Towards More Clinically Comprehensive Assessment and Management of Central Auditory Processing Disorders by Subprofiling

A report on a study presented to the Department of Communication Sciences and Disorders.

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ABSTRACT

At present few formal behavioural, audiological measures of central auditory processing are used in clinical practice in South Africa. This study aimed to select a behavioural, audiological central auditory processing test battery and determine whether this battery would be able to diagnose central auditory processing disorders (CAPD). It also aimed to determine whether this assessment battery would allow for subprofiling into the Bellis/Ferre model of CAPD (Bellis, 1999). Sixteen school-going subjects were selected to participate in this study. The subjects were selected from mainstream primary schools and were English first language speakers. Each subject completed a test battery, which included a peripheral hearing assessment and a battery of behavioural, audiological central auditory processing tests. The main finding in this study was that all subjects were able to be diagnosed with CAPD, using this specific test battery. Twelve out of sixteen subjects were able to be subprofiled into the Bellis/Ferre model of CAPD, two subjects presented with a mixed subprofile, the remaining two subjects could not be subprofiled possibly as a result of a more global delay. All subject's academic and language difficulties were related to their CAPD subprofile. This study has numerous clinical implications and the findings in this study support the use of these behavioural audiological CAPD tests in the assessment and management of children with CAPD in South Africa.

Key words: *Central auditory processing disorders, subprofiling , Bellis/Ferre Model*

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1. INTRODUCTION

"What we do with what we hear"

Katz, 1992, pg. 81

For many years professionals working in the disciplines of education, language and hearing have been aware that academic and learning difficulties in the classroom, together with speech and language deficits may sometimes be caused by difficulties with processing auditory signals (Bamford and Saunders, 1985).

Over the past few decades, there has been an increased interest in the importance of the auditory system and the critical role it plays in learning, language and academic skills (Katz, Stecker and Henderson, 1992). Furthermore, the increased interest in central auditory processing is a result of the increasing understanding of neurobiology and the link with language and cognitive systems (Chermak and Musiek, 1997).

Although the area of central auditory processing disorders (CAPD) has evoked much interest across various professions, it is an area that is fraught with much dispute and controversy. Reports of central auditory dysfunction have been documented in literature since the 1950's, however controversy still plagues this area (Chermak and Musiek, 1997). As noted by Bellis (1996) it is one of the topics that has resulted in the most misunderstanding, confusion and frustration. In addition, the nature, aetiology, assessment and management of CAPD still remains controversial (Silman, Silverman and Emmer, 2000).

The misunderstanding and confusion surrounding CAPD has led to much uncertainty regarding the selection of CAPD tests and uncertainty about which intervention procedures to use following diagnosis (Campbell, 2001). Furthermore, teachers and parents who deal with children presenting with academic difficulties are often frustrated as little or no information is available regarding the practical aspects of CAPD management (Bellis, 1996).

A further possible reason for the controversy relates to the fact that there has been a lack of consensus on how to precisely define central auditory processing (ASHA, 1996). In an attempt to define central auditory processing, the American Speech, Language and Hearing Association (ASHA) convened a Taskforce that arrived at consensus on a definition (ASHA, 1996).

Central auditory processes are the auditory system mechanisms and processes responsible for the following:

- auditory pattern recognition,
- sound localisation and lateralisation,
- auditory discrimination,
- temporal aspects of audition including temporal resolution, temporal masking, temporal integration and temporal ordering,
- auditory performance with competing acoustic signals,
- auditory performance with degraded acoustic signals (ASHA, 1996,pg. 41).

ASHA (1996) states that a central auditory processing disorder is an observed deficit in one or more of the processes mentioned above.

Although statements of consensus regarding CAPD continue to evolve they still fail to address the issue of how to determine the specific nature of the deficit (Bellis, 1996; Chermak and Musiek, 1997). Furthermore, the difficulty in defining CAPD is related to the heterogeneity of the disorder, similar to that of other learning and language disorders (ASHA, 1996; Bellis, 1999).

Knowledge of the central auditory nervous system (CANS) is critical for interpretation of the effects of a pathology on the auditory system (Bellis, 1996). Hence, a brief description of the central auditory nervous system and various lesions are now presented.

The central auditory nervous system extends from the level of the low brainstem up to the auditory cortex, involving a number of important structures (Zimmerman, 1994). Several brainstem structures comprise the auditory pathway. These include the cochlear nuclei, the superior olivary complex, lateral lemniscus, inferior colliculus and medial geniculate body (Bellis, 1996). The auditory pathway separates into ipsilateral and contralateral pathways. The contralateral pathways cross to the medial geniculate body on the opposite side (Zimmerman, 1994). The auditory pathway then ends at the level of the primary and associate auditory cortex in the left and right cerebral hemispheres (Musiek and Lamb, 1994). The corpus callosum, consisting of interhemispheric auditory fibres, is responsible for the communication and integration of information between the two cerebral hemispheres (Musiek and Lamb, 1994).

In the case of auditory function, the left cerebral hemisphere is thought to be dominant for language, rapid sequence and analysis of auditory stimuli whereas the right hemisphere is dominant for music perception, acoustic contour recognition as well as perception of the gestalt (Bellis, 1996).

Pathology along the auditory pathway may result in a number of auditory symptoms that can be identified by diagnostic behavioural auditory central auditory processing tests (Musiek and Lamb, 1994; Bellis, 1996). The classic finding on behavioural auditory central auditory processing tests can be described by dichotic listening (Chermak and Musiek, 1997). Dichotic listening refers to auditory stimuli that are presented to both ears simultaneously, with the presented stimulus being different for each ear (Bellis, 1996).

Kimura (1961, in Bellis, 1996) postulated a theory of dichotic listening. This theory hypothesised that the contralateral pathways are stronger and more numerous than the ipsilateral pathways in the CANS. When dichotic auditory stimuli are presented, the stronger contralateral pathways suppress the ipsilateral pathways. Therefore a lesion in one hemisphere will result in a deficit in the ear contralateral to the lesion (Musiek and Lamb, 1994; Bellis, 1996).

In subjects with right temporal lobe lesions, left ear suppression occurs due to contralateral suppression of the ipsilateral pathways, likewise in left temporal lobe lesions, right ear suppression occurs in the contralateral pathways (Musiek and Lamb, 1994; Bellis, 1996). Furthermore, right ear extinction does not occur with a right temporal lesion because the primary contralateral pathway to the left hemisphere remains intact. However, ipsilateral left ear disruption occurs with left hemisphere lesions because the stimulus to the left ear initially arrives at the right hemisphere and then crosses via the corpus callosum to the left hemisphere (Musiek and Lamb, 1994).

As the corpus callosum provides the link between the two hemispheres, lesions in this region will result in deficits related to the interhemispheric transfer of auditory information (Musiek and Lamb, 1994). Damage to the posterior section of the corpus callosum has resulted in left ear deficits on dichotic CAPD tasks as well as a bilateral deficit on tasks requiring linguistic labelling of patterned stimuli (Musiek, Reeves and Baran, 1985 in Bellis, 1996).

Brainstem lesions will affect test results according to the size and location of the lesion. Central auditory processing tests such as interaural timing tasks and masking level differences will indicate a lesion in the brainstem with an abnormal score (Jerger and Jerger, 1974 in Chermak and Musiek, 1997).

Due to the individuality of brain organisation and the pathologies that can affect this organisation, CAPD may affect individuals differently (ASHA, 1996). Hence, CAPD has been reported for persons presenting with a wide and diverse range of clinical problems (ASHA, 1996).

Much research has been conducted in the field of CAPD, which has focused on a number of areas. Over the past few decades, research has focused on the anatomical and physiological mechanisms of auditory processing and the effect brain lesions have on the processes of auditory perception (Musiek, Gollegly and Baran, 1984; Katz, 1986; Musiek and Baran, 1987). Furthermore, the development of assessment tools used for diagnosing CAPD has also been a focus of research over the past three decades (Jerger and Jerger, 1984; Wilson and Mueller, 1984; Katz, 1986).

Recently, research in CAPD has concentrated on the co-morbidity of CAPD with other clinical populations such as attention deficit disorder and attention deficit hyperactivity disorder (ADD/ADHD). Furthermore, Hyperlexia, Dyslexia, Autism, Pervasive Developmental Disorder, Aphasia and Otitis Media have been documented in children diagnosed with CAPD (ASHA, 1996; Bellis, 1996; Chermak and Musiek, 1997; Cacace and McFarland, 1998).

ADD/ADHD is the most common neurobehavioural disorder of childhood, where the core symptoms are inattention, hyperactivity and impulsivity (American Academy of Pediatrics, 2000). The relationship between ADD/ADHD and CAPD is complex and research outcomes have varied considerably (Gascon, Johnson and Burd, 1986; Katz, 1992; Keller, 1992; Riccio, Cohen, Hynd and Keith, 1996; Gomez and Condon 1999; Chermak, Hall and Musiek, 1999). Some studies have described CAPD and ADD/ADHD as a single developmental disorder whereas other studies have interpreted auditory processing deficits in children with ADD/ADHD as an indication of the co-morbidity of ADD/ADHD and CAPD (Chermak et al., 1999).

A number of studies have shown that children with ADD can present with a general attention problem, which is not restricted to a single sensory modality (Bedi, Halperin and Sharma, 1994 in Cacace and McFarland, 1998). This is supported by Riccio et al. (1996) who found that there was no difference between children with ADD and CAPD compared to children with CAPD and no ADD by using an auditory modality test alone.

Research has also investigated the effect of medication on CAPD assessment in children presenting with ADD/ADHD. This research has shown that children with ADD/ADHD improve in central auditory processing ability when they are on stimulant medication (Keith and Engineer, 1991;Tillery, Katz and Keller, 2000). Therefore children presenting with a CAPD may not have a CAPD but rather an ADD/ADHD.

