can, just like a statue. This is a quick test for your ears. Your ears may feel a bit blocked and you will hear some loud sounds". The immittance meter is automated and immediately prints the results after each test. During the puretone audiometry the participants were instructed, "to push the button even if the beep-beep sound is very soft".

The complete specific multi-dimensional test battery was administered after the immittance and puretone audiometry. The IVA CPT (Sandford and Turner, 2001) was administered following the standardized instructions and procedures stipulated in the IVA CPT Test manual (Sandford and Turner, 2001). The participants were told that the IVA CPT was a "fun computer game" and that they had to click on the mouse every time they heard or saw the number "1" and ignore any number "2's" that they heard or saw. They were told the computer would repeat the instructions and that there would be a practice session first before the actual "game" started. The IVA CPT (Sandford and Turner, 2001) is an automated test that generates an automated test summary with scores presented as both raw scores and quotient scores. All 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 hand preference of each child was noted prior to commencing with the IVA CPT. The IVA CPT Test Manual (Sandford and Turner, 2001) recommends that the person's dominant hand be positioned over the mouse, with the index finger over the leftmost button. The left-handed children at the school had, however, been taught to use their right hand when working with a computer mouse and all preferred to use their right hands. The left-handed child included in Phase II of the pilot study (Table 4.7) also showed a right hand preference when using a computer mouse. The left-handed children were thus permitted to use their right hand for manipulating the computer mouse during the administration of the IVA CPT.

The IVA STAR (narrative report writer for the IVA CPT of Sandford and Turner, 2001) does not require any additional testing and is an automated report that provides a comparison of the auditory and visual modalities based on the results of the IVA CPT (Sandford and Turner, 2001) results.

The CAPD test battery comprising the Dichotic digits test (double digits), the Frequency pattern test, the Low pass filtered speech test, the Speech masking level difference test and the acoustic reflex measurements was administered after the IVA CPT, with the exception of the acoustic reflex measurements (as already discussed earlier in this section). Scores were obtained for both ears for each CAPD test, with the exception of the Speech masking level difference test, where only one score was obtained, as this is a binaural interaction task.

As for the pilot study (discussed under 4.6), the behavioral CAPD tests were administered at an intensity of 50dBSL (re: average puretone threshold at 500, 1000 and 2000Hz). Puretone thresholds, rather than speech reception thresholds, were used as the testing was done in one room at the participants' school and live voice speech audiometry was thus not possible. The use of recorded USA speech audiometry materials (no equivalent measures are available in South Africa) was considered but decided against, as no normative data are available for the South African population for these measures. Prior to commencing with the CAPD testing, the participants were familiarized with the test material as outlined and motivated in Table 4.8. The participants' attention was also drawn to the fact that the accent of the recorded material was American and that the pronunciation of some of the words might differ a bit from the South African pronunciation. Children in South Africa are frequently exposed to American accents through the media in the form of television programs, films and training materials.

The Dichotic digits test consists of 25 items (5 practice items and twenty test items). The dichotic digit test was administered at an intensity of 50dBSL (re: average puretone threshold for 500, 1000 and 2000Hz). The participants were instructed as follows: "You will hear numbers in both your ears. Say / repeat the numbers that you hear". The scoring sheet used to record the responses is presented in Appendix IV.

The Frequency pattern test consists of 30 items (5 test practice items and 25 test items). The test was administered at an intensity of 50dBSL (re: average puretone threshold for 500, 1000 and 2000Hz). The test was administered separately to both ears under the two test conditions, namely labeling and humming. The comparison of the results under the two test conditions provides information about the inter-hemispheric transfer of information. The instructions for the labeling condition provided to the subjects were as follows: "You will be hearing short tunes. You must say what you are hearing, for example "low low high" or "high low high". For the humming condition the participants were instructed as follows: "You will be hearing short tunes. You must hum what you hear, for example (demonstrated by humming) "low low high" or "high low high". The scoring sheets used are included in Appendix V and Appendix VI.

The Low pass filtered speech test consists of 50 items. The Low-pass filtered speech test was administered at an intensity of 50dBSL (re: average puretone threshold for 500, 1000 and 2000Hz). The first 5 items were used as practice items for the left ear and the next 20 items were included as test items for the left ear. The remaining 25 items were used for the right ear (5 practice items and 20 test items). The instructions provided were as follows: "The words that you will hear sound funny. They do not sound very clear. Say/repeat the words that you hear. You can guess the word if you are not sure of it". The researcher read the list of words to each participant and discussed the meaning of the words prior to commencing with the testing. This was done to familiarize the participants with the words and thereby reduce the possible confounding influences of language ability. The scoring sheet used is included in Appendix VII.

For the Speech masking level difference test the participant was given a printed list of the 10 spondaic words and asked to "ignore the noise that you hear and just say/repeat the word that you hear". The researcher read through the printed list of words with each participant and discussed the meaning of the words prior to commencing with the testing. This was done to familiarize the participants with the words and thereby reduce the possible confounding influences of language and reading abilities. The Speech masking level difference test was administered at an intensity of 50dBSL (re: average puretone threshold for 500, 1000 and 2000Hz). The scoring sheet used is included in Appendix VIII.

4.8 DATA ANALYSIS

The correct responses for each test in the behavioral CAPD test battery (with the exception of the Speech masking level difference test) were totaled and converted to percentages for each participant. The ipsi- and contra-lateral stapedial acoustic reflexes of each participant for each ear were analyzed in terms of the following categories:

- Two or more of the acoustic reflexes at 500, 1000 and 2000Hz within the normal range (70-90dBSL)
- Two or more of the acoustic reflexes at 500, 1000 and 2000Hz elevated (> 90dBSL) or absent at maximum intensity settings.

The percentage ipsi- and contra-lateral stapedial reflexes occurring in each of the above categories was then determined for each research group.

The IVA CPT and IVA STAR both provide automated scoring. The scores in these automated result sheets include both raw scores and quotient scores. All 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+) takes gender and age into account. The results of research groups 1, 2 and 3 were compared with the above mean quotient score of 100 and standard deviation of 15 and results below 85 and above 115 were seen to reflect significant differences in relation to the normative data. A validity check is built into the interpretation of the IVA CPT and IVA STAR scores as discussed under 4.5.2.1.2. In cases where the comprehension scales for both modalities are identified as very low (as shown in the automated report of the results) further interpretation of the remaining scales is not possible. In cases where the comprehension score is identified as very low for one modality only, for example the auditory modality, further interpretation of the remaining auditory scales is not possible. Further interpretation of the visual scales in this case is, however, possible as the visual comprehension scale was valid (Sandford and Turner, 2001). Low comprehension scales, despite cooperation from the individual being tested, can be ascribed to severe ADHD and/or difficulty in shifting mental sets between the different modalities (Sandford and Turner, 2001).

The results of each participant in research groups 1 and 2 for each of the tests in the behavioral CAPD test battery, the IVA CPT and the IVA STAR were then transferred by the researcher to Microsoft Excel Spreadsheets for statistical analysis. Only those scores that were valid for the IVA CPT and IVA STAR as discussed in the preceding paragraph were used. The SAS Program (SAS Institute Inc., 1999) was used for the statistical analysis of the results of research groups 1 and 2. The specific procedures employed in achieving each sub aim are presented in Table 4.9. Research group 3 consisted of one participant and the results could thus not be analyzed statistically. The results of the participant in research group 3 are discussed qualitatively against the results of research group 1 and 2 in Chapter 5.

4.9 SUMMARY OF CHAPTER 4

"The method that was used to collect data-including the sample, measurement instruments, and procedures – should be described with the utmost precision" (Leedy and Ormrod, 2001: 289).

Table 4.9: The procedures used to achieve the sub-aims of the study

Sub-aim	Procedures
To compare the inter- and intra-group tendencies of *central auditory processing* of research groups 1 and 2 in the medicated and non-medicated state.	- The Kruskal-Wallis test (Non-parametric one-way ANOVA) was used to compare the behavioral CAPD test results of research groups 1 and 2 (in the medicated and non-medicated state) with the CAPD normative data (Appendix XI) and to determine whether significant differences occurred at the 5% level of significance, by using the BMDP3S procedure of the BMDP. The null hypothesis (namely no significant difference at the 5% level of significance) was rejected if the Z value (observed value from standard normal distribution) was larger than the critical value ZC, where 1-PHI (ZC)=ALPHA/(K(K- 1)). PHI refers to the cumulative standard normal distribution function, ALPHA the desired overall significance level, and K the number of groups compared
	- ANOVA (cross-over design) was applied by using the General Linear Means procedure of the SAS (SAS Institute Inc., 1999) to: - determine the overall effect of medication on the behavioral CAPD test results - compare the overall behavioral CAPD test results of research groups 1 and 2 Probability factor values (p)<0,05 (5% level of significance) were seen to be significant.
	- ANOVA (cross-over design), the General Linear Means procedure and Scheffe's multiple comparisons test were used (at the 5% level of significance) in the analysis 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
To compare the inter- and intra-group tendencies of *auditory and visual continuous performance* of research groups 1 and 2 in the medicated and non-medicated state.	- The results of research groups 1, 2 and 3 were compared with the mean quotient score of 100 and standard deviation of 15 (as stipulated in the IVA CPT test manual, Sandford and Turner, 2001) and results below 85 and above 115 were seen to reflect significant differences in relation to the IVA CPT and IVA STAR normative data.
	- ANOVA (cross-over design) was applied by using the General Linear Means procedure of SAS (SAS Institute Inc., 1999) to: - determine the overall effect of medication on the IVA and IVA STAR test results - compare the overall IVA and IVA STAR test results of research groups 1 and 2 Probability factor values (p) <0,05 (5% level of significance) were seen to be significant.
	- ANOVA (cross-over design), the General Linear Means procedure and the Scheffe's multiple comparisons test were used (at the 5% level of significance) in the analysis of the inter- and intra-group tendencies of the IVA CPT and IVA STAR test results of research groups 1 and 2 in the medicated and non-medicated state

Table 4.9 continued

Sub-aim	Procedures
To analyze the central auditory processing and continuous performance results in relation to the different types of ADHD and subprofiles of CAPD	- The results of each participant in the medicated state on the behavioral CAPD test battery were qualitatively analyzed in terms of the audiometric results outlined in the subprofiles of the Bellis/Ferre model (Bellis, 1999) as summarized in Chapter 3 and where appropriate assigned to a specific CAPD subprofile.
	- The IVA CPT procedural guidelines, presented in the test manual (Sandford and Turner, 2001), and included as AppendixXII were followed in allocating participants (based on scores obtained in the non-medicated state) to the different types of ADHD. The results of the above procedural guidelines were then compared with the DSM IV diagnosis originally used to allocate the participants to the 3 research groups.

The research methodology presented in Chapter 4 entails a description and discussion of the aims, research design, participant selection criteria and procedures as well as a description of the participants, apparatus and material, data collection procedures and finally the data analysis procedures used in the study. A detailed discussion of the above aspects is provided to allow for replication of the research method.

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

IVA CPT scores	Medication		
	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

	Research group		
IVA CPT scores	**Research group 1 (Combined type of ADHD)**	**Research group 2 (Inattentive type of ADHD)**	**Comparison of research groups 1 and 2**
	Mean (%) (n= 11-15)	**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.