Some researchers have highlighted the relationship between CAPD and learning disabilities (Katz and Wilde, 1985 in Cacace and McFarland, 1998; ASHA, 1996; Gomez and Condon, 1999). A learning disability (LD) can be described as a significant difficulty in reading, spelling, arithmetic and written language in spite of average or above average intelligence (Cantwell and Baker, 1991; Siegel, 1999). These studies have raised the question whether LD children present with auditory processing problems. Gomez and Condon (1999) found that children presenting with ADHD and LD performed much poorer on CAPD tests than children presenting with only an ADHD.

Despite a large amount of research conducted in the field of CAPD, this area still remains plagued with much controversy and complexity. As a result the true nature of CAPD is still yet unknown (Cacace and McFarland, 1998).

An exciting area of research in the field of CAPD has emerged, which concentrates on subprofiling CAPD. The concept of subprofiling was originally coined by Musiek, Gollegly and Ross (1985) and Katz, Smith and Kurpita (1992 in Katz, 1992) who described profiles of auditory processing deficits. Bellis (1996, 1999, 2001) extended previous research efforts on subprofiling CAPD and developed the Bellis/Ferre model, which is driven by the fundamental assumption that dysfunction in specific regions of the brain will lead to auditory processing deficits associated with those regions. Furthermore, Bellis (1999) delineates deficits that are likely to arise from dysfunction in a given region as well as relating auditory processing difficulties with language and learning difficulties.

Unlike Katz (1992) the Bellis/ Ferre model is a descriptive model that relates the relationship between auditory assessment findings and the underlying neuroanatomy and neurophysiology of the central auditory nervous system. Furthermore, this model considers the underlying auditory mechanisms with behavioural characteristics, language difficulties and academic results (Bellis, 1999; 2001). In addition, the aim of the Bellis/Ferre model is to assist with the interpretation of central auditory processing disorders and speech and language assessments resulting in deficit specific management plans for individuals with CAPD (Bellis, 2001).

As suggested by Bellis (1999) the Bellis/Ferre model consists of three primary profiles and two secondary profiles of CAPD. The three primary profiles highlight dysfunction in the primary auditory cortex (usually the left hemisphere), the nonprimary auditory cortex (usually the right hemisphere) and the corpus callosum (interhemispheric). The secondary profiles represent dysfunction that is considered to be as a result of deficits in higher-level processing or executive functions (Bellis, 1999).

Table 2.1 presents the primary and secondary profiles as presented by Bellis (1999).

Table 1.2 The Bellis/Ferre Model of CAPD

Primary Subprofiles	Auditory Decoding Deficit
	Prosodic Deficit
	Integration Deficit
Secondary Subprofiles	Auditory Associative Deficit
	Organisation /Output Deficit

The primary finding in an Auditory Decoding Deficit is poor auditory closure skills. This deficit is characterised by poor scores on dichotic speech tests and monaural low- redundancy speech tasks (Bellis, 1999). This deficit is suggestive of a left primary auditory cortex region of dysfunction (Bellis, 1999).

A Prosodic Deficit is characterised by difficulty in recognising the prosodic elements of spoken language. This is characterised by poor scores on dichotic speech tests and temporal patterning tasks in both the labelling and humming condition (Bellis, 1999). This pattern is suggestive of a right or nonprimary auditory cortex region of dysfunction (Bellis, 1999).

An Integration Deficit is characterised by difficulty in tasks that require interhemispheric communication. This deficit would be indicated if the subject presents with poor scores on dichotic speech tests and a deficit in the linguistic labelling condition of the temporal patterning test with normal performance on the humming condition (Bellis, 1999). This subprofile indicates a corpus callosum region of dysfunction (Bellis, 2001).

An Auditory Associative Deficit is an underlying difficulty with applying the rules of language to acoustic stimuli. This is characterised by a bilateral deficit on dichotic speech tests. This deficit indicates a left associative cortex region of dysfunction (Bellis, 1999).

An Output/ Organisation Deficit is determined by a deficit in the ability to sequence, plan and organise responses. This is characterised by poor scores on CAPD tasks that require report of more than two elements. This subprofile indicates a temporal to frontal region of dysfunction (Bellis, 1999).

Bellis (2003, personal communication) states that not all children fit into one single subprofile and mixed subprofiles could occur.

In summary, from a review of the literature, very little research has been conducted on the clinical implications of CAPD. As discussed above, research over the past few decades has concentrated on developing assessment tools, understanding the neuroanatomy of CAPD and investigating the co-morbidity of CAPD. Very few scientists have commented on the clinical implications of their research and ASHA (1996) stresses the importance of clinicians and scientists communicating research outcomes in the area of CAPD. The future research priorities outlined by ASHA (1996) call for mostly clinical research in the area of assessment and management of CAPD.

There are an increasing number of school going children presenting with language and learning difficulties in the classroom that cannot be accounted for by a known pathology. Poor academic performance, particularly poor reading and spelling abilities, are often the initial reason for referral for a suspected CAPD (Chermak and Musiek, 1997). The impact of a CAPD has an effect on both the use of language and the ability to learn language as the acquisition of oral language depends on the processing of acoustic information (Bellis, 1996; Kraus, Kock, McGee, Nicol and Cunningham, 1999).

Elsewhere, there are a large number of assessment tools available for diagnosing CAPD, however in South Africa the availability of these tests is limited. The purpose and aim of each test needs to be fully understood in order to obtain the maximum benefit of each assessment tool (Chermak and Musiek, 1997; Bellis, 1999). Currently, there are two theoretical approaches to the assessment of CAPD: an audiological model and a speech -language model (Gomez and Condon, 1999).

Traditionally, speech-language pathologists use the speech-language model to assess auditory perceptual difficulties. The speech - language model considers CAPD to be a language deficit involving poor semantic, linguistic and higher cognitive processing skills that are used for interpreting auditory stimuli (Gomez and Condon, 1999). Assessment tools used by speech-language pathologists are instrumental in defining the child's receptive and expressive language difficulties.

The importance of speech and language measures is highlighted by the fundamental rule of CAPD assessment, which is to relate all CAPD test results to the child's language and educational abilities (Bellis, 1996). This is particularly important when understanding the impact the CAPD has on the child's quality of life (Bellis, 1996).

Furthermore, these tests provide information regarding the child's communicative function, which aids in the differential diagnosis of CAPD (Bellis, 1999). However, speech-language measures do not provide information on the underlying auditory processing deficit and should not be used in isolation when diagnosing CAPD (Musiek and Lamb, 1994).

The audiological model provides an important but different approach to diagnosing CAPD. This model views CAPD as a perceptual disorder, involving problems with attending to, analysing and comprehending auditory stimuli (Gomez and Condon, 1999). There are clear advantages of the audiological approach for assessment of CAPD as current technology allows for excellent control of the acoustic stimuli. The technology provides good acoustic environment control, which is critical for test validity and reliability. However, the disadvantage of this model is the cost of the equipment and the restrictions on the utility (Chermak and Musiek, 1997).

Traditionally, the audiologist employs a battery of electrophysiological or behavioural audiological central auditory tests when assessing central auditory processing disorders (Koay, 1992). These measures are fundamental in providing information on the underlying auditory processes responsible for the auditory processing deficit (Bellis, 1996). This highlights the role of the audiologist.

To date in South Africa little assessment using behavioural audiological central auditory processing tests is being conducted in clinical practice in the area of CAPD (Campbell, 2003, personal communication). Poor availability of these tests in South Africa and poor training in the administration and interpretation of test scores has resulted in limited use. Currently in tertiary universities the theory of CAPD is taught, however very little clinical knowledge is gained, as students are not being sufficiently exposed to the clinical application and interpretation of CAPD tests. There is a drive to extend clinical teaching of CAPD at tertiary universities across South Africa, with the aim to implement student clinics in major universities towards the end of 2003 (Campbell, 2003, personal communication).

The increased need for clarity in CAPD assessment and management led to the formation of a South African CAPD Taskforce in 1999. This Taskforce aimed to address the unique challenges facing clinicians in South Africa namely: the challenge of eleven official languages, poor training in the administration and interpretation of CAPD tests and the lack of standardised South African CAPD test materials. The S.A Taskforce started to develop low linguistically loaded test material, with the aim to provide South African test material to a large number of children who are not proficient in English. However, the S.A taskforce was unfortunately disbanded in 2002.

A comprehensive assessment for diagnosing CAPD should be conducted by a multi-disciplinary team, with the audiologist conducting the behavioural audiological CAPD measures which provide information on the underlying deficits in auditory processes (ASHA, 1996; Bellis, 1996). The speech and language measures conducted by the speech –language pathologist provides information on the impact of the CAPD on communication abilities (Bellis, 1999). Furthermore, the educator provides information on the academic manifestations of CAPD in the classroom. Often, in South Africa, the behavioural audiological component of CAPD testing is omitted.

Furthermore the management of these children may be inappropriate as many children are receiving therapy without a comprehensive CAPD assessment. The danger is that these children often receive therapy that does not treat the underlying mechanisms of CAPD, as may be identified by behavioural audiological CAPD measures. Surely a clearer picture of the underlying auditory processes is needed in order to determine the appropriate therapy. This raises questions about the appropriacy and efficacy of therapy for children with CAPD.

To the best of the researchers knowledge the concept of subprofiling has not filtered into clinical practise in South Africa. As discussed previously, very little training has been conducted at tertiary universities resulting in very few speech therapists and audiologists being aware of this means of diagnosing and treating CAPD. Hence, multiple children are either not being diagnosed or receiving inappropriate therapy. The Bellis/Ferre model offers a means of easily identifying disordered auditory processes by profiling the disorder into subtypes. Furthermore, this model dictates completely different management strategies to those provided by traditional speech and language therapy.

CAPD has not been well understood, especially in the school going population. This has resulted in the lack of support services they truly need to succeed (Chermak and Musiek, 1997). This study recognises the importance of producing relevant clinical research that may add to the body of clinical knowledge on the assessment and management of CAPD in children presenting with difficulties in the classroom in South Africa.