CHAPTER 6: CONCLUSION

6.1 INTRODUCTION

The aim of the study was to determine the central auditory processing and continuous performance patterns of children with ADHD in the medicated and non-medicated state. A specific multi-dimensional test battery consisting of a comprehensive CAPD test battery (as recommended by Bellis and Ferre, 1999), the IVA CPT test and the IVA STAR (narrative report writer for the IVA CPT) (Sandford and Turner, 2001) was used to assess the children. The inter- and intra-group tendencies of central auditory processing and (auditory and visual) continuous performance of three groups of children representing the three different types (combined, hyperactive-impulsive and inattentive) of ADHD were compared. Thereafter, the results of the specific multi-dimensional test battery were analyzed in relation to the different types of ADHD and subprofiles of CAPD as outlined in the Bellis/Ferre Model (Bellis, 1999).

As discussed in Chapter 5, statistical analysis was only possible for research group 1 (combined type of ADHD) and research group 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 have been discussed qualitatively against the background of the results of research groups 1 and 2 in Chapter 5.

6.2 CONCLUSIONS

The results of the study show that:

- The incidence of the hyperactive-impulsive type of ADHD among children appears to be lower than for the combined and inattentive types of ADHD. This finding is consistent with the reports of Millstein et al (1998) and Wilens et al (2002) and is reflected in the fact that only one participant with the hyperactive-impulsive type of ADHD (representing research group 3) was identified to partake in the study.

- Stimulant medication enhanced the performance of the children with the combined and hyperactive-impulsive types of ADHD on measures of CAPD and continuous performance, but did not appear to have a significant effect on the performance of children with the 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 visual modality than for 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.

- The analysis of the CAPD test results of the participants in the different research groups in relation to the subprofiles outlined in the Bellis/Ferre Model (Bellis, 1999) suggest that a relatively high number (40%) of participants diagnosed with the combined type of ADHD additionally met the requirements for the Output-organization subprofile. Bellis (2003b) has suggested that the Output-organization subprofile more likely reflects an attention disorder than a CAPD. The results of this study thus support this theory.

- 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 a 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 had 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.

6.3 EVALUATION OF THE RESEARCH METHODOLOGY

A strength of this study is that the participants included in the study were clearly defined. The defining characteristics of the participants in many previous studies on ADHD have been subjective, poorly defined, and disconnected from any theoretical construct or empirical base (Chermak and Musiek, 1997). In this study the defining characteristics of the participants were based on the DSM-IV criteria (American Psychiatric Association, 1994), with the different types of ADHD reflected in the 3 research groups. A double criterion was also set for allocating each participant to a specific research group: Firstly, the participants were required to have been diagnosed as having ADHD by a medical practitioner, and secondly, the participants, were required to meet the DSM-IV criteria (American Psychiatric Association, 1994) for a specific type of ADHD as reported by both the parents of the child and the teacher. Checklists (Appendices I and II), based on the DSM-IV (American Psychiatric Association, 1994), were completed independently by the teacher and the parents. To summarize, each participant was required have a medical diagnosis of ADHD, and to meet the specific ADHD type criteria by both the teacher and the parents before being allocated to a particular research group.

Another strength of the study was that the teachers administered the medication at the school where the data collection was also done. The researcher was thus able to accurately record the time of administration of the medication, the type of medication as well as the dosage of the medication. The children were also assessed in their school that was a familiar environment and thus a less-threatening test environment.

An additional strength of the study was that the participants were required to have no reported medical history of neurological functioning or other co-occurring disorders such as a hearing disorder, visual disorder, Tourette syndrome, Oppositional defiant disorder, Conduct disorder and Obsessive compulsive disorders. By controlling for and excluding children with these additional disorders, the extraneous variables affecting the study could be better controlled.

The limitations of the study are as follows:

- A limited number of participants were included in the study. Ten participants were allocated to research groups 1 (combined type of ADHD) and 2 (inattentive type of ADHD), and only one participant was allocated to research group 3 (hyperactive-impulsive type of ADHD). The number of participants allocated to research groups 1 and 2 was limited to ten participants per group due to the lengthy testing required. Furthermore, it was also necessary to test each participant twice, namely in the medicated and the non-medicated state. The reason for including only one participant in research group 3 (hyperactive-impulsive type of ADHD) was that only one of the children at the school used in the study met the participant selection criteria for inclusion in this group. This finding is consistent with reports in the literature (Millstein et al, 1998) of a lower incidence of the hyperactive-impulsive type of ADHD. Wilens et al (2002) estimate that in the ADHD population, 50-75% of children have the combined type of ADHD, 20% of children have the inattentive type of ADHD with less than 15% of children having the hyperactive-impulsive type of ADHD.

- The test materials used in compiling the specific multi-dimensional test battery were not South African based, and had been compiled in the USA, as similar measures are not available in South Africa.

CAPD measures with a low linguistic load were included in the test battery to control for the effects of differences in grammatical structures and vocabulary that could have influenced the test results of the participants. The stimuli used in the Dichotic digits test (digits) and the Frequency pattern test (frequency patterns) require the ability to repeat four single digits and the ability to label tones as "low" or "high", as discussed in Chapter 4. Words are the stimuli used in the Low pass filtered speech test and the Speech masking level difference test. Although the Low pass filtered speech test and Speech masking level difference tests were compiled for the USA population, an examination of the words included in the tests revealed that these words should also be familiar to children in SA. Some of the words included in the tests do, however, require a fairly advanced level of vocabulary, for example words such as "seize", "dodge" and "void".

The children included in both the pilot and actual study ranged in age from 8 to 12 years and thus had different levels of linguistic ability. The children in the actual study also attend a school for children with learning disability and children with learning disability are reported to have a higher incidence of language impairment (Medwetsky, 2002). It was thus decided to read the list of words to each child and discuss the meaning of the words prior to commencing with the testing. By familiarizing the children with the words the effects of language ability could be reduced in order to obtain a more accurate reflection of each child's central auditory processing. Prior to commencing with the CAPD testing, the children were familiarized with the test material, as outlined and motivated in Table 4.8. These procedures were also followed in compiling the normative data using 50 mainstream children, as discussed in the pilot study. The results of the participants included in the study could thus be compared with the locally compiled CAPD normative data (collected as part of the pilot study).

The IVA CPT and IVA STAR (Sandford and Turner, 2001) used for assessing auditory and visual continuous performance have also been compiled in the USA. The stimuli consist of the numbers "1" and "2" that are heard and seen by the participant. The participant is required to click the mouse each time s/he hears or sees a "1". The stimuli used thus place a low demand on both linguistic and visual perception abilities, as opposed to other tests of continuous performance as discussed in Chapter 2. Normative data could not be compiled locally as an automated database is used (n=1700 normal individuals, aged 5-90+) with results being presented as quotient scores that take both age and gender into account.

- The CAPD test battery used in the study is based on the recommendations of Bellis and Ferre (1999). As discussed in Chapter 3, Bellis (2003a) recently provided an update on recommendations for the components of a comprehensive CAPD test battery. The value of this updated comprehensive CAPD test battery, in differentiating between ADHD and CAPD, warrants further investigation but was beyond the scope of this study as the data collection for this study had been completed prior the publication of these recommendations.

- The number of individuals used in the compilation of the CAPD 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.

- Based on the recent shift in conceptualizing ADHD as an executive dysfunction (Chermak et al, 1999) the inclusion of a test of executive dysfunction would have been a valuable adjunct to the specific multi-dimensional test battery. The decision not to include a test of executive function was based on the fact that there is currently no agreed on test battery for assessing executive dysfunction in children (Packer, 2002). The inclusion of a test battery of executive function would have increased the length of the test sessions that were already 1 hour and 15 minutes long. The specific multi-dimensional test battery was also administered twice to each participant, i.e. in both the medicated and non-medicated state.

- The testing was done at the school in the teachers' computer room, where the noise levels were monitored using a Rion Sound Level Meter NA-24 set on function A. The room is situated away from the central noise areas of the school, has a dimension of $3x2m^2$ and is fitted with a carpet and curtains. The noise levels were monitored in the room and noise levels were kept below the 40-45dBSPL marker on the sound level meter. The sound level meter had been calibrated according to SABS standards. Ideally, the testing should have been done in a soundproof booth but for the reasons discussed under 4.4.2 this was not possible as the data collection needed to be done at the school. By using a sound level meter and controlling the environmental noise, the researcher was able to assess all the subjects under the same controlled and quiet conditions.

6.4 CLINICAL IMPLICATIONS OF THE STUDY

The results of the study have yielded the following important clinical implications:

- While the pharmacological management of the combined and hyperactive-impulsive types of ADHD appears to be indicated, the use of stimulant medication in children with the inattentive type of ADHD should be carefully considered. Children with the inattentive type of ADHD did not derive any significant benefit from stimulant medication as reflected in the measures of CAPD and continuous performance used in the study.

- The relatively high number (40%) of the participants diagnosed with the combined type of ADHD that also met the requirements of the Output-organization subprofile as outlined in the Bellis/Ferre Model (Bellis, 1999) suggests that the management strategies for these two disorders be reconsidered. Bellis (2003b) has suggested that the Output-organization subprofile more likely reflects an attention disorder than a CAPD. It is thus possible that some children diagnosed with the Output-organization subprofile may benefit from stimulant medication. It is also possible that some children with the combined type of ADHD may benefit from the management strategies typically used for children with the Output-organization subprofile, for example: a highly structured environment, training in the use of organizational aids, speech therapy focusing on expressive language, and assistive listening technology (Bellis, 1999).

- The linkages between ADHD and CAPD underscore the importance of a thorough and multi-disciplinary approach. Differentiating ADHD and CAPD hinges on the accurate diagnosis of these conditions and thus warrants a multi-disciplinary approach (Chermak et al, 1999).

6.5 RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the results of the study the following recommendations are made for further research:

- An investigation into the executive function of the three different types of ADHD, namely the combined type, the hyperactive-impulsive type and the inattentive type.

- An investigation into the relationships between the combined and hyperactive-impulsive types of ADHD (DSM-IV) and the Output-organization subprofile of Bellis and Ferre (1999) and Bellis (2003a).

- An investigation into the possible links between the Tolerance fading memory category of Katz et al (1992) and the Output-organization subprofile of Bellis and Ferre (1999) and Bellis (2003a).

- An investigation into the value of stimulant medication in the management of the inattentive type of ADHD.

- The development of test measures for CAPD and continuous performance for the South African context.

- An investigation to determine the prevalence of ADHD and the different types of ADHD using clearly defined participant characteristics, i.e. the DSM-IV (American Psychiatric Association, 1994) criteria rather than checklists and rating scales.

- An investigation into the relationship between Hyperkinetic disorder (ICD-10, World Health Organization, 1992) and the Combined type of ADHD (DSM-IV, American Psychiatric Association, 1994).

- An investigation into the continuous performance of children diagnosed with the different CAPD subprofiles outlined in the Bellis/Ferre Model (Bellis, 2003a) to determine whether CAPD is modality specific or supramodal in nature.

6.6 CONCLUDING REMARKS

ADHD is the most commonly occurring neurobehavioral disorder in children (National Institutes of Health Consensus Committee, 1998, Chermak et al, 1999) and yet remains shrouded in controversy. Despite progress made in the assessment, diagnosis and treatment of ADHD in recent years, questions are still raised concerning the existence of the disorder, whether it can be reliably diagnosed and, if treated, what interventions are the most effective. In particular, concern is expressed regarding the perceived over-diagnosis of ADHD pointing to the dramatic increase in prescriptions for stimulant medication among children in recent years (American Academy of Pediatrics, 2000).

At the heart of the controversy lies the lack of congruity in defining ADHD as a disorder. The defining characteristics of children with ADHD in both clinical practice and in many research studies have been subjective, poorly defined, frequently changing and disconnected from any theoretical construct or empirical base (Chermak and Musiek, 1997). This has led to the controversy surrounding the etiology and prevalence of ADHD (and the different types of ADHD), as well as the value of different assessment methods and treatment options in the management of children with ADHD.