Hence the purpose of this study is to show the clinical usefulness of subprofiling CAPD, using behavioural audiological CAPD measures and the Bellis/Ferre model. Furthermore to relate the underlying auditory processing deficits with language and academic difficulties reported in the classroom. In addition, using guidelines provided by Bellis (1999) suggest the appropriate management strategies.

The aim of this study is to select and administer a behavioural audiological CAPD test battery to individuals with a suspected CAPD. This aims to allow for subprofiling of each subject's suspected CAPD as defined by the Bellis /Ferre model (Bellis, 1999). It also aims to determine whether the specified CAPD test battery allows for differential diagnosis into sub-profiles as suggested by Bellis (1999). The identification of subprofiles will allow for the recommendation of management intervention that is deficit specific for each subject diagnosed with CAPD as defined by Bellis (1996, 1999, and 2001). In addition, each subject's subprofile will be related to their academic difficulties.

Due to the scope of this study and the current availability of tests in South Africa, subjects were restricted to proficient English language speakers. Obviously the need to conduct this type of research within other language groups in South Africa is very much needed. Furthermore, the lack of normative data for CAPD testing in South Africa has limited the subject selection to those children proficient in English.

In this study, children over the age of eight years were selected in the attempt to reduce the effect of neuromaturational development of the CANS. Many of the CAPD tests require an age of seven to eight years as younger children show considerable variation in their test scores (ASHA, 1996; Bellis, 1996; Chermak and Musiek, 1997). In addition, normative data for the tests used in this study are available from the age of eight years and onwards (Katz, 1986; Jerger and Jerger, 1984; Wilson and Mueller, 1984).

In this study, an attempt was made to exclude those subjects presenting with a general ADD/ADHD. As stated previously, the relationship between ADD/ADHD and CAPD is complex and continues to be at the centre of much debate. There are many questions relating to whether CAPD and ADD are a single entity or disorders that co-exist (Gomez and Condon, 1999).

CAPD can be diagnosed by behavioural and electrophysiologic measures (ASHA, 1996; Bellis, 1996). However, these measures are not needed for subprofiling according to Bellis (1996). Furthermore, the equipment needed for these tests is limited and the procedure is expensive.

This study is a clinical endeavour, which hopes to show that with a minimal test battery it is possible to diagnose and subprofile CAPD. It is not attempting to test the Bellis/Ferre model of CAPD, but is rather using it as a tool to allow for diagnosis and subprofiling of each subjects CAPD.

The reality is that subprofiling is not being used in South Africa. This study will hopefully inform and promote the use of a behavioural, audiological CAPD test battery in the diagnosis and management of CAPD.

"There is a great need to gather clinical knowledge to serve this challenging population." (Chermak and Musiek, 1997, pg xvi)

2. METHODOLOGY

This chapter presents the aims, methodological design, subject selection criteria and description of the subjects used in this study. In addition the test battery, methods of data collection and data analysis are described.

2.1 Aims

The primary aims of this study were to:

- Select a behavioural audiological central auditory processing test battery for the diagnosis of CAPD.
- Determine whether the selected behavioural audiological central auditory processing disorder test battery will allow for the diagnosis of CAPD.
- To subprofile each subject's proposed behavioural audiological central auditory processing disorder using the Bellis/ Ferre model with a view to provide deficit specific management (Bellis, 1999).
- To relate all subjects documented and reported academic, learning and language difficulties with their respective CAPD subprofiles.

2.2 Research Design

A multiple, descriptive case study design was employed in this study (Katzenellenbogen, Joubert and Abdool Karim, 1997). A multiple case study would allow for in depth analysis of each subject's test scores and associated language and learning difficulties. This was thought to be the most appropriate method of research due to the widely acknowledged heterogeneity of this population (ASHA, 1996; Bellis, 1996).

2.3 Subjects

2.3.1 Sample Size

Sixteen subjects between the ages of eight and fourteen years were employed in this study. No control group was required, as normative data is available for each CAPD assessment tool (Katz, 1986; Jerger and Jerger, 1984; Wilson and Mueller, 1984).

2.3.2 Subject Selection Criteria

a) All subjects were required to present with a suspected CAPD. A formal diagnosis of CAPD made with the use of behavioural audiological CAPD tests was not required as it is recognised that these tests are rarely being used in a clinical setting in South Africa.

b) Each subject was required to present with scholastic or language difficulties thought to be related to a suspected CAPD. These difficulties may have been determined by remedial therapists, psychologists, speech -language pathologists or academic reports. In addition interviews with teachers were conducted in order to obtain information that may indicate a suspected CAPD.

c) The subjects were required to have no known attention deficit hyperactivity disorder/ attention deficit disorder (ADHD/ADD). As previously mentioned, the relationship between ADHD/ADD and CAPD is largely undefined and complex. Children with ADHD/ ADD may perform normally or poorly across all CAPD measures, indicating that no clear pattern is present (Gomez and Condon, 1999). Subjects with a suspected ADD may present with a CAPD or children with a suspected CAPD may present with an ADD. Hence it was hoped to exclude subjects that presented with a general ADD/ADHD. Perusal of academic reports, psychology reports and interviews with parents and educators were conducted in order to attempt to exclude children with a suspected ADD/ADHD from this study.

d) The subjects were required to be eight years or older. The minimum age of eight years was selected, as normative data is mostly only available from this age onwards (Bellis, 1996). In addition, Bellis (1996) stated that a minimum mental age of seven years or eight years is required for CAPD testing as neuromaturational factors may influence the reliability of the test results. Furthermore Bellis (2001) states that all assessments should be related back to the subject's language and learning skills. Assessment of each subject's language and learning ability are available through academic reports at primary school level. The final grade at primary school level is Grade 7, where pupils are generally thirteen to fourteen years of age.

e) All subjects were required to be male. Fundamental differences have been found between electrophysiological test results in male and female subjects (Jerger and Hall, 1980 in Abramovich and Thornton, 1990). Female latencies are shorter and have larger amplitudes than males, which is due to different head sizes (Hall, 1984). Due to the scope of this study, only male subjects were selected.

f) An average to above average non-verbal I.Q. as determined by a formal intellectual ability test conducted by a psychologist was required for all subjects. Poor cognitive functioning may lead to poor performance on certain auditory processing tasks (Bellis, 1996).

g) All subjects were required to be English first language speakers, as currently normative data for CAPD tests is only available in English (Katz, 1986; Jerger and Jerger, 1984, Wilson and Mueller, 1984).

h) All subjects were required to present with normal peripheral hearing at the time of testing. Cacace and McFarland (1998) describe CAPD as a modality specific perceptual dysfunction that is not due to a peripheral hearing impairment. According to Bellis (1996) and Chermak and Musiek (1997) a peripheral hearing loss is a confounding variable on many central auditory assessment tasks.

2.3.3 Subject Recruitment

The subjects participating in this study were recruited from local mainstream primary schools that used a first language English medium of teaching. The sixteen subjects were identified primarily by their teachers who highlighted their academic and learning difficulties noted in the classroom. Academic reports, speech and language reports and psychology reports were also used to select subjects that were suspected of having a CAPD that had not formally been diagnosed. All of the subjects selected to participate in this study were first language English speakers. In addition, all subjects were from a middle socio-economic background.

2.3.4 Subject Description

In Table 2.1 below, each subject's age and grades are presented.

Table 2.1 Subject Description

Subject	Age	Grade
1	10.0	4
2	9.11	4
3	12.6	7
4	9.8	3
5	11.9	5
6	13.3	7
7	13.6	7
8	12.8	7
9	12.6	7
10	13.4	7
11	8.9	2
12	8.3	2
13	9.2	3
14	10.4	4
15	9.8	3
16	10.4	4

As can be seen in Table 2.1, the subjects participating in this study ranged between 8.3 years and 13. 6 years and their grades ranged from Grade 2 to 7. All subjects were right handed. In addition, all subjects presented with I.Q.'s ranging from "average to above average" according to their respective psychological reports.

2.3.5 Subject's Academic and Language Difficulties

A fundamental aim of conducting CAPD assessment is to relate all findings back to the individual's academic difficulties (Bellis, 1996). As stated previously, each subject was required to present with scholastic or language difficulties that may have been identified by teachers, remedial teachers, psychologists or speech -language pathologists. These difficulties may suggest a central auditory processing disorder. Interviews were conducted with teachers and perusal of all reports was undertaken to obtain this information. Table 2.2 presents each subject's academic and language difficulties as noted by their academic reports and teachers.

Table 2.2 Subject's Academic and Language Difficulties

Subject	Academic and Language Difficulties
1	Difficulty with task organisation, poor arithmetic and written work, easily distracted by auditory stimuli.
2	Poor auditory memory, poor language and written language difficulties.
3	Poor reading and phonetic spelling, poor written work. Poor auditory discrimination skills.
4	General language difficulties, repeated a grade, weak spelling, poor reading, weak written work and arithmetic skills. Auditory memory and discrimination difficulties were noted. Struggles with listening in noise.
5	Repeated Grade 1, comprehension difficulties, auditory discrimination difficulties.
6	Expressive language difficulties, poor reading and phonetic spelling, poor arithmetic skills. Poor social skills.
7	Significant spelling difficulties, weak reading skills and written work. Poor social skills.
8	Difficulties with written language, poor comprehension, reading and spelling difficulties, phonetic spelling, word decoding problems.
9	Poor spelling and reading, weak written language.
10	Difficulty with task organisation, very poor spelling and written work, difficulty listening in noise.
11	Reading and spelling difficulties, poor written ability. Poor auditory discrimination.
12	Reading and spelling difficulties, weak auditory discrimination skills. Generally weak language.

13	Poor arithmetic skills, phonetic spelling and reading difficulties.
14	Reading and spelling difficulties, poor written work. Poor auditory discrimination skills.
15	Poor listening in noise, weak arithmetic skills, poor phonological and auditory discrimination skills.
16	Appears to mishear sounds, difficulty applying spelling rules, weak arithmetic skills, reading delay.