In this study a "specific multi-dimensional test battery" comprising a measure of (auditory and visual) continuous performance and a CAPD test battery was compiled to assess children with the three different types of ADHD (diagnosed using the DSM-IV criteria of the American Psychiatric Association, 1994). It was envisaged that, by investigating the continuous performance and central auditory processing abilities of children with ADHD, new insights could be developed into the theoretical constructs underlying ADHD. The specific multi-dimensional test battery used in the study was administered to the children in the three research groups (each representing one of the three types of ADHD) in both the medicated and non-medicated state.

A strength of the study is that the characteristics of the children included in the study have been clearly defined. The results of the study, discussed in Chapter 5 and summarized in Chapter 6, provide some valuable insights into the theoretical constructs underlying the three different types of ADHD. In Chapter 6 recommendations are also made for further research and the clinical implications of the results are discussed.

Research in the field of ADHD is both challenging and intriguing but, in the process of research, the children living daily with this disorder and their families should not be forgotten. It is hoped that the results of this study and their clinical implications will prove to be valuable in managing children with ADHD in the clinical setting.

***"ADHD is real – a real disorder, a real problem, and often a real obstacle. It can be heartbreaking and nerve-wracking"* (Barkley, 2000: 19).**

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"A good book cannot lengthen your arm
but it can lengthen your reach by hoisting you
on the shoulders of great thinkers"
(Marican, 2000:22)

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Email : shugo@postino.up.ac.za

APPENDIX I: Letter to parents requesting permission to include their child in the study and checklist of behavior completed by the parents

Dear Parents

I am a speech therapist and audiologist working in the Department of Communication Pathology at the University of Pretoria. We have recently purchased a number of new test materials that are being recommended in the USA for assessing children with Attention Deficit Hyperactivity Disorder.

These tests include:

- **The Integrated Visual and Auditory Continuous Performance Test:**

  "NEW! Now introducing IVA Version 4.2 for Windows 98, 2000 or ME. Updated norms. IVA, the Integrated Visual & Auditory Continuous Performance Test, is a comprehensive, computerized test combining auditory and visual stimuli to measure objectively the triad of symptoms — inattention, impulsivity and hyperactivity — associated with ADHD. Written by Joseph A. Sandford, Ph.D., and Ann Turner, M.D., IVA provides clinicians with the "state-of-the-art" in computerized attention and response control testing." (from the BrainTrain website)

  The preliminary results in the literature show that the IVA CPT may be a valuable tool in assessing children with ADHD and determining the effects of medication.

- **The auditory processing assessment battery (CD purchased form the Department of Veterans Affairs):**

  The test material is played through an audiometer (machine used to assess hearing). This battery of tests provides valuable information about a child's auditory processing abilities with suggestions for therapy should any difficulties be identified.

I am interested in determining the value of the above tests in assessing children with ADHD when on and off medication. Your principal has kindly agreed to allow the testing to take place at your school and I have arranged to have all the equipment installed at the school so that the testing can take place there with no inconvenience to you as the parents. There is also no cost involved in the testing.

The testing will take approximately 1 hour and will be presented in a fun way to children participating in the project. The tests are of such a nature that they are more like games on the computer and audiometer than a formal assessment situation. I would like to assess each child under 2 conditions: firstly while on medication and secondly while not on medication. For the second condition, we will ask that the medication be given at school after the assessment (which will take place first thing in the morning). In cases where children are using medication with a longer "half-life" (Ritalin SR) I would like to see these children on a Monday morning after at least a full day of not taking the medication.

The results of the testing will be presented to the school in the form of a report for each child and it is hoped that the results will provide valuable information that can be used for each child.

You are most welcome to contact me should you require any further information. My contact details are as follows:

Work: 420 3684
Home: 361 2383
Cell: 082 9256461

Please complete the form and checklist below if you agree to your child taking part in the above testing.

Yours sincerely

Mrs. Nicci Campbell / Speech Therapist and Audiologist
Department of Communication Pathology
University of Pretoria

I/ We, ..., parent(s)/ guardian(s) of .... agree to my/our child taking part in the above tests.

Signed: ....
Date: ....

Appendix I continued

Checklist (Given to the parents to complete)

Name of your child: ....

1.) Is your child currently taking any medication for ADHD?

....

2.) Who has prescribed the medication? (Name of professional and field of training, e.g.: *Dr Smith –Pediatrician*)

....

3.) What medication is your child taking for ADHD?

....

4.) What dosage of medication is your child taking for ADHD?

- Strength of medication: ....
- How often is your child taking the medication?

  ....
- Does your child take medication over weekends?

  ....

5.) Please "tick" (✔) the behaviors which describe your child when he/she is **not taking any medication** for his/her AD(H)D. **There is no limit to the number of behaviors that can be "ticked"**

Behavior	**Present when not on medication (Mark with a ✔)**
Poor attention to details or careless mistakes	
Interrupts or intrudes on others	
Difficulty sustaining attention in tasks	
Fidgets or squirms	
Difficulty in engaging in quiet activity	
Leaves seat in classroom or at table	
Does not seem to listen when spoken to	
Runs or climbs excessively	
Talks excessively	
Does not follow through on instructions and tasks	
Blurts out answers	
Difficulty organizing tasks	
Difficulty waiting turn	
Difficulty with sustained mental effort	
Loses things necessary for tasks	
Often distracted by extraneous stimuli	
Often forgetful in daily activities	
"On the go" or acts as if "driven by a motor"	

Thank you for your time and assistance

in completing this checklist!

APPENDIX II: Checklist given to teachers to complete

Dear Teachers

Please complete the checklist below for the following child:

…………………………………………………………………………………………………

1.) Is the child currently taking any medication for AD(H)D?

…………………………………………………………………………………………

2.) What medication is the child taking for AD(H)D? ……………………………………

3.) What dosage of medication is the child taking for AD(H)D?

- Strength of medication:

  …………………………………………………………………………………………
- How often is the child taking the medication?

  …………………………………………………………………………………………
- Does the child take medication over weekends?

  …………………………………………………………………………………………

4.) Please "tick" (✔) the behaviors which describe the child when he/she is not taking any medication for his/her AD(H)D. There is no limit to the number of behaviors that can be "ticked"

Behavior	Present when not on medication (Mark with a ✔)
Poor attention to details or careless mistakes	
Interrupts or intrudes on others	
Difficulty sustaining attention in tasks	
Fidgets or squirms	
Difficulty in engaging in quiet activity	
Leaves seat in classroom	
Does not seem to listen when spoken to	
Runs or climbs excessively	
Talks excessively	
Does not follow through on instructions and tasks	
Blurts out answers	
Difficulty organizing tasks	
Difficulty waiting turn	
Difficulty with sustained mental effort	
Loses things necessary for tasks	
Often distracted by extraneous stimuli	
Often forgetful in daily activities	
"On the go" or acts as if "driven by a motor"	

Thank you for your time and assistance in completing this checklist!

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APPENDIX III: Audiogram

Departement Spraakheelkunde en Oudiologie, Universiteit van Pretoria. Tel: 420-2357

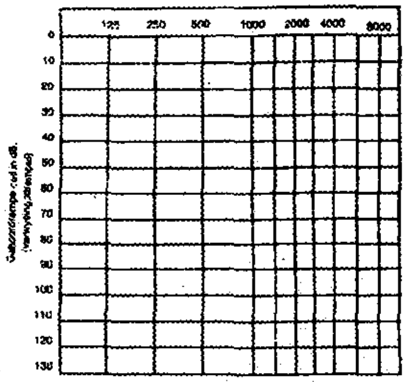
Voorname en van: ______________________ Datum: ______________________

Geboortedatum: ______________________ Oudioloog: ______________________

Verwys deur: ______________________ Student: ______________________

SUIWERTOONOUDIOGRAM

Linkeroor



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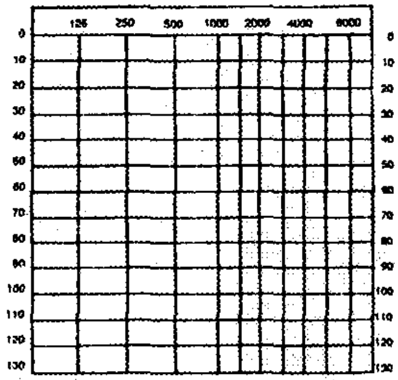

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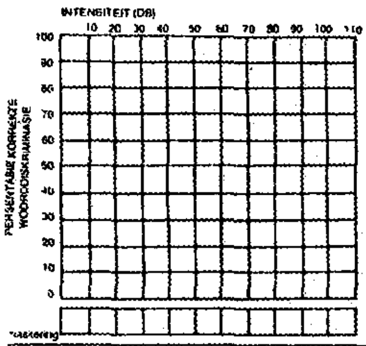
SPRAAKOUDIOGRAM



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APPENDIX IV: The scoring sheet used for the Dichotic digits test

Name of participant:___________________________________

Medicated or non-medicated state:___________________________

Test item	Left channel	Right channel
1.	4___ 3___ Practice item	1___ 6___ Practice item
2.	3___ 1___ Practice item	9___ 10___ Practice item
3.	9___ 6___ Practice item	1___ 5___ Practice item
4.	2___ 10___ Practice item	4___ 8___ Practice item
5.	4___ 8___ Practice item	6___ 9___ Practice item
6.	9___ 1___	10___ 2___
7.	2___ 4___	9___ 10___
8.	1___ 9___	8___ 6___
9.	2___ 4___	3___ 9___
10.	1___ 4___	10___ 5___
11.	2___ 5___	1___ 3___
12.	4___ 5___	2___ 6___
13.	3___ 10___	5___ 6___
14.	4___ 1___	9___ 5___
15.	4___ 5___	3___ 8___
16.	9___ 5___	4___ 1___
17.	4___ 5___	10___ 2___
18.	9___ 8___	3___ 4___
19.	9___ 10___	8___ 5___
20.	8___ 6___	4___ 1___
21.	6___ 8___	10___ 2___
22.	9___ 1___	2___ 8___
23.	6___ 9___	3___ 1___
24.	1___ 2___	3___ 9___
25.	5___ 3___	2___ 1___
Total:	___/20 _____%	___/20 _____%

APPENDIX V: The scoring sheet used for the Frequency pattern test (labeling condition)

Name of participant :______________________________

Medicated or non-medicated state:______________________________

Test item	Left ear	Right ear
1.	LLH (Low Low High) Practice item	LLH (Low Low High) Practice item
2.	LHH Practice item	LHH Practice item
3.	HLL Practice item	HLL Practice item
4.	HHL Practice item	HHL Practice item
5.	HLH Practice item	HLH Practice item
6.	LHL	LHL
7.	LHH	LHH
8.	LLH	LLH
9.	HHL	HHL
10.	HLH	HLH
11.	LHL	LHL
12.	HLL	HLL
13.	HHL	HHL
14.	LHL	LHL
15.	HLH	HLH
16.	LHH	LHH
17.	HLL	HLL
18.	LLH	LLH
19.	HHL	HHL
20.	LLH	LLH
21.	LHL	LHL
22.	HLH	HLH
23.	LHH	LHH
24.	HLL	HLL
25.	LLH	LLH
26.	HLL	HLL
27.	LHL	LHL
28.	LHH	LHH
29.	HHL	HHL
30.	HLH	HLH
Total:	___/25 _____%	___/25 _____%

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APPENDIX VI: The scoring sheet used for the Frequency pattern test (humming condition)