2.4 Subject Consent

Consent with regard to the subject' participation in this study was obtained prior to examination. As all the subjects participating in this study were younger than 18 years of age, written consent was obtained from each subject's guardian. The purpose of this study and the procedures to be undertaken were explained to the subjects and their guardians prior to them giving consent. In addition, permission was granted from the principals of the participating schools for the perusal of all subject's reports. A report and summary of each subject's assessment results was provided to their respective guardian and school.

2.5 Data Collection

This section presents the data collection conducted in this study.

The differential diagnosis of CAPD relies on the administration of behavioural auditory central auditory processing tests as well as the examination of speech-language measures. This allows for a cohesive picture of the underlying auditory processing deficits and the implications for language, learning and communication (Bellis, 1999).

In order to address the aim of this study, a test battery was selected which includes a peripheral hearing assessment and a diagnostic behavioural audiological central auditory processing disorder test battery. The tests employed in this study are presented in Table 2.3 .

Table 2.3 Tests Employed in this Study

Assessment of Peripheral Hearing	a) Puretone Air-conduction Threshold Testing b) Speech Reception Threshold
Diagnostic Behavioural Audiological CAPD Test Battery	a) Staggered Spondaic Word Test b) Pitch Pattern Sequence Test c) Northwestern University No. 6 , Time Compressed to 60% d) Masking Level Difference – pure tones

2.5.1 Assessment of Peripheral Hearing

This aspect of the assessment aims to assess the subject's peripheral hearing to ensure that it was within normal limits at the time of the CAPD assessment. The inherent distortion of sound caused by a peripheral hearing loss affects many of the scores on CAPD tests (Katz, 1992; Bellis, 1996; Musiek and Rintellman, 1999). As mentioned previously, for the purpose of this study, all subjects were required to present with peripheral hearing that was within normal limits.

2.5.1.1 Puretone Air-Conduction Threshold Testing

Puretone air-conduction threshold audiometry is the standard behavioural procedure for determining auditory sensitivity (Yantis, 1994). Hearing threshold can be defined as the lowest level at which the sound stimulus is audible in more than half of the ascending trials (Silman and Silverman, 1991). In this study the puretone air-conduction thresholds were used to determine the status of each subject's peripheral hearing. Secondly, these results were used to determine presentation levels of the CAPD tests.

- **Procedure**

Pure-tone air-conduction thresholds were determined by using the Carhart- Jerger Modified Hughson- Westlake Method (Carhart and Jerger, 1959). Tones were manually presented via supra-aural earphones. The following frequencies were tested in the following order 1000Hz, 2000Hz, 4000Hz, 8000Hz, 500Hz and 250 Hz. The subjects were required to press the response button to indicate when they heard the tone. Responses were plotted on an audiogram (Silman and Silverman, 1991).

The subjects were considered to have normal peripheral hearing if their thresholds were at or less than 26 decibels across the tested frequencies (Silman and Silverman, 1991). The pure tone average (PTA) was determined by averaging the obtained thresholds for 500Hz, 1000Hz and 2000Hz (Yantis, 1994). The puretone air-conduction testing was conducted in a sound proof audiometric booth at the Speech and Audiology Department, Groote Schuur Hospital.

2.5.1.2 Speech Reception Threshold (SRT)

The speech-recognition threshold is the lowest level at which a person correctly recognises speech 50 % of the time (Penrod, 1994). The use of SRT in this study is twofold. Firstly, the SRT provides a check of the validity of the puretone air-conduction threshold as the relationship between speech and pure tone sensitivity is well-documented (Carhart, 1952 in Silman and Silverman, 1991). Secondly, the SRT were used to calculate the presentation levels for certain of the CAPD tests.

- **Procedure**

The SRT's were calculated bilaterally, by using the procedure suggested by Chaiklin and Ventry (1964, in Silman and Silverman, 1991). The list of spondees were presented live-voice, with the carrier phrase *"Say the word...."* Spondees are two syllable words with approximately equal stress on each syllable (Penrod, 1994). Each subject was required to verbally repeat the stimulus. Each subject's response was recorded on a score sheet.

The SRT's were considered to be within normal limits if they fell within twelve decibels of the pure- tone average (PTA) of 500Hz, 1000Hz and 2000Hz (Silman and Silverman, 1991).

SRT testing was conducted in a sound proof audiometric booth at the Speech and Audiology Department, Groote Schuur Hospital.

2.5.2 The Behavioural Audiological Central Auditory Processing Test Battery

2.5.2.1 Selection of the CAPD Test Battery

In its simplest form a behavioural audiological central auditory processing test battery should:

- Assess several different auditory processes (Chermak and Musiek , 1997).
- Provide information regarding the presence or absence of a central auditory processing disorder, thus diagnosing the subject with a CAPD (Bellis, 1996).

Furthermore,

- These tests need to identify the subject's weaknesses as well as their strengths regarding auditory processing (Chermak and Musiek, 1994; 1997; Bellis, 1999, 2001).
- All information and test scores should be related back to speech, language and academic arenas (Bellis, 1996).

A test battery allows for easier interpretation of scores as patterns or a global reduction of test scores may be identified. In addition, a test battery allows for deficit specific management strategies to be identified (Bellis, 1999).

CAPD tests should include measures of both verbal and non-verbal stimuli to examine the different levels of auditory processing and the auditory nervous system. Non-verbal measures include tests using tones or clicks as stimuli (ASHA, 1996). In this study both verbal and non-verbal measures were used. Furthermore, central auditory processing assessments can be conducted by either behavioural or electrophysiological measures (Chermak and Musiek, 1997). For the purpose of this study behavioural tests were used.

In addition Bellis (2001) suggested that a CAPD test battery should include a full audiological assessment to determine the peripheral hearing status. The test battery should not comprise of more than five tests, especially when assessing children (Chermak and Musiek, 1997).

Central auditory processing involves a number processes. Categories of behavioural auditory measures can be used effectively to assess CAPD include tests from the following areas (ASHA, 1996):

1. **Dichotic Listening.** Dichotic speech tests assess the process of binaural integration and binaural separation. Stimuli are presented to each ear and are composed of a portion of the whole message. Integration of the information is necessary for the listener to perceive the whole message.
2. **Temporal Processing**. Temporal processing tests assess temporal ordering, temporal discrimination and frequency discrimination. These tasks require a listener to make discriminations based on the temporal sequence or order of the acoustic stimuli.
3. **Monaural Low Redundancy.** These tests assess the process of auditory closure and auditory discrimination when portions of the signal are missing or distorted.
4. **Binaural Interaction**. Tests of binaural interaction generally assess the ability of the CANS to process separate but complementary information presented to both ears.

In this study, the following tests were selected according to their availability in South Africa. One test was selected to assess each of the categories stated above hence, each test assesses a different auditory process. The tests selected for the CAPD test battery are presented in Table 2.4 below.

Table 2.4 The Behavioural Audiological Central Auditory Processing Test Battery

CAPD CATEGORY	TEST
a) Dichotic Listening	Staggered Spondaic Word Test
b) Temporal Processing	Pitch Pattern Sequence Test
c) Monaural Low Redundancy	Northwestern University No. 6; Time Compressed to 60%
d) Binaural Interaction/ Fusion	Masking Level Difference – pure tones

The above mentioned tests were conducted in a sound proof audiometric booth at the Speech and Audiology Department, Groote Schuur Hospital. The Staggered Spondaic Word Test, Pitch Pattern Sequence Test and NU 6 Time Compressed to 60% were recorded on cassette tape (Campbell, 2001). The tests were conducted with the use of cassette tapes (TDK) and were presented via a diagnostic two- channel audiometer ; Technics Stereo Cassette Deck (RS-BX501) and a ROTEL stereo power amplifier (RB-850) . The Masking Level Difference Test was adminstered via the Belltone 2000 Audiometer. The full test battery took approximately two hours per subject to administer.

a) Dichotic Listening: Staggered Spondaic Word Test (SSW)

Dichotic listening tasks involve simultaneous presentation of sound stimuli to both ears, in which the stimulus to the right ear will differ to that of the left ear (Chermak and Musiek, 1997).

Two types of dichotic tasks have been identified, namely binaural integration and binaural separation. Binaural integration involves the identification of both signals or the ability to process information that is presented to both ears simultaneously. Binaural separation involves only the recognition of one specified signal or the ability to recognise one signal in one ear while ignoring any signals being presented to the other ear at the same time. Both these processes are important for everyday listening particularly in a school environment (Bellis, 1996).

Dichotic tests, such as the SSW, have been shown to be sensitive to lesions along the CANS, including the lower brainstem (Katz, 1986; 1992; Musiek, Baran and Pinheiro, 1994 in Bellis, 1996). The SSW is one of the most commonly used test of binaural integration (Katz and Ivey, 1994). Originally it was used for site of lesion testing by Katz (1986) but was later applied to CAPD in learning disabled children (Bellis, 1996).

The SSW is a linguistically loaded dichotic listening task, involving binaural integration, sequencing and selective listening (Smoski, Brunt and Tannahill, 1992).

- **Procedure**

The SSW is comprised of 40 test items, each consisting of two spondaic words. As stated previously spondees are two syllable words with approximately equal stress on each syllable (Penrod, 1994).The two words are presented with a staggered onset, with one word presented to each ear. This results in three separate sequential events (Silman and Silverman, 1991). The first and last events are referred to the non-competing event, while the middle event is referred to as the competing event (Katz, 1986). The subject is required to integrate the three events and provide two verbal responses. For example as seen in the Table 2.5, the correct response would be: sunset and sunrise.

Table 2.5 The Three Events of the SSW

EVENT 1	EVENT 2	EVENT 3
NON COMPETING	COMPETING	NON COMPETING
S U N	S E T	
	S U N	R I S E

The stimuli were presented via cassette player at 50 decibels above the subject's PTA (Katz, 1986). Responses were recorded on a score sheet and analysed according to the test manual (Katz, 1986).

- **Scoring**

The scoring procedure for the SSW is complex (Bellis, 1996). Test scores may be interpreted both quantitatively and qualitatively (Katz, 1986). The quantitative component includes analysis of the raw scores, corrected and adjusted scores. The qualitative component involves analysis of response bias (Katz and Ivey, 1994). For the purpose of this study, the quantitative data was used for interpretation.

In summary, quantitative analysis includes analysis of the subject's raw scores to determine whether the subject presented with a bilateral deficit, left ear deficit (peak) or right ear advantage (peak). This will allow for categorisation into the Bellis/Ferre model (Bellis, 1999).

Left ear peaks or bilateral deficits are calculated according to the percentage of errors made from four conditions: left competing (LC), left non-competing (LNC), right competing (RC) and right non-competing (RNC). These percentages were plotted on a graph, which allowed for easy identification of peaks. The percentage of errors was compared to normative data, which determined whether the scores for each condition were normal or below average (Katz, 1986).

b) Temporal Processing: Pitch Pattern Sequence (PPS)

Temporal processing is an important element of central auditory processing (Pinheiro and Musiek, 1985 in Bellis, 1996). It is critical to a number of everyday listening tasks such as speech perception and perception of music. It allows the listener to interpret the prosodic features of speech including rhythm and stress, which are important for comprehension skills (Bellis, 1996; Chermak and Musiek, 1997). Deficits in temporal processing may contribute towards specific learning impairments including deficits in phonological processing and discrimination (Bellis, 1996).

Pinheiro (1977, in Stecker, 1992) used the Pitch Pattern Sequence Test (PPS) to assess pattern perception and temporal sequencing skills. The PPS requires the subject to make discriminations based on the sequence or temporal order of stimuli (Bellis, 1996). Furthermore it assesses processes of frequency discrimination, temporal ordering and linguistic labelling (Bellis, 1996).

Pattern perception tests, such as the PPS, require the interaction of the right and left hemisphere to decode stimuli for linguistic labelling (Chermak and Musiek, 1997). Hence the integrity of both temporal lobes and the corpus callosum is necessary for linguistic labelling of temporal patterns (Bellis, 1996). Therefore a dysfunction in either hemisphere or the corpus callosum results in a bilateral deficit on pattern perception tasks (Musiek, Gollegly and Baran, 1984 in Chermak and Musiek, 1997, Bellis, 1999).

The PPS is sensitive to lesions affecting areas that are involved in interhemispheric transfer of auditory information (Bellis, 1996). Patients with auditory cortex dysfunction in either hemisphere present with a reduced ability to perform this task regardless of the response mode. Verbal responses on the PPS involve interaction between the right and left cerebral hemispheres. The right hemisphere decodes the sound stimuli and transfers it to the left hemisphere via the corpus callosum. Furthermore, the left hemisphere provides the stimuli with a linguistic label (Chermak and Musiek, 1997).

If a subject fails the linguistic labelling response of the PPS but passes the hummed response then a left hemisphere or corpus callosum site of dysfunction is indicated as suggested by Bellis (1999). Furthermore, Bellis (1999) suggests that a normal hummed response indicates an intact right hemisphere function, however if the hummed section is also failed this indicates a right hemisphere site of dysfunction (Bellis, 2001)

- **Procedure**

The test comprises of a number of sets of tree tone bursts that are presented monaurally. The subject is required to identify the correct sequence of these tone bursts. The three tone bursts are comprised of a combination of high and low pitches. In this study, the frequency of the high tone was 1122Hz and the low tone was 880Hz. Both the tone bursts had a duration of 200ms (Stecker, 1992; Campbell and Wilson, 1999).

For example: High, High, Low

Low, Low, High

High, Low, High

There are 60 test items in the PPS, with an interval of seven seconds between each item. Ten of these sets are practice items, which ensured that the nature of the task was understood.

The tone bursts were firstly presented to the right ear and then to the left ear at 50 decibels above each subject's 1000Hz pure tone threshold. Each subject was asked to verbally label the tone bursts in the correct sequence. This is referred to as the linguistic labelling or spoken response. If the subject failed the linguistic labelling response (according to the test manual) the test was repeated and the subject was asked to hum their response rather then respond verbally. This is indicated as the hummed response (Jerger and Jerger, 1984).

- **Scoring**

Both the spoken and hummed responses were recorded on a record sheet. The scores were calculated as a percentage of the correct responses. Reversals were counted as correct responses. Reversals are a result of the subject replacing the high tones with the low tones or the other way around (Bellis, 1996).

The test manual describes a percentage range of 85 to 100% as the range of normal scores (Jerger and Jerger, 1984). For the purpose of this study scores below 85% were considered below average.

c) Monaural Low Redundancy: The NorthWestern University No.6 Word Lists, Time Compressed to 60% (NU 6 TC)

Low redundancy monaural speech tasks are used to assess auditory closure skills (Bellis, 1996). These tests comprise of tasks where the speech signal is degraded or there is some form of acoustic competition (Chermak and Musiek, 1997). The reduction in the redundancy of the acoustic signal makes these tests suitable for assessing auditory closure skills (Chermak and Musiek, 1997). Auditory closure is an important auditory processing skill as it aids in the comprehension of spoken utterances (Bellis, 1996).

The normal listener will typically be able to achieve auditory closure even when a portion of the auditory signal is missing or distorted (Bellis, 1996). A listener with CAPD will be able to achieve auditory closure when auditory stimuli are presented in an ideal listening environment, however they will show significant problems when the task is made more difficult by signal distortion, such as in a noisy classroom environment (Bellis, 1996).

The NU-6 TC is a low monaural speech test, which differs from standard speech recognition tests because the method of compression alters the temporal duration of the word. A time compressed speech test can be defined by the reduction of the temporal characteristics without an affect on the frequency characteristics (Campbell and Wilson, 1999). These tests are sensitive to auditory dysfunction, however site of lesion cannot be determined with the use of these tests (Bellis, 1996).

A compression rate of 60% results in 60% of the signal being extracted in small acoustic components (Wilson and Mueller, 1984). This process results in minimal distortion of the frequency characteristics of each word (Fairbanks, Everitt and Jaeger, 1954 in Bellis, 1996). A 60% compression rate was used in this study, as this is the highest rate of compression at which normal listeners can still obtain normal scores. In addition, the difference in performance between non- CAPD subjects and those with CAPD, is most significant at 60% compression (Stecker, 1992).

- **Procedure**

Monosyllabic words from the NU 6 TC list A were time compressed to 60% and presented via cassette tape. The words were initially presented to the subject's right ear and then to the left ear at 46 decibels above their speech reception threshold. The subject was asked to repeat the word that they heard and the responses were recorded on a record sheet.

- **Scoring**

Each subject's raw scores were converted to a percentage. A range of 72% to 100 % was considered to be within normal limits (Wilson and Mueller, 1984). For the purpose of this study all scores below 72% were considered to be below average.

d) Binaural Interaction: Masking Level Difference (MLD)

The term binaural interaction can be described as the way the left and right ear work together (Bellis, 1996). A primary example is sound localisation and lateralisation of auditory stimuli (Bellis, 1996). This is considered to be a function of the lower brainstem (Chermak and Musiek, 1997).

The Masking Level Difference (MLD), a test of binaural interaction, is the difference in binaural threshold for tones that are in or out of phase with the left and right ear (Chermak and Musiek, 1997). The MLD test is well known for its good sensitivity measures and a short administration time (Noffsinger, Martinez and Schaefer, 1985; Bellis, 1996). It is widely used for both clinical and research purposes (Chermak and Musiek, 1997).

This test procedure is sensitive to lower brainstem lesions that are not affected by cortical or cochlear dysfunction (Chermak and Musiek, 1997; Schoeny and Talbottt , 1994). Lesions of the lower brainstem include acoustic schwannomas and degenerative diseases such as multiple sclerosis (Bellis, 1996).

- **Procedure**

For the purpose of this study, the MLDs were determined according to the procedure outlined by Schoeny and Talbott (1994). Masking is presented in phase between both ears and in phase with the signal and the initial threshold is obtained. The process is repeated but the signal is presented out of phase and a second threshold is obtained. Two phase conditions were tested:

- SoNo This is the homophasic condition where the signal at both ears is in phase and the noise in both ears is in phase.
- SπNo This is the antiphasic condition where the signal at both ears is 180 degrees out of phase and the noise in both ears is in phase.

The masking level difference was taken as the difference between these two conditions, MLD = SoNo- SπNo.

Narrow band masking was presented at 60 decibels HL at 500Hz. A pure tone signal was presented ten to fifteen decibels below the masking level. The tone was increased in one decibel steps until the subject responded. The final threshold for each condition was taken as an average of two test sessions.

- **Scoring**

For normal subjects, thresholds obtained during the homophasic condition are poorer than those obtained for the antiphasic condition (Silman and Silverman, 1991). These improvements reflect release from masking (Silman and Silverman, 1991). Large threshold differences may be expected at moderate presentation levels such as 60 decibels in the low frequencies (500 Hz) (Noffsinger, Martinez and Schaefer, 1985; Silman and Silverman, 1991).

The norms reported for MLDs have shown considerable variation amongst authors, largely due to different variables (Stecker, 1992). Bellis (1996) states that the MLD for pure tones may be as high as ten to fifteen decibels depending on the frequency of the tone and characteristics of the masking. Wilson, Zizz and Sperry (1994 in Bellis, 1996) stated that

MLD's smaller than five decibels should be considered abnormal. For the purpose of this study a range of eight to sixteen decibel difference was considered to be average (Bellis, 1996).

2.6 Analysis of the Behavioural Audiological Central Auditory Processing Test Battery

All scores obtained for each CAPD test was scored according to their respective test manual. The scoring procedure for each test has been discussed above.