Name of participant :____

Medicated or non-medicated state:______________________________

Test item	Left ear	Right ear
1.	LLH (Low Low High) Practice item	LLH (Low Low High) Practice item
2.	LHH Practice item	LHH Practice item
3.	HLL Practice item	HLL Practice item
4.	HHL Practice item	HHL Practice item
5.	HLH Practice item	HLH Practice item
6.	LHL	LHL
7.	LHH	LHH
8.	LLH	LLH
9.	HHL	HHL
10.	HLH	HLH
11.	LHL	LHL
12.	HLL	HLL
13.	HHL	HHL
14.	LHL	LHL
15.	HLH	HLH
16.	LHH	LHH
17.	HLL	HLL
18.	LLH	LLH
19.	HHL	HHL
20.	LLH	LLH
21.	LHL	LHL
22.	HLH	HLH
23.	LHH	LHH
24.	HLL	HLL
25.	LLH	LLH
26.	HLL	HLL
27.	LHL	LHL
28.	LHH	LHH
29.	HHL	HHL
30.	HLH	HLH
Total:	___/25 _____%	___/25 _____%

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APPENDIX VII: The scoring sheet used for the Low pass filtered speech test

Name of participant :______________________________

Medicated or non-medicated state:______________________________

Test item	Left ear	Test item	Right ear
1.	Youth Practice item	26.	Wine Practice item
2.	Mouse Practice item	27.	Cool Practice item
3.	Lid Practice item	28.	Ditch Practice item
4.	Pole Practice item	29.	Bar Practice item
5.	Beg Practice item	30.	Mess Practice item
6.	Hire	31.	Dodge
7.	Pearl	32.	Cheek
8.	When	33.	Five
9.	Soup	34.	Team
10.	Pain	35.	Search
11.	Shell	36.	Seize
12.	Cab	37.	Gun
13.	Tell	38.	Cause
14.	Note	39.	Good
15.	Germ	40.	Void
16.	Base	41.	Phone
17.	Talk	42.	Half
18.	Walk	43.	Date
19.	Luck	44.	Mop
20.	Road	45.	Jug
21.	Name	46.	Late
22.	Sheep	47.	Ring
23.	Rush	48.	Life
24.	Chat	49.	Rat
25.	Thin	50.	Hit
Total:	___/20 ____%		___/20 ____%

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APPENDIX VIII: The scoring sheet used for the Speech masking level difference test

Name of participant :______________________________________

Medicated or non-medicated state:______________________________

0dB S/N Ratio	**-8dB S/N Ratio**	**-16dB S/N Ratio**	**-24dB S/N Ratio**
1. Horseshoe	17. Headlight	33. Armchair	49. Horseshoe
2. Mushroom	18. Sidewalk	34. Toothbrush	50. Hotdog
3. Northwest	19. Hotdog	35. Mushroom	51. Oatmeal
4. Toothbrush	20. Inkwell	36. Hotdog	52. Armchair
-2dB S/N Ratio	**-10dB S/N Ratio**	**-18dB S/N Ratio**	**-26dB S/N Ratio**
5. Sidewalk	21. Sidewalk	37. Sidewalk	53. Mushroom
6. Inkwell	22. Hotdog	38. Inkwell	54. Horseshoe
7. Oatmeal	23. Mushroom	39. Headlight	55. Hotdog
8. Hotdog	24. Oatmeal	40. Northwest	56. Toothbrush
-4dB S/N Ratio	**-12dB S/N Ratio**	**-20dB S/N Ratio**	**-28dB S/N Ratio**
9. Headlight	25. Armchair	41. Headlight	57. Sidewalk
10. Armchair	26. Northwest	42. Mushroom	58. Headlight
11. Oatmeal	27. Inkwell	43. Sidewalk	59. Inkwell
12. Toothbrush	28. Horseshoe	44. Inkwell	60. Northwest
-6dB S/N Ratio	**-14dB S/N Ratio**	**-22dB S/N Ratio**	**-30dB S/N Ratio**
13. Horseshoe	29. Headlight	45. Toothbrush	61. Oatmeal
14. Armchair	30. Toothbrush	46. Armchair	62. Armchair
15. Mushroom	31. Oatmeal	47. Oatmeal	63. Sidewalk
16. Northwest	32. Horseshoe	48. Northwest	64. Mushroom

The thresholds in both conditions and final MLD are computed as follows:

S_oN_o Threshold = **(dBHL of audiometer) + 1 – (total number of words repeated correctly/2)**

_______**dB**

$S_\pi N_o$ Threshold = **(dBHL of audiometer) + 1 – (total number of words repeated correctly/2)**

_______**dB**

The final MLD Threshold **is calculated as follows:**

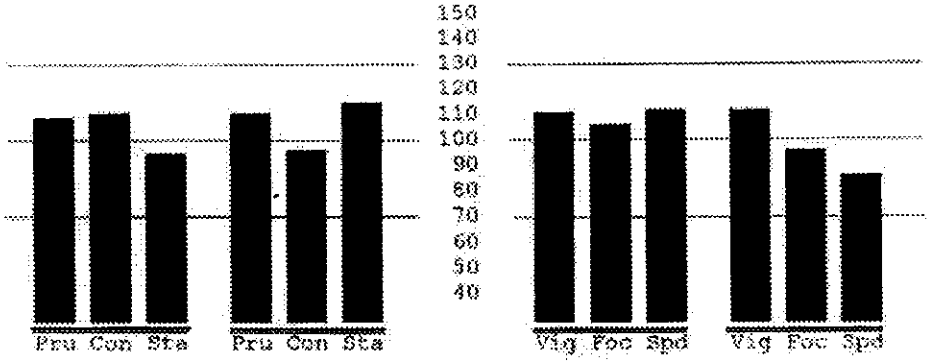
Final MLD threshold = S_oN_o Threshold - $S_\pi N_o$ Threshold

_______dB

APPENDIX IX: The IVA CPT scoring sheet

IVA Continuous Performance Test Report

Full Scale Response Control Quotient = 109		Full Scale Attention Quotient = 106	
Auditory RCQ = 107	Visual RCQ = 110	Auditory AQ = 114	Visual AQ = 97



Standard Scores for Factors of
Prudence, Consistency & Stamina + Vigilance, Focus & Speed

Hyperactivity: None | Mild | Mod | Sev | Ext

PERSONAL INFORMATION

Last Name First Name

Social Security # Educational Level

Date of Birth (MM-DD-YYYY) 11/02/1990 Age 11 years

Sex (M/F) F On medication (Y/N) Y

Diagnosis 1 (ICD code) Medication A
Diagnosis 2 (ICD code) Medication B
Diagnosis 3 (ICD code) Medication C

Test Version 4.2 **TEST INFORMATION** Analysis Version 4.2

Group Code ID Code Examiner Code

Date Note

Comment

Appendix IX continued

Auditory — RESPONSE CONTROL — Visual

Raw	Quotient	Scales	Quotient	Raw
93%	109	Prudence	111	97%
76%	111	Consistency	96	70%
92%	95	Stamina	115	106%
Hyperactivity: 2 events			Fine Motor Reg. Quot: 113	

Auditory — ATTENTION — Visual

Raw	Quotient	Scales	Quotient	Raw
100%	111	Vigilance	112	100%
74%	106	Focus	96	69%
645ms	112	Speed	86	585ms

Attribute		Raw	Q	<----+----+----Q----+----+---->
Balance		91%	134	Vis Dom — No Bias — Aud Dom (marker near Aud Dom)
Readiness	A	106%	123	A
	-			Freq — No Bias — Rare (A/V marker between No Bias and Rare)
	V	102%	122	V

Validity Check		Raw	Q	OK	?	??	???
Comprehension	A	99%	109	A			
	-			■			
	V	98%	104	V			
Persistence	A	109%	112	A			
	-			■			
	V	109%	114	V			
Sensory/Motor	A	226ms	117	A			
	-			■	■		
	V	267ms	81		V		

Norms: IVA v4.x with USB mouse 03-14-2001 for F age 11 - 11

APPENDIX X: The IVA STAR scoring sheet

IVA CPT Special Report

IVA-STAR: Comparison of Attention Modalities

Name: Date of Test:
Date of Birth: Age: 11 Sex: F
Comment:
End Note:

Graphical Tables of Test Results

Primary Scales

Factor A=Aud V=Vis		Raw Score	Q Score	70 85 100 115 130 <----+-----+-----|-----+-----+---->
Alertness	A	100%	111	
	V	100%	112	
Steadiness	A	100%	112	
	V	97%	107	
Promptness	A	614ms	126	
	V	575ms	98	
Constancy	A	61ms	131	
	V	96ms	112	

Combined Scales

Attention Modality	Q Score	70 85 100 115 130 <-----+-----+-----|-----+-----+----->
Auditory Specific	126	
Visual Specific	109	
Global (Aud & Vis)	123	

APPENDIX XI: CAPD Normative data (means and standard deviations)