Test scores for each subject were analysed to allow for the diagnosis of CAPD. Furthermore the scores were analysed in depth and subprofiling of their CAPD into the Bellis/ Ferre model was undertaken (Bellis, 1999). These scores were analysed in combination with each subject's scholastic performance which was used to verify the correct subprofile. Furthermore, discussion was undertaken with the relevant educators to further ensure that the correct subprofiling of each subject had been undertaken. Once each subject was subprofiled, management strategies according to Bellis (1999) were suggested.

This chapter presents the methodology adopted in this study. In the following section the results of the each subject's performance on the behavioural audiological central auditory assessment battery is presented. Furthermore, the subprofiling of each subject will be presented and then related to each subject's academic and language difficulties.

3. Results and Discussion

In this section the findings of each subject's performance on the peripheral hearing assessment and behavioural central auditory processing test battery are presented and discussed. Furthermore each subject is subprofiled into the Bellis/ Ferre model of CAPD (Bellis, 1999) and their academic difficulties are discussed. Lastly, management strategies for each subject are suggested.

3.1 Assessment Results

3.1.1 Assessment of Peripheral Hearing

Each subject's peripheral hearing was assessed to determine whether they present with peripheral hearing within normal limits.

Puretone air-conduction thresholds were determined, which allowed for calculation of the pure tone average (PTA). The PTA is used to calculate the presentation level for the Speech Reception Threshold (SRT) and the SSW in the CAPD test battery. The SRT's were used to calculate the presentation level for the NU 6 TC for each subject. Table 3.1 presents each subject's bilateral PTA and SRT scores.

As seen in Table 3.1 below, each subject presents with SRT scores that are within 12dB of their PTA. This verifies the thresholds obtained for air-conduction threshold testing and provides reliable presentation levels for the CAPD tests (Silman and Silverman, 1991).

Table 3.1 Subject Scores for Pure Tone Average and Speech Reception Threshold

Subject Number	PTA		SRT	
	Right	Left	Right	Left
1	0	0	5	10
2	0	0	10	10
3	5	10	10	15
4	17	15	15	15
5	5	0	15	5
6	2	10	10	10
7	0	0	10	10
8	0	0	0	0
9	0	5	10	10
10	0	0	10	10
11	5	10	10	10
12	10	10	15	20
13	5	0	5	5
14	5	5	10	10
15	0	5	10	10
16	10	5	15	10

3.1.2 The Behavioural Audiological Central Auditory Processing Test Battery Results

3.1.2.1 Staggered Spondaic Word Test (SSW)

As stated previously, the scoring procedure for the SSW is complex. As stated previously test scores may be interpreted both quantitatively and qualitatively. For the purpose of this study, quantitative measures were used as this allowed for easier categorisation into the subprofiles as highlighted by Bellis (1999).

Dichotic stimulation scores for normal listeners are consistently higher for the right ear than scores for the left ear. This is due to the fact that the stronger contralateral pathways suppress ipsilateral pathways. This is known as a right ear advantage (Kimura, 1961 cited in Bellis, 1996). For the purpose of this study, a right ear advantage or peak was considered to indicate normal dichotic listening. Left ear peaks or bilateral deficits are calculated according to the percentage of errors made from four conditions: Left competing, left-non competing, right competing and right-non competing (Katz, 1986).

Table 3.2 presents each subject's scores for the SSW.

Table 3.2 Subject's Scores for the SSW

SSW category	Subject number
Left ear deficit	1, 2, 3, 4, 6, 9, 10, 12, 13,15, 16
Bilateral deficit	5, 7, 8, 11, 14

Table 3.2 above indicates that Subjects **1, 2, 3, 4, 6, 9, 10, 12, 13, 15** and **16** presented with scores that indicated a left ear deficit. These subjects may present with a possible left hemisphere dysfunction or a corpus callosum dysfunction as suggested by Bellis (1999).

Subjects **5, 7, 8, 11** and **14** presented with bilaterally poor scores, which would indicate a possible right hemisphere dysfunction as suggested by Bellis (1999).

No subjects obtained a right ear peak, which would indicate normal dichotic listening skills (Bellis, 1999).

Katz (1992) conducted a study on the distribution of CAPD in children with learning disorders using the SSW. A sample of 94 subjects was selected according to reported classroom difficulties. Their results are similar to those found in this study where only one child in the entire sample of 94 presented with normal scores on the SSW. Katz (1992) described the sensitivity of the SSW to dysfunction in the central auditory system as a reason why all but one subject performed poorly on the SSW. Similarly, in this study the sensitivity of the SSW may account for all sixteen subjects presenting with poor scores on this test.

3.1.2.2 Pitch Pattern Sequence Test (PPS)

The PPS is a temporal patterning task, which requires linguistic labelling of non- speech stimuli (Baran and Musiek, 1995).

The test manual describes a percentage range of 85 to 100% as the range of normal scores (Jerger and Jerger, 1984). Hence, scores below 85% were considered below average. For the purpose of this study, if the subject achieved more than 86% on the linguistic labelling response then the hummed response was not obtained.

Table 3.3 presents the scores for the linguistic labelling and hummed responses for each subject. These scores are presented as percentages.

Table 3.3 Subject's Scores for Linguistic Labelling and Hummed Responses for the PPS

Subject number	Labelling		Hummed	
	Right ear	Left ear	Right ear	Left Ear
1	86	85	NA	NA
2	78	78	98	98
3	85	85	92	92
4	38	58	85	100
5	42	50	69	84
6	84	85	82	80
7	100	100	NA	NA
8	100	98	NA	NA
9	80	80	94	90
10	85	85	98	100
11	100	100	NA	NA
12	58	48	96	98
13	60	58	96	100
14	96	100	NA	NA
15	42	24	40	50
16	60	60	86	96

* NA – not assessed

As seen in Table 3.3 Subjects **1, 7, 8, 11** and **14** fell within the normal range for labelling responses. This suggests that these subjects present with normal temporal processing skills.

Subjects **2,3, 4, 9,10,12,13** and **16** failed their labelling responses but passed their hummed responses. This indicates a possible dysfunction in either the left hemisphere or the corpus callosum as suggested by Bellis (2001).

Subjects **5, 6** and **15** failed both the labelling and hummed responses indicating a possible right hemisphere dysfunction as suggested by Bellis (2001).

3.1.2.3 The NorthWestern University No. 6 Word Lists, Time Compressed to 60% (NU 6 TC)

This test was selected to assess each subject's auditory closure skills. For the purpose of this study all scores below 72% were considered to be below average (Wilson and Mueller, 1984). Table 3.4 presents the scores of each subject for the NU 6 TC. The scores are depicted as a percentage.

Table 3.4 Subject's Scores for NU 6 TC

Subject	Right ear	Left ear
1	72	76
2	76	76
3	75	80
4	**40**	**32**
5	**54**	**62**
6	84	82
7	78	78
8	**48**	**52**
9	82	74
10	74	72
11	**56**	**40**
12	**38**	**50**
13	72	72
14	**42**	**36**
15	**44**	**52**
16	72	72

As seen in Table 3. 4, Subjects **1, 2, 3, 6, 7** and **9, 10** presented with scores in the normal range indicating normal auditory closure skills.

The remaining Subjects **4, 5, 8,11,12,14** and **15** presented with bilaterally poor scores on this test. Bilaterally poor scores indicate a possible left hemisphere region of dysfunction as suggested by Bellis (1999).

3.1.2.4 Masking Level Difference (MLD)

This assessment allows for investigation of each subject's binaural interaction. For subjects with normal binaural interaction, thresholds obtained during the homophasic condition are poorer than those obtained for the antiphasic condition (Silman and Silverman, 1991).

As stated previously, the norms reported for MLD have shown considerable variation (Stecker, 1992). For the purpose of this study a range of eight to sixteen decibel difference was considered to be average.

Table 3. 5 presents each subject's scores for the MLD.

Table 3.5 Subject's Scores for the MLD

Subject	SoNo	SπNo	SoNo - SπNo
1	61	46	15
2	60	46	14
3	60	45	15
4	57	47	10
5	61	55	8
6	62	53	9
7	61	45	16
8	61	51	10
9	63	47	16
10	55	45	10
11	57	49	8
12	60	48	12
13	62	47	15
14	60	47	13
15	54	46	8
16	62	53	9

As seen in Table 3.5 all subjects presented with MLD scores within the normal range, indicating normal binaural interaction. All subjects passed the MLD, possibly indicating that very few children present with lower brainstem difficulties in a mainstream school. As discussed previously, MLD are sensitive to lower brainstem dysfunction such as acoustic schwannomas (Bellis, 1996).

3.2 Central Auditory Processing Disorder as a Diagnosis

In its simplest form a behavioural audiological central auditory assessment should provide information regarding the presence or absence of a central auditory processing disorder (ASHA, 1996; Bellis, 1996).

The presence of CAPD can be established if one or more of the underlying auditory processes are disordered (ASHA, 1996; Bellis, 1996). The aim of a test battery is for each test to assess a different auditory process, hence if a subject performs poorly on a test then that specific auditory process can be identified as being disordered (Bellis, 1996). Therefore, if a subject presents with poor scores for one or more of the four CAPD tests, they can be considered to present with a CAPD (Chermak and Musiek, 1997). As stated previously, ASHA (1996) describes a CAPD as a deficit in one or more auditory process.

Furthermore, poor performance on one test needs to be combined with significant educational findings, to indicate the extent the CAPD has impacted on the child's ability to learn (Bellis, 1996).

Table 3.6 presents the diagnosis of CAPD for each subject.

Table 3.6 Presence of CAPD

Subject	SSW	PPS	NU-60%	MLD	Presence
1	Poor	Normal	Normal	Normal	**YES**
2	Poor	Poor	Normal	Normal	**YES**
3	Poor	Poor	Normal	Normal	**YES**
4	Poor	Poor	Poor	Normal	**YES**
5	Poor	Poor	Poor	Normal	**YES**
6	Poor	Poor	Normal	Normal	**YES**
7	Poor	Normal	Normal	Normal	**YES**
8	Poor	Normal	Poor	Normal	**YES**
9	Poor	Poor	Normal	Normal	**YES**
10	Poor	Normal	Normal	Normal	**YES**
11	Poor	Normal	Poor	Normal	**YES**
12	Poor	Poor	Poor	Normal	**YES**
13	Poor	Poor	Normal	Normal	**YES**
14	Poor	Normal	Poor	Normal	**YES**
15	Poor	Poor	Poor	Normal	**YES**
16	Poor	Poor	Normal	Normal	**YES**

All subjects performed poorly on the SSW and as discussed above and stated by Katz (1992) this appears to be a result of the sensitivity of this test. The SSW is a complex test to score and interpret and only the quantitative data was used in this study. Furthermore, there are different degrees of dysfunction on the SSW. Further interpretation of the test scores may provide information on the degree of difficulty experienced on the SSW. For the purpose of subprofiling, only a left peak, right peak or bilaterally poor scores needed to be shown.

All subjects passed the MLD test, which indicates that none of the subjects presented with lower brainstem regions of dysfunction as suggested by Bellis (1996).

3.3 Categorisation According to the Bellis/ Ferre Model

Identification of the presence of a CAPD is only the initial step. The most important step is to describe the disorder and determine how this disorder impacts on the child's ability to perform academically (Bellis, 1996). The use of subprofiles is helpful in determining the impact of a CAPD on a child's quality of life (Bellis, 1996).

As stated previously, Bellis (1999) highlights three primary CAPD subprofiles in the Bellis/Ferre model: Auditory Decoding Deficit, Prosodic Deficit and Integration Deficit. The secondary CAPD subprofiles are: Auditory Associative Deficit and Output-Organisation Deficit. Each subprofile presents a specific behavioural auditory central auditory finding that will allow for the classification of the subjects into these subprofiles.

The scores obtained on the SSW, PPS and NU 6 TC were analysed and used to categorise each subject into a subprofile. Scores from the MLD were not needed for classification into subprofiles as suggested by Bellis/Ferre model (Bellis, 2001).

Table 3.7 presents the expected test scores for each subprofile.

Table 3.7 Summary of Each Subprofile and Expected Test Results

		SSW	PPS	NU 6 TC
Primary Subprofiles	**Auditory Decoding Deficit**	Bilateral deficit	Normal	Bilateral deficit
	Prosodic Deficit	Left ear deficit	Deficit in both humming and labelling	Normal
	Integration Deficit	Left ear deficit	Deficit with labelling only	Normal
Secondary Subprofiles	**Auditory Associative Deficit**	Bilateral deficit	Normal	Normal
	Output / Organisation Deficit	Deficit on any task requiring report of more than two elements such as in SSW , PPS		Normal

In summary,

- Auditory Decoding Deficit: Bilateral deficits on the SSW and NU 6 TC would indicate that the subject presents with an Auditory Decoding Deficit as suggested by Bellis (1999).

- Prosodic Deficit: In this study, a left ear deficit would be shown on the SSW and poor performance for both humming and linguistic labelling would be expected on the PPS. This would indicate the presence of a Prosodic Deficit as suggested by Bellis (1999).

- Integration Deficit: A left-ear deficit on dichotic speech tasks, namely the SSW, combined with the poor performance on only the linguistic labelling condition of the PPS would indicate an Integration Deficit (Bellis, 1999).

- Auditory Associative Deficit : In this study, a bilateral deficit only on a dichotic listening task, namely the SSW, would indicate that the subject presents with an Auditory Associative Deficit as suggested by Bellis (1999).

- Output / Organisation Deficit : These subjects would show difficulty on a task that requires the report of more than one element, such as on the SSW, where two responses are needed for each test item. These subjects will not show any difficulty on a task that only requires the report of one element, such as monaural low-redundancy tasks (NU 6 TC) (Bellis, 1999). In this study, subjects presenting with only a left ear deficit on the SSW or PPS and normal scores on the NU 6 TC will be classified as presenting with an Output/Organisation Deficit as suggested by Bellis (1999).

Most of the subjects in this study could be subprofiled into the Bellis/Ferre model. The subprofile for each subject was determined by in depth analysis of their CAPD test scores.

The subjects, their test scores for the SSW, PPS and NU 6 TC and their related subprofiles are presented in Table 3.8.

Table 3.8 Classification into Subprofiles According to the Bellis/Ferre Model

Subject	SSW	PPS	NU 6 TC	Category
1	Left ear deficit	Normal	Normal	Output /Organisational Deficit
2	Left ear deficit	Labelling deficit	Normal	Integration Deficit
3	Left ear deficit	Labelling deficit	Normal	Integration deficit
4	Left ear deficit	Labelling deficit	Bilateral deficit	Mixed Integration and Auditory Decoding Deficit
5	Bilateral deficit	Labelling and hummed deficit	Bilateral deficit	Unclassified
6	Left ear deficit	Labelling and hummed deficit	Normal	Prosodic Deficit
7	Bilateral deficit	Normal	Normal	Auditory Associative Deficit
8	Bilateral deficit	Normal	Bilateral deficit	Auditory Decoding Deficit
9	Left ear deficit	Labelling deficit	Normal	Integration Deficit
10	Left ear deficit	Normal	Normal	Output/ Organisational deficit
11	Bilateral deficit	Normal	Bilateral deficit	Auditory Decoding Deficit
12	Left ear deficit	Labelling deficit	Bilateral deficit	Mixed Integration and Auditory Decoding Deficit
13	Left ear deficit	Labelling deficit	Normal	Integration Deficit
14	Bilateral deficit	Normal	Bilateral deficit	Auditory Decoding Deficit
15	Left ear deficit	Labelling and hummed deficit	Bilateral deficit	Unclassified
16	Left ear deficit	Labelling deficit	Normal	Integration Deficit

As seen in Table 3.8, the majority of subjects in this study could be classified into subprofiles according to the Bellis/Ferre model of CAPD (Bellis, 1999).

Subjects **8, 11** and **14** were categorised as presenting with an **Auditory Decoding Deficit**. These subjects presented with bilaterally poor scores for the NU 6 TC and a bilateral ear deficit on the SSW. They achieved normal scores on the PPS.

Subject **6** was classified as presenting with a **Prosodic Deficit.** This subject presented with a left ear deficit on the SSW and performed poorly on both the labelling response and hummed responses of the PPS. This subject achieved normal scores for the NU 6 TC.

Subjects **2, 3, 9, 13** and **16** presented with an **Integration Deficit**. These subjects performed poorly on the labelled response of the PPS but achieved normal scores on the hummed responses. They also presented with a left ear deficit for the SSW. Furthermore they achieved normal scores for the NU 6 TC.

Subject **7** presented with an **Auditory Associative Deficit** as he has a bilateral deficit on the dichotic listening task, namely the SSW. He achieved normal scores for the PPS and NU 6 TC.

Subject **1** and **10** were categorised as presenting with an **Output/ Organisation Deficit** as they obtained a left ear peak on the SSW. Subjects presenting with deficits on tasks requiring a report of two critical elements can be classified as presenting with an Output/ Organisation deficit (Bellis, 1999).

Subjects **4** and **12** presented with left ear deficit on the SSW, they failed the labelling response on the PPS and obtained a bilateral deficit on the NU 6 T. This indicates that they present with a mixed **Auditory Decoding Deficit and Integration Deficit** (Bellis, 2003, personal communication).

Subjects **5** and **15** could not be classified into a specific profile as they performed poorly across all three CAPD measures. This pattern of CAPD test scores does not allow for categorisation into a subprofile as described by Bellis (1999).

3.4 Relating Each Subject's Subprofile to their Associated Difficulties

Once the presence of a CAPD is established, the next important step is to relate all results back to the subjects speech and language and academic difficulties (Bellis, 1996). The following section presents each subject's profile and their academic, language and listening difficulties.

3.4.1 Auditory Decoding Deficit

The primary deficit of an Auditory Decoding Deficit is the inability to hear the acoustic signal correctly (Bellis, 2002). These children often ask for repetition as they display difficulty with listening in a noisy environment. They often appear to mishear what is said (Bellis, 1999). For example, the child with Auditory Decoding Deficit is similar to the child with a hearing loss in that many portions of the message are missing or heard incompletely or inaccurately.

An Auditory Decoding Deficit reduces a child's phonemic representation ability resulting in poor sound blending, poor analytic skills and auditory discrimination. A child with this subtype would present with poor phonological skills and their errors would be phonemically similar to the target (Bellis, 1996). For example the child would say dine instead of dime.

In addition, a child presenting with Auditory Decoding Deficit displays difficulty with reading especially when a phonetic approach is applied. Their speech to print skills will be affected due to poor phonemic representation resulting in poor spelling and written work (Bellis, 1996). Written work is affected as many of the words may be misspelled or the wrong words may be substituted because of the child's difficulty in hearing information clearly (Bellis, 2002). These children will often present with no arithmetic difficulties as no phonetic knowledge is needed (Bellis, 2001).

- **Subject 8 (12.8 years)**

Perusal of this subject's academic report indicated that he presents with poor phonetic spelling. He presents with weak reading, comprehension skills and poor written work. It was also reported that he is easily distracted in a noisy environment. Furthermore, speech and language reports also indicate weak auditory discrimination skills. The academic report indicated that arithmetic skills are average.

- **Subject 11 (8.9 years)**

Subject 11's academic report indicated weak spelling, reading and written skills. His class teacher indicated that he is easily distracted in the class especially when it was noisy. Poor auditory discrimination was noted during the assessment battery.

- **<u>Subject 14 (10.4 years)</u>**

His academic report indicated poor reading spelling and written work. His remedial teacher noted poor auditory discrimination skills and difficulty listening in noise. His class teacher reported that he has average arithmetic skills.