Age	CAPD Tests								
	Dichotic digits test – right ear	Dichotic digits test – left ear	Frequency pattern test: labeling condition – right ear	Frequency pattern test: labeling condition – left ear	Frequency pattern test: humming condition – right ear	Frequency pattern test: humming condition – left ear	Low pass filtered speech – right ear	Low pass filtered speech – left ear	Speech masking level difference test
8 years (n=10)	Mean: 87,00 SD: 7,53 M-1 SD: 79,47 M-2 SD: 71,94	Mean: 77,25 SD: 8,78 M-1 SD: 68,47 M-2 SD: 59,70	Mean: 49,40 SD: 14,49 M-1 SD: 34,91 M-2 SD: 20,42	Mean: 50,20 SD: 12,87 M-1 SD: 37,33 M-2 SD: 24,45	Mean: 56,80 SD: 8,80 M-1 SD: 48,00 M-2 SD: 39,19	Mean: 56,40 SD: 9,70 M-1 SD: 46,70 M-2 SD: 37,00	Mean: 43,50 SD: 13,13 M-1 SD: 30,37 M-2 SD: 17,23	Mean: 37,50 SD: 15,50 M-1 SD: 22,00 M-2 SD: 6,50	Mean: 5,15 SD: 1,13 M-1 SD: 4,02 M-2 SD: 2,89
9 years (n=10)	Mean: 88,00 SD: 7,43 M-1 SD: 80,57 M-2 SD: 73,13	Mean: 82,00 SD: 7,89 M-1 SD: 74,11 M-2 SD: 66,23	Mean: 64,00 SD: 9,57 M-1 SD: 54,43 M-2 SD: 44,86	Mean: 64,00 SD: 7,65 M-1 SD: 56,75 M-2 SD: 49,10	Mean: 67,20 SD: 6,20 M-1 SD: 61,00 M-2 SD: 54,81	Mean: 68,20 SD: 6,29 M-1 SD: 61.91 M-2 SD: 55,63	Mean: 49,50 SD: 9,26 M-1 SD: 40,24 M-2 SD: 30,97	Mean: 50,50 SD: 12,57 M-1 SD: 37.93 M-2 SD: 25,36	Mean: 5,75 SD: 0,82 M-1 SD: 4,93 M-2 SD: 4,10
10 years (n=10)	Mean: 93,25 SD: 3,55 M-1 SD: 89,70 M-2 SD: 86,16	Mean: 90,00 SD: 8,16 M-1 SD: 81,84 M-2 SD: 73,67	Mean: 73,60 SD: 8,47 M-1 SD: 65,13 M-2 SD: 56,65	Mean: 72,60 SD: 5,97 M-1 SD: 66,63 M-2 SD: 60,67	Mean: 77,00 SD: 4,26 M-1 SD: 73,54 M-2 SD: 69,27	Mean: 75,80 SD: 5,20 M-1 SD: 70,60 M-2 SD: 65,39	Mean: 52,50 SD: 11,61 M-1 SD: 40,89 M-2 SD: 29,29	Mean: 54,00 SD: 8,76 M-1 SD: 45,24 M-2 SD: 36,49	Mean: 5,40 SD: 0,88 M-1 SD: 4,52 M-2 SD: 3,65
11 years (n=10)	Mean: 94,25 SD: 6,13 M-1 SD: 88,12 M-2 SD: 81,99	Mean: 92,00 SD: 5,11 M-1 SD: 86,90 M-2 SD: 82,00	Mean: 80,00 SD: 4,62 M-1 SD: 75,38 M-2 SD: 81,78	Mean: 81,20 SD: 5,67 M-1 SD: 75,53 M-2 SD: 70,76	Mean: 82,40 SD: 5,72 M-1 SD: 76,68 M-2 SD: 69,85	Mean: 82,80 SD: 4,64 M-1 SD: 78,16 M-2 SD: 70,96	Mean: 57,00 SD: 9,49 M-1 SD: 47,51 M-2 SD: 38,02	Mean: 55,00 SD: 8,16 M-1 SD: 46,84 M-2 SD: 38,03	Mean: 5,80 SD: 1,72 M-1 SD: 4,08 M-2 SD: 2,36
12 years (n=10)	Mean: 93,50 SD: 4,59 M-1 SD: 88,91 M-2 SD: 84,31	Mean: 92,75 SD: 5,06 M-1 SD: 87,69 M-2 SD: 82,63	Mean: 82,40 SD: 10,70 M-1 SD: 71,70 M-2 SD: 61,00	Mean: 79,60 SD: 11,38 M-1 SD: 68,22 M-2 SD: 56,83	Mean: 84,80 SD: 9,20 M-1 SD: 75,60 M-2 SD: 66,40	Mean: 82,40 SD: 8,26 M-1 SD: 74,14 M-2 SD: 65,88	Mean: 69,00 SD: 7,75 M-1 SD: 61,25 M-2 SD: 53,51	Mean: 67,90 SD: 7,05 M-1 SD: 60,85 M-2 SD: 53,81	Mean: 6,20 SD: 1,23 M-1 SD: 4,97 M-2 SD: 3,74
Average	Mean: 91,20 SD: 6,57 M-1 SD: 84,63 M-2 SD: 78,06	Mean: 86,80 SD: 9,24 M-1 SD: 77,56 M-2 SD: 68,31	Mean: 69,88 SD: 15,55 M-1 SD: 54,33 M-2 SD: 38,78	Mean: 69,60 SD: 14,47 M-1 SD: 55,13 M-2 SD: 40,65	Mean: 73,80 SD: 12,53 M-1 SD: 61,27 M-2 SD: 48,73	Mean: 73,12 SD: 12,09 M-1 SD: 61,03 M-2 SD: 48,94	Mean: 54,30 SD: 13,21 M-1 SD: 41,09 M-2 SD: 27,88	Mean: 52,98 SD: 14,32 M-1 SD: 38,65 M-2 SD: 24,33	Mean: 5,66 SD: 1,21 M-1 SD: 4,45 M-2 SD: 3,25

KEY:		**SD**	Standard deviation
M-1 SD	Mean – 1 standard deviation	**M-2 SD**	Mean – 2 standard deviations

APPENDIX XII: The IVA CPT Procedural Guidelines for diagnosing the type of ADHD (Sandford and Turner, 2001: 6-7)

"After taking into account clinically the use of a differential diagnosis, the IVA test analysis cab best be diagnostically interpreted by carefully following the step by step procedural guidelines outlined below:

1. If the IVA CPT is determined to be valid for one or both sensory modalities (see page 4-1, Validity Checks) then proceed to step 2, else go to step 20.

2. If the IVA CPT is determined to be valid for both sensory modalities, then proceed with step 3 below, else skip to step 7.

3. If either the Full Scale Response Control Quotient (FSRCQ) or the Full Scale Quotient (FSAQ) is less than 80, then the test results support the diagnosis of ADHD. Go to step 12.

4. If either the Full Scale Response Control Quotient (FSRCQ) or the Full Scale Attention Quotient (FSAQ) is less than 85 and the Fine Motor Regulation Quotient is less than 85 or either Comprehension scale is less than 85, then the test results support the diagnosis of ADHD. Go to step 12.

5. If any response control or attention primary scale quotient scores are less than 75, then further clinical data are needed to make a diagnosis of ADHD, Not otherwise Specified. The individuals who present with a history of ADHD symptoms may have learned to compensate or have possibly matured cognitively in some ways. Otherwise, one or two quotient scores less than 75 suggest significantly impaired functioning which may be due to other psychiatric disorders. Go to step 18.

6. If this step is reached, then the IVA test results can generally be interpreted as not supporting the diagnosis of ADHD. Go to step 20.

7. If only the auditory or visual sensory modality is determined to be valid based on the Comprehension scale, then the interpretation can proceed only for that modality. The procedure is to follow the similar rules and cut-off scores of steps 3 through 6, using only the valid scores. Proceed to step 8.

8. If either the specific valid sensory modality's Response Control Quotient (ARCQ or VRCQ) or its Attention Quotient (AAQ or VAQ) is less than 80, then the test results support the diagnosis of ADHD. Go to step 15.

9. If either the specific valid sensory modality's Response Control Quotient (ARCQ or VRCQ) or its Attention Quotient (AAQ or VAQ) is less than 85 and the Fine Motor Regulation Quotient scale score is less than 85 or the same modality Comprehension scale is less than 85, then the test results support the diagnosis of ADHD. Go to step 15.

10. If any of the specific valid sensory modality's response control or attention primary scale quotient scores are less than 75, then further clinical data are needed to make a diagnosis of DAHD, Not otherwise Specified. The individuals who present with a history of ADHD symptoms may have learned to compensate or have possibly matured cognitively in some ways. Otherwise, one or two quotient

scores less than 75 suggest significantly impaired functioning which may be due to other psychiatric disorders. Go to step 18.

11. If this step is reached, then the IVA test results can generally be interpreted as not supporting a diagnosis of ADHD. Go to step 20.

12. If the FSRCQ is less than 85 and the FSAQ is greater than 85, then the IVA test results support a diagnosis of ADHD, Predominantly Hyperactive-Impulsive type. Go to step 19.

13. If the FSRCQ is greater than 85 and the FSAQ is less than 85, then the IVA test results support a diagnosis of ADHD, Predominantly In attentive type. Go to step 19.

14. If the FSRCQ is less than 85 and the FSAQ is less than 85, the IVA test results support a diagnosis of ADHD, Combined type. Go to step 19.

15. If the specific valid sensory modality's Response Control Quotient (ARCQ or VRCQ) is less than 85 and its Attention Quotient (AAQ or VAQ) is greater then 85, then the IVA test results support a diagnosis of ADHD, Predominantly Hyperactive-Impulsive type. Go to step 19.

16. If the specific valid sensory modality's Response Control Quotient (ARCQ or VRCQ) is greater than 85 and its Attention Quotient (AAQ and VAQ) is less than 85, then the IVA test results support a diagnosis of ADHD, Predominantly Inattentive type. Go to step 19.

17. If the specific valid sensory modality's Response Control Quotient (ARCQ or VRCQ) is less than 85 and its Attention Quotient (AAQ or VAQ) is less than 85, then the IVA test results support a diagnosis of ADHD, Combined type. Go to step 19.

18. If this step is reached, the most likely interpretive conclusions are that the IVA supports response control and/or attentional problems congruent with other psychiatric disorders (see section below on differential diagnosis) or that IVA scores indicate less sever, residual ADHD symptoms which do not fully meet ADHD diagnostic criterion. Go to step 21.

19. If this step is reached, then the most likely clinical conclusion is that the IVA results do support a diagnosis of ADHD. This conclusion does not rule out a secondary diagnosis, especially in the case of an adult. Go to step 21.

20. If this step is reached, this IVA interpretive procedural analysis strongly indicates that any behavioural response control or attentional problems observed or reported are not likely to be attributable to an ADHD disorder. In other words, reaching this step lends support to the conclusion that the person does not have ADHD. Proceed to step 21.

21. After a clinical diagnostic decision has been made, then it can be clinically useful to interpret the various IVA scales in terms of strengths, weaknesses, and styles of performance. Based on this clinical analysis, recommendations for different medication, psychological or behavioral treatments may be made".

APPENDIX XIII: The probability factor values of the CAPD tests for the variables "age" and "order of test condition"

	Age	Order of test condition
	Probability factor values	Probability factor values (p)
Dichotic digit test – right ear	<0,0001*	0,1601
Dichotic digit test – left ear	<0,0001*	0,7513
Frequency pattern test: labeling – right ear	<0,0001*	0,7676
Frequency pattern test: labeling – left ear	<0,0001*	0,8907
Frequency pattern test: humming – right ear	<0,0001*	0,4138
Frequency pattern test: humming – left ear	<0,0001*	0,4973
Low pass filtered speech test: right ear	<0,0001*	1,0000
Low pass filtered speech test: left ear	<0,0001*	0,3357
Speech masking level difference test	<0,0001*	0,3624

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

APPENDIX XIV: The probability factor values of the IVA CPT scores for the variables "age" and "order of test condition"

	Age	Order of test condition
	Probability factor values	Probability factor values (p)
Full Scale Control Quotient	0,2810	0,9410
Auditory Response Control Quotient	0,1752	0,5561
Visual Response Control Quotient	0,6003	0,6194
Full Scale Attention Quotient	0,4688	0,4583
Auditory Attention Control Quotient	0,5070	0,4466
Visual Attention Control Quotient	0,0582	0,0573
Fine Motor Regulation / Hyperactivity	0,0577	0,1207
Response Control		
Auditory prudence	0,5322	0,0367*
Visual prudence	0,4025	0,2167
Auditory consistency	0,2636	0,6016
Visual consistency	0,4548	0,4395
Auditory stamina	0,2011	0,4598
Visual stamina	0,0749	0,8602
Attention		
Auditory vigilance	0,0947	0,5416
Visual vigilance	0,1525	0,5544
Auditory focus	0,2323	0,5774
Visual focus	0,6294	0,4761
Auditory speed	0,0546	0,0557
Visual speed	0,0635	0,7657
Attribute		
Balance	0,3083	0,0176*
Auditory readiness	0,0540	0,1921
Visual readiness	0,5853	0,4214
Validity		
Auditory comprehension	0,6342	0,6169
Visual comprehension	0,1246	0,4672
Auditory persistence	0,4739	0,5259
Visual persistence	0,7802	0,3199
Auditory sensory motor	0,0540	0,6489
Visual sensory motor	0,0573	0,9389

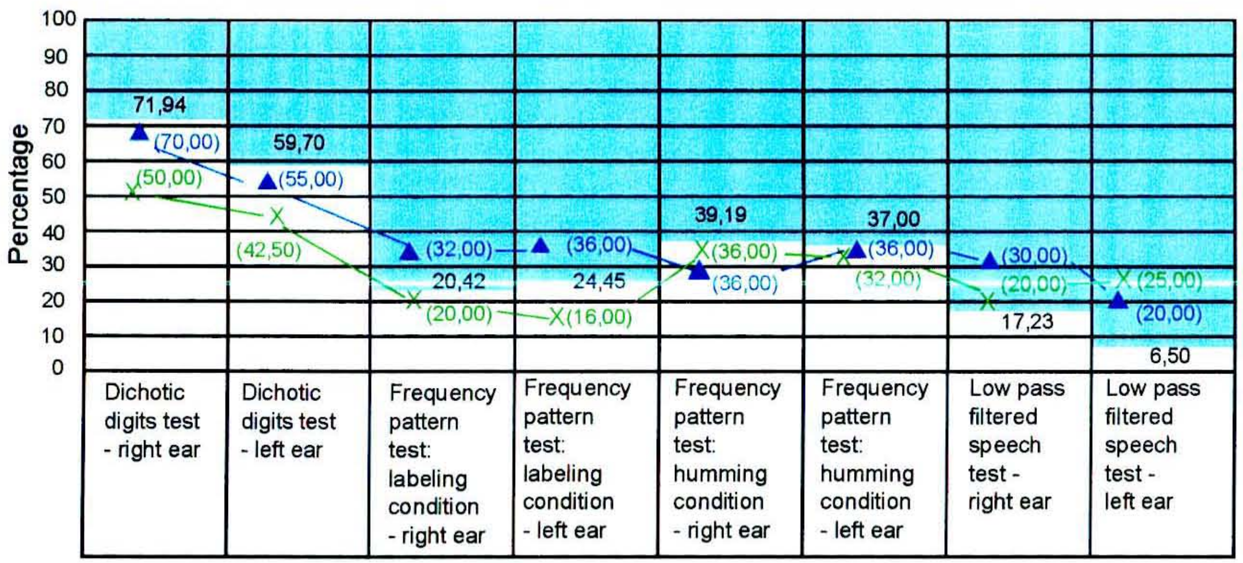
KEY:	
*	Significant difference at the 5% level of significance (Probability factor values (p)<0,05 = significant difference)

APPENDIX XV: The probability factor values of the IVA STAR scores for the variables "age" and "order of test condition"

	Age	Order of test condition
	Probability factor values	Probability factor values (p)
Primary Scales		
Auditory alertness	0,1001	0,5776
Visual alertness	0,1712	0,9650
Auditory steadiness	0,9850	0,4251
Visual steadiness	0,1705	0,0855
Auditory promptness	0,3966	0,0519
Visual promptness	0,1485	0,3119
Auditory constancy	0,6111	0,9092
Visual constancy	0,4902	0,7077
Combined Scales		
Auditory specific	0,4339	0,2942
Visual specific	0,2045	0,2926
Global (Auditory and Visual)	0,7459	0,4852

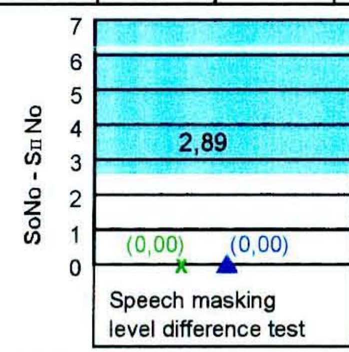
KEY:	
*	Significant difference at the 5% level of significance (Probability factor values <0,05 = significant difference)

Appendix XVI: The CAPD test results of the two 8 year old participants in research group 1



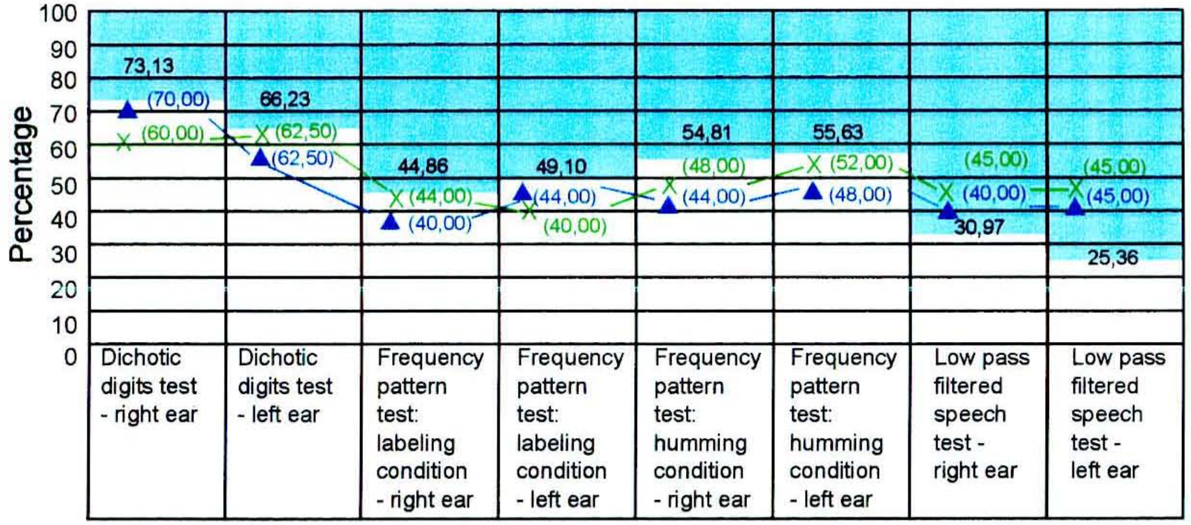
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
1	A/E	A/E	N	A/E
6	N	N	N	N



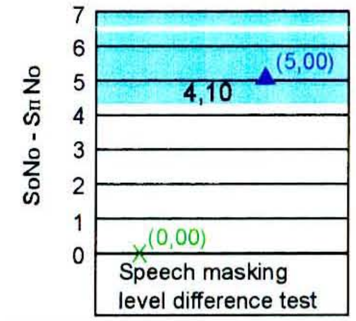
Key :	
X	Participant 1
▲	Participant 6
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out of phase and Noise in phase

Appendix XVII: The CAPD test results of the two 9 year old participants in research group 1



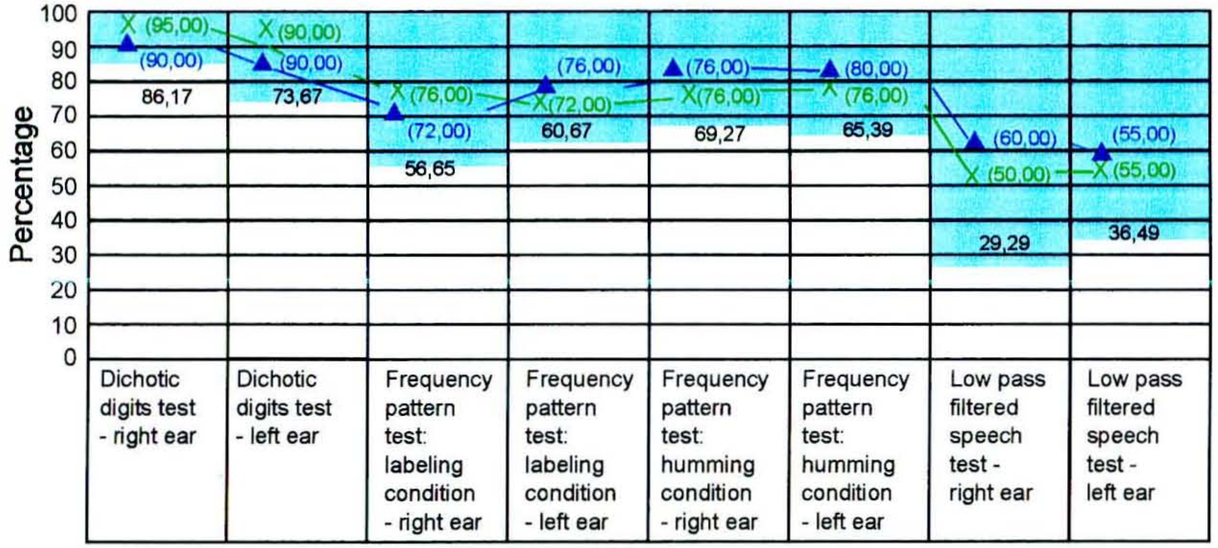
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
2	A/E	A/E	A/E	A/E
7	A/E	A/E	A/E	A/E



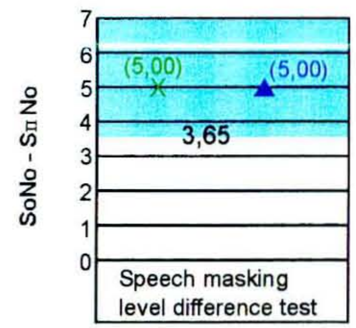
Key :	
X	Participant 2
▲	Participant 7
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out of phase and Noise in phase

Appendix XVIII: The CAPD test results of the two 10 year old participants in research group 1



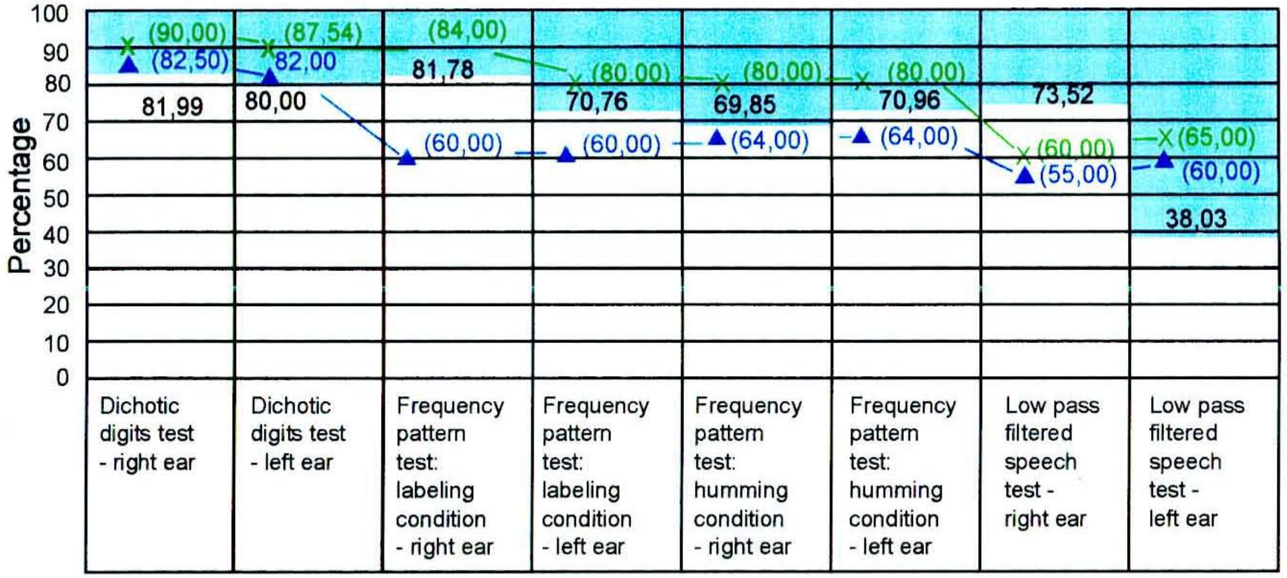
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
3	N	N	N	N
8	N	A/E	N	N



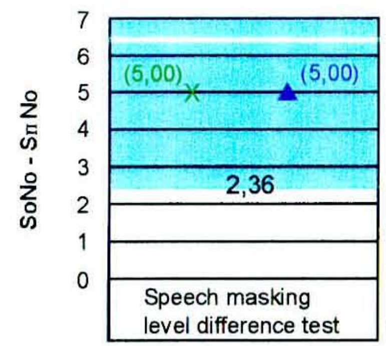
Key :	
X	Participant 3
▲	Participant 8
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out of phase and Noise in phase

Appendix XIX: The CAPD test results of the two 11 year old participants in research group 1



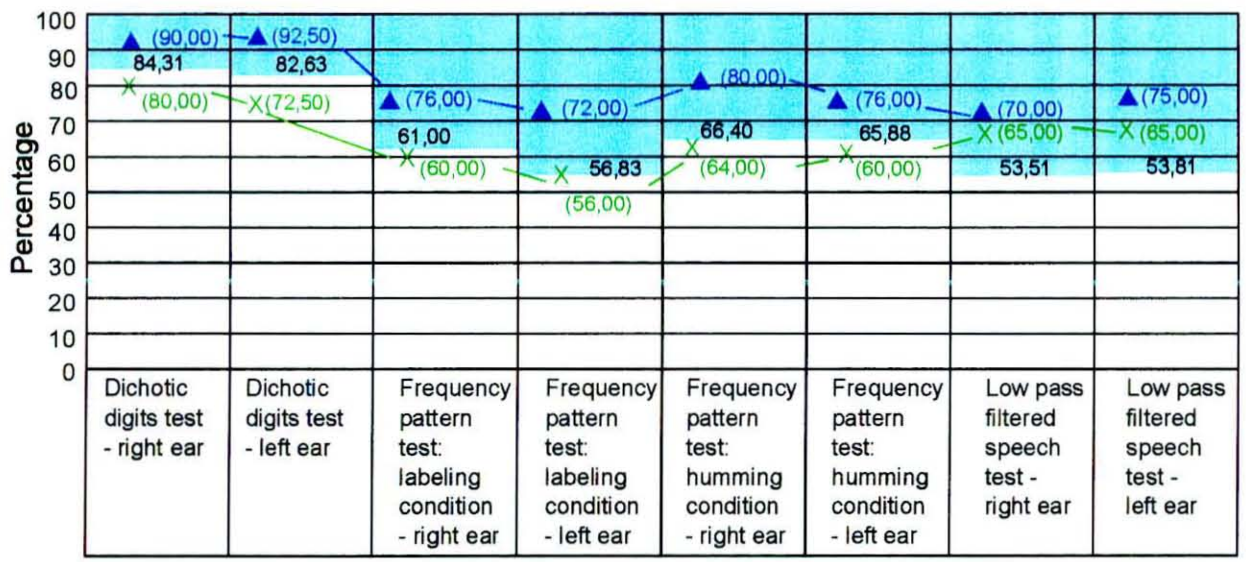
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
4	N	N	N	N
9	N	N	N	N



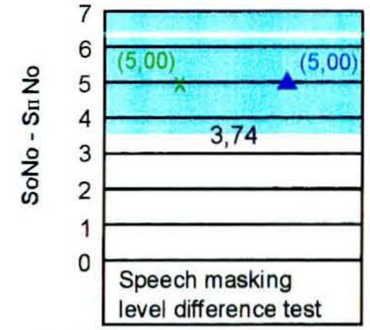
Key :	
X	Participant 4
▲	Participant 9
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out and Noise in phase

Appendix XX: The CAPD test results of the two 12 year old participants in research group 1



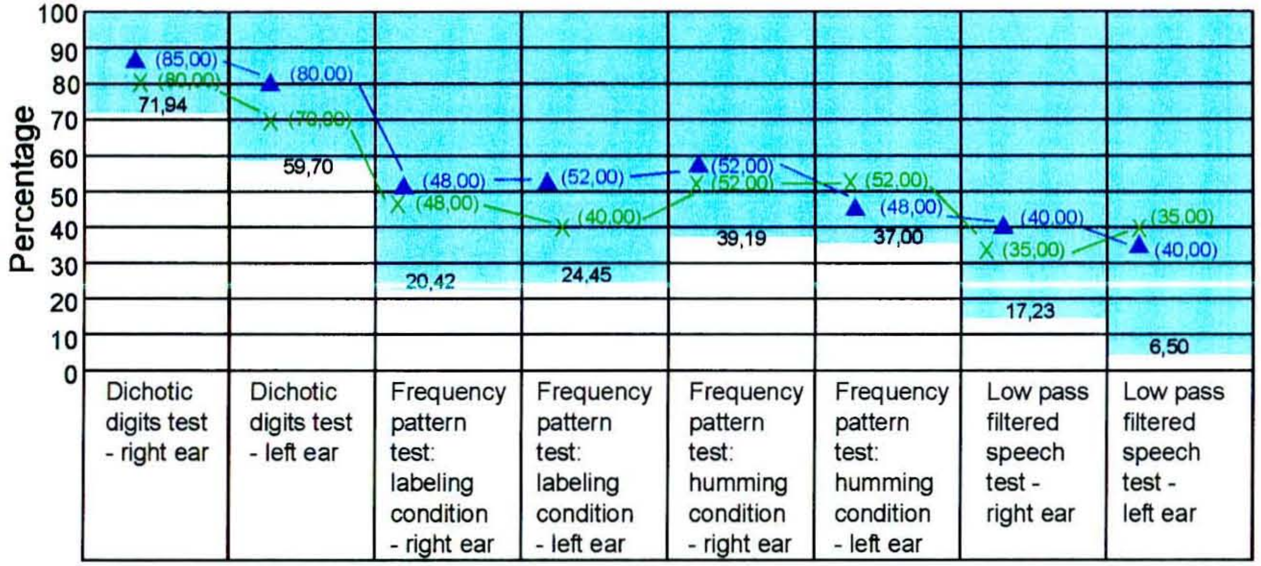
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
5	N	A/E	A/E	A/E
10	N	N	N	N



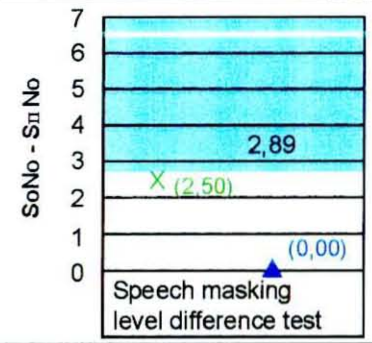
Key :	
X	Participant 5
▲	Participant 10
	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out and Noise in phase

Appendix XXI: The CAPD test results of the two 8 year old participants in research group 2



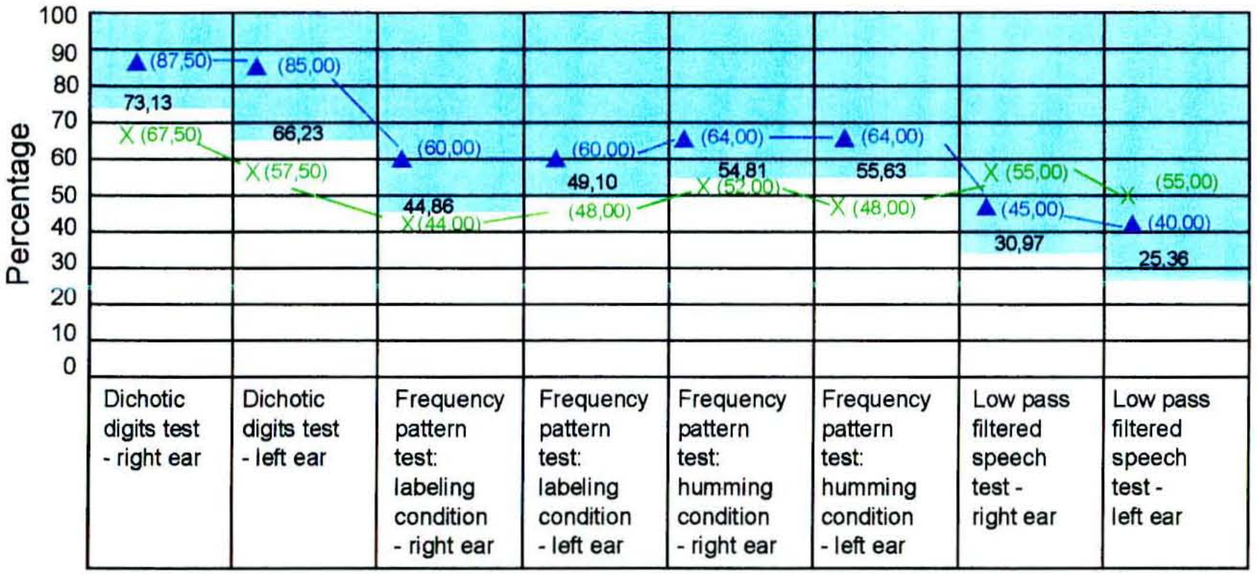
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
11	N	N	N	N
16	N	N	A/E	N



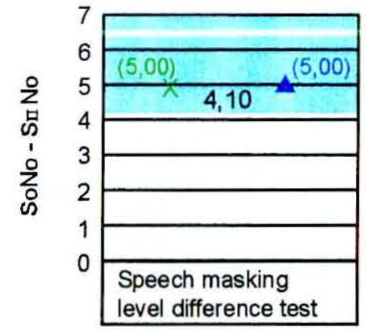
Key:	
X	Participant 11
▲	Participant 16
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out and Noise in phase

Appendix XXII: The CAPD test results of the two 9 year old participants in research group 2



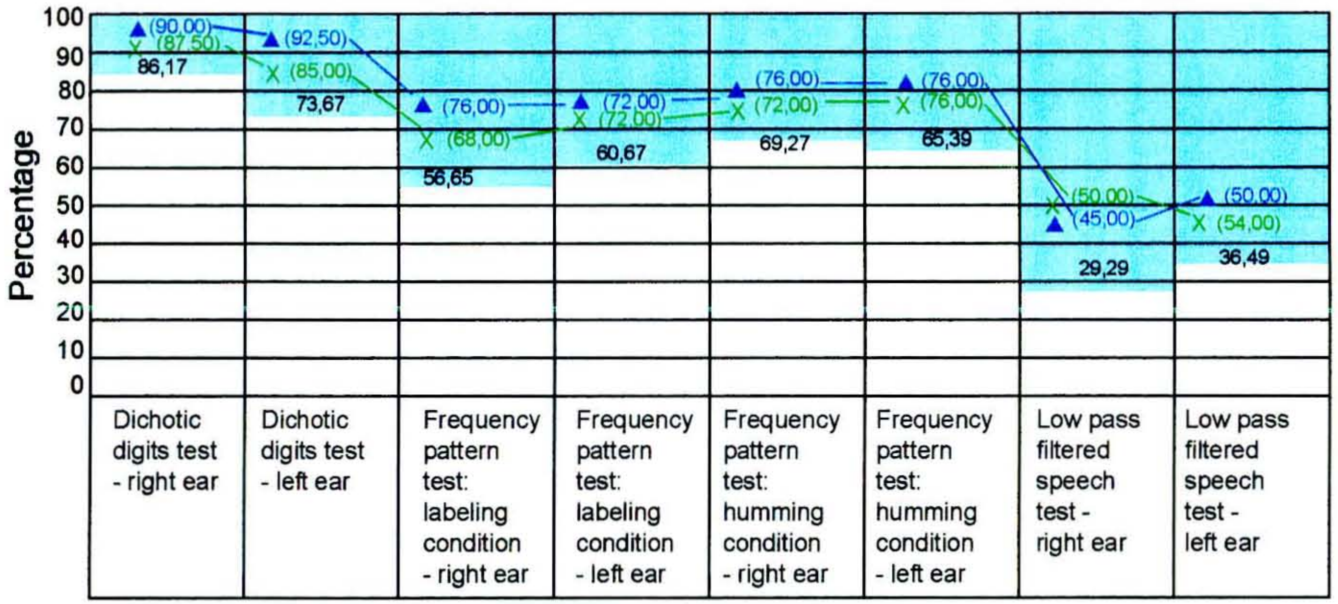
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
12	A/E	A/E	N	A/E
17	N	N	N	N



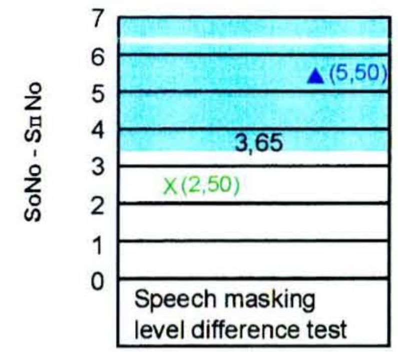
Key :	
X	Participant 12
▲	Participant 17
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signel in phase and Noise in phase - Signal out and Noise in phase

Appendix XXIII: The CAPD test results of the two 10 year old participants in research group 2



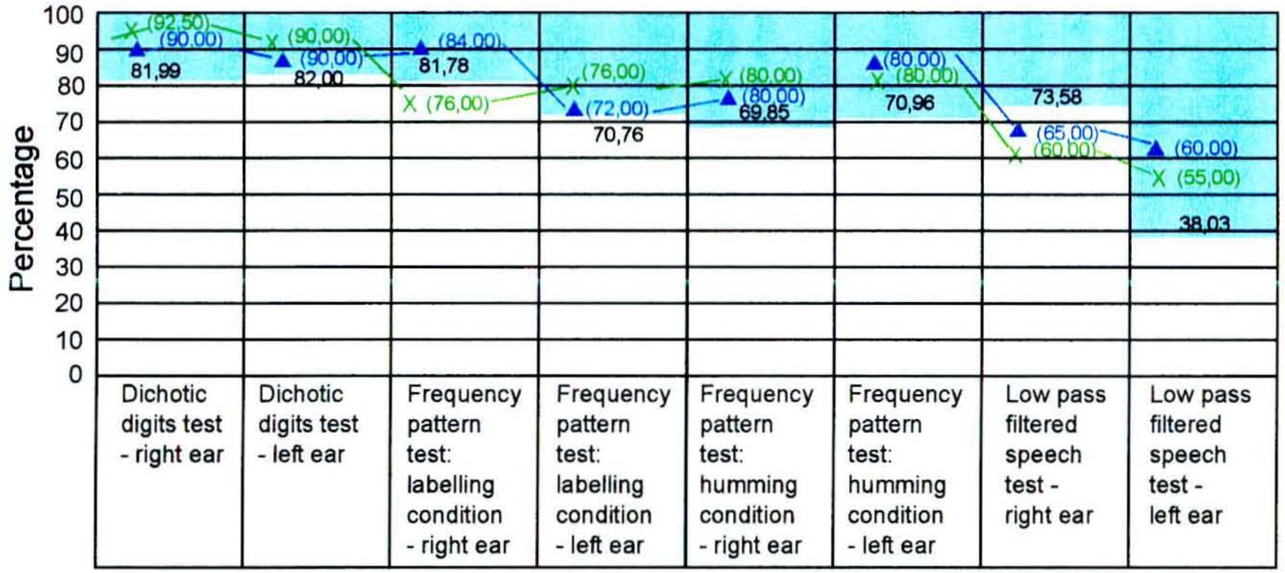
Stapedial acoustic reflexes

	Right ear		Left ear	
Participant	Ipsi-lateral reflexes	Contra-lateral reflexes	Ipsi-lateral reflexes	Contra-lateral reflexes
13	N	N	N	N
18	N	N	N	N



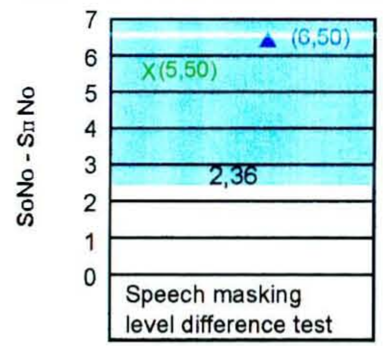
Key :	
X	Participant 13
▲	Participant 18
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out andNoise in phase

Appendix XXIV: The CAPD test results of the two 11 year old participants in research group 2



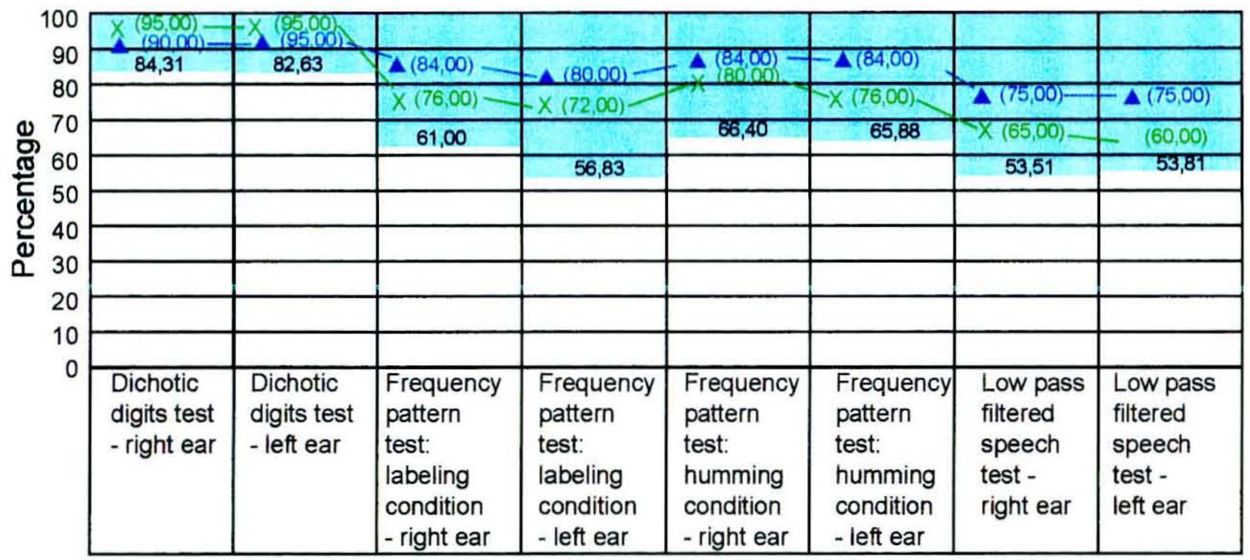
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
14	N	A/E	N	A/E
19	N	N	N	N



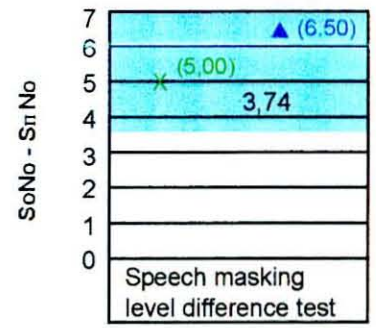
Key :	
X	Participant 14
▲	Participant 19
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out and Noise in phase

Appendix XXV: The CAPD test results of the to 12 year old participants in research group 2



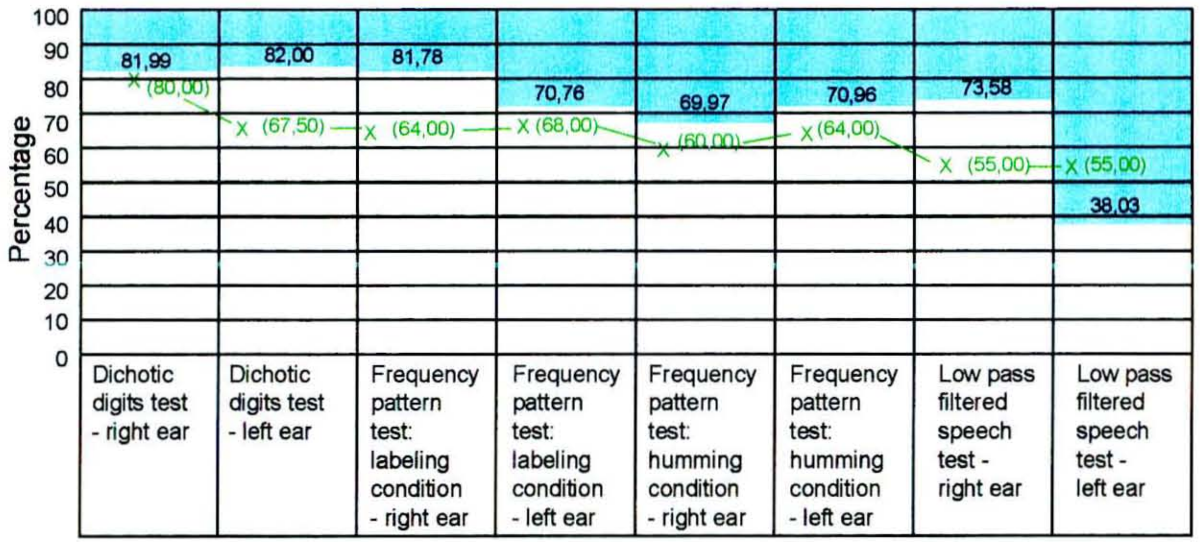
Stapedial acoustic reflexes

Participant	Right ear: Ipsi-lateral reflexes	Right ear: Contra-lateral reflexes	Left ear: Ipsi-lateral reflexes	Left ear: Contra-lateral reflexes
15	N	N	N	N
20	N	N	N	N



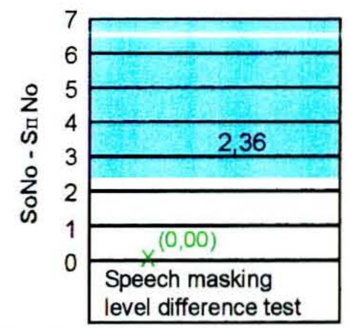
Key:	
X	Participant 15
▲	Participant 20
(shaded)	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out and Noise in phase

Appendix XXVI: The CAPD test results of the one 11 year old participant in research group 3



Stapedial acoustic reflexes

	Right ear		Left ear	
Participant	Ipsi-lateral reflexes	Contra-lateral reflexes	Ipsi-lateral reflexes	Contra-lateral reflexes
21	N	A/E	N	A/E



Key :	
X	Participant 21
	Normal range
N	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were within the normal range (70-90dBSL)
A/E	Two or more of the three acoustic reflexes at 500, 1000 and 2000Hz were elevated or absent at maximum intensity settings
SoNo - SπNo	Signal in phase and Noise in phase - Signal out and Noise in phase

Appendix XXVII: 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 (Participants 1, 2, 5, 7)	1 (Participant 12)	1 (Participant 21)	**6**
Failure on one / more CAPD tests but no clear test pattern suggesting a CAPD subprofile	4 (Participants 4, 6, 8 and 9)	5 (Participants 11, 13, 14, 16, 19)	0	**7**
CAPD results within the normal range	2 (Participants 3 and 10)	4 (Participants 15, 17, 18, 20)	0	**8**
	10	**10**	**1**	**21**

Appendix XXVIII: The results of the individual participants using the IVA CPT procedural guidelines for assisting in the diagnosis of the different types of ADHD.

	Research groups		
ADHD type according to the IVA CPT 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**
Combined type of ADHD	**5** (Subjects 2, 5, 6, 7 and 8) Subject 8 - Only auditory modality valid	**1** (Subject 12 – only auditory modality valid)	**1** (Subject 21)
Inattentive type of ADHD	**2** (Subjects 4 and 9)	**3** (Subjects 15,18, and 19)	**0**
Hyperactive-impulsive type of ADHD	**0**	**0**	**0**
No ADHD	**0**	**6** (Subject 20) (Subject 11 – only auditory modality valid) (Subjects 13,14, and 16 – FSRQC and FSAQ differ with more than 15) (Subject 17 – only auditory modality valid, difference between ARCQ and AAQ greater than 15)	**0**
Other	**3** (Subjects 1, 3 and 10 – validity of test results low and a low fine motor regulation score)	**0**	**0**

KEY:	
AAQ	Auditory Attention Quotient
ARCQ	Auditory Response Control Quotient
FSAQ	Full Scale Attention Quotient
FSRQC	Full Scale Response Control Quotient