The academic difficulties, such as poor listening in noise, described for Subjects 8, 11 and 14 support the presence of an Auditory Decoding Deficit.

3.4.2 Prosodic Deficit

The child with Prosodic Deficit has a type of auditory difficulty that is not related to the clarity of the signal. Even under ideal listening conditions, these children still have problems understanding intent and extracting the key words from a message (Bellis, 2002).

The primary difficulty presenting in this deficit is the inability to judge communicative intent. These children often miss key words and have poor perception of prosody due to difficulty interpreting the suprasegmental aspects of speech (Bellis, 2001). These children miss humour and sarcasm, thus misinterpreting messages. These children may complain of hurt feelings (Bellis, 2001).

In addition, these children present with reading difficulties as they fail to pick up on the pattern and rely on phonological skills for reading and spelling. Their spelling, writing and use of symbolic language is also poor (Bellis, 2001)

Furthermore, these children may also present with poor social skills as they often have poor pragmatic skills (Bellis, 2001).

- **<u>Subject 6 (13.3 years)</u>**

The academic report indicated significantly poor written language and arithmetical skills. His speech therapy report stated that he presents with expressive language problems. He has difficulty creating stories and has poor verbal problem solving skills. His class teacher expressed her concern regarding his auditory processing skills. Furthermore the academic report states the school's concern regarding his poor social skills. These academic difficulties and his poor social skills support the presence of a Prosodic Deficit.

3.4.3 Integration Deficit

This subprofile is characterised by difficulty with tasks that require interhemispheric communication (Bellis, 1999). A child with this type of CAPD will experience difficulties integrating auditory and visual functions or integrating linguistic based auditory information with non-linguistic auditory information, such as rhythm and pattern perception (Bellis, 1996). They struggle with linking prosody with linguistic content.

Academically, these children may present with difficulties in reading, spelling and writing. These difficulties are not due to the inability to develop phonemic representation of the letters but rather the inability to recognise and utilise the gestalt patterns which is necessary in sight word reading and spelling (Bellis, 1996). Furthermore, tasks that require the use of symbolic language, such as arithmetic may be affected (Bellis, 1996).

Furthermore, the child with interhemispheric Integration Deficit has difficulty with many cross -modality skills, such as note-taking which, relies on listening and writing simultaneously. This is a task requiring both sides of the brain to work together effectively (Bellis, 1999).

As seen in this section, Subjects **2, 3, 9, 13** and **16** presented with an Integration Deficit. These subjects all presented with a left ear deficit on the SSW and failed the labelling response on the PPS. These scores should alert to difficulties with listening in noise, ignoring information from one source to focus on another and difficulty recognising and using prosodic features of speech. Bellis (1996) states those children with an Integration Deficit often present with a wide variety of behavioural auditory complaints. Discrimination abilities should remain intact as scores on the NU6 TC are not affected (Bellis, 2001).

- **Subject 2 (9.11 years)**

The academic report for Subject 2 indicated general language difficulties. His phonological awareness is generally good however he presented with rhyming problems and semantic difficulties were reported in his speech therapy report. The report indicated average auditory discrimination abilities. He also presented with weak reading and spelling skills. Listening in noise skills were noted to be average.

- **Subject 3 (12.6 years)**

This subject presented with poor reading and spelling skills and the academic report indicated significantly poor written work. He was described as an underachiever. His arithmetic skills were noted to be good. His teacher noted that he was very distracted by noise in the classroom environment and further reported poor auditory discrimination skills.

- **Subject 9 (12.6 years)**

This subject' s academic report indicated poor reading and spelling. His written work was poor due to decreased neatness as noted by his class teacher. His class teacher also highlighted his difficulty listening in a noisy environment.

- **Subject 13 (9.2 years)**

This subject generally presents with difficulties in all areas. His academic report indicates poor phonological skills, reading and writing skills. His arithmetic skills are also weak. Listening in noise was noted to affect his concentration.

- **Subject 16 (10.4 years)**

This subject was reported to have difficulty with his hearing although his peripheral hearing was within normal limits. He was reported to "mishear sounds". He presents with difficulty applying spelling rules in his creative work. He has a reading delay and his arithmetic skills are weak. His class teacher reported that he has poor planning and organisational skills.

The above subject descriptions support their scores in the assessment battery, especially the reported difficulty with listening in noise, which classifies them as presenting with a possible Integration Deficit.

3.4.4 Auditory Associative Deficit

For the child with an Associative Deficit, the primary issue is meaning rather than clarity. Even if the information is heard clearly, the child may be unable to understand the message (Bellis, 2002).

A feature of this deficit is the inability to apply the rules of language to incoming information (Bellis, 1996). The severe form of this deficit is known as a receptive childhood aphasia (Bellis, 1996). Children presenting with this deficit may exhibit receptive language deficits in vocabulary, semantics and syntax. In addition their pragmatic and social skills may be poor (Bellis, 1999). For many of these children early academic achievement appears to be age appropriate however, as demands in the classroom increase, general academic difficulties arise (Bellis, 2001).

These children present with bilaterally poor scores on the SSW. These children would also present with difficulties listening in a noisy environment.

- **Subject 7 (13.6 years)**

Subject 7 presents with poor spelling skills. His academic report further indicates very weak reading and written work. He has received receptive language therapy in the past. His class teacher reported that he is highly distracted in the class environment possible due to auditory stimuli. The academic report indicated extreme concern regarding his social skills at school.

Subject 7 presents with associated academic difficulties that support the presence of an Auditory Associative Deficit.

3.4.5 Output /Organisation Deficit

This deficit is apparent in the inability to sequence, plan and organise responses. These children generally exhibit good auditory skills however, the difficulties lies in the ability to act upon incoming auditory information (Bellis, 1996). As previously stated, these children perform poorly on a task that requires the report of two or more critical elements. Performance is poor on the PPS and SSW, as these tasks require the report of more than two elements. (Bellis, 1999).

Academically, these children demonstrate poor organisational skills and have difficulty following instructions. Their reading is generally good, however spelling and writing skills are poor due to the multi-element nature of these tasks (Bellis, 1999).

Subjects 1 and 10 are categorised in this subprofile. They presented with a left ear deficit on the SSW.

- **Subject 1 (10.0 years)**

This subject's teacher describes his primary difficulty as his inability to organise tasks and appears to be forgetful. His written work is poor, however his reading, spelling and arithmetical skills are generally average. Furthermore, his class teacher complained that he does not seem to listen and he is easily distracted by auditory stimuli.

- **<u>Subject 10 (13.4 years)</u>**

Subject 10's class teacher reports that he struggles with following instructions. His academic report indicates very poor spelling and written work, however his arithmetic skills are average. His class teacher also indicated that he has difficulty putting his thoughts onto paper. It was further noted that he has difficulty with listening in noise. In addition, his academic reports reflect a difficulty with task organisation.

Subjects 1 and 10 both present with listening difficulties especially in noise, and both have been described as having difficulty with organisation of various tasks. These difficulties support the presence of an Output/Organisation Deficit.

As seen above some of the associated difficulties of each subprofile overlap, namely difficulties listening in noise or reading and spelling difficulties. Listening in noise appears to be a general difficulty that is experienced by subjects presenting with most of the subprofiles,

Furthermore, spelling and reading difficulties are noted for all subprofiles, however the underlying cause differs between each subprofile. For example spelling and reading problems noted in an Auditory Decoding Deficit are a result of difficulty with phonemic representation. Whereas spelling and reading difficulties that are noted in an Integration Deficit are related to the inability to recognise and use gestalt patterns necessary for such skills (Bellis, 1999).

3.5 Mixed Subprofiles

Bellis (2003, personal communication) states that not all subjects fit into one single subprofile and subprofiles may exist in combination. The subjects described below are seen to be presenting with assessment scores indicting more than one region of dysfunction. These subjects present with a mixed subprofile and can be defined into more than one subprofile.

- **Subject 4 (9.8 years)**

This subject presented with a left ear deficit on the SSW and failed the linguistic labelling response for the PPS. These scores indicate an **Integration Deficit**. While bilaterally poor scores on the NU 6 TC indicate an **Auditory Decoding Deficit**. This subject presents with a mixed subprofile of CAPD.

Subject 4 presents with general language difficulties. He has repeated a grade, indicating the severity of his difficulties. His class teacher described weak spelling, reading, written work and arithmetic skills. His remedial therapist reported that he also presents with auditory memory difficulties and auditory discrimination difficulties. Furthermore, he struggles with listening in the class environment.

- **Subject 12 (8.3 years)**

This subject obtained a left ear deficit on the SSW and he only failed the labelling response on the PPS. These scores classify him with an **Integration Deficit**. Bilaterally poor scores on the

NU 6 TC also indicate an **Auditory Decoding Deficit**. This subject presents with a mixed subprofile of CAPD.

This subject's teacher reported generally weak language and learning abilities, especially poor reading and spelling skills. According to his speech and language report he also presents with very weak auditory discrimination skills.

3.6 Unclassified Subjects

A child who exhibits difficulties across all assessment tasks argues for a more global deficit rather than a CAPD. Subject 5 and 15 presented with poor scores across all tests and this pattern of scores does not allow forsubprofiling, but may rather suggest a more global deficit (Bellis, 2003, personal communication). CAPD may co-exist with more global dysfunction that affects performance across modalities, such as an attention deficit disorder and learning disabilities (Chermak et al., 1999).

- **Subject 5 (11.9 years)**

This subject presented with bilaterally poor scores for the SSW and bilaterally poor scores obtained on the NU 6 TC. He presented with poor scores for the labelling and hummed responses for the PPS. These test scores do not allow for classification into the Bellis/Ferre model and suggest a more global delay.

Subject 12 repeated Grade 1. His class teacher reported generally poor progress in all areas, particularly very weak comprehension skills. Auditory discrimination difficulties were also reported.

- **Subject 15 (9.8 years)**

This subject presented with a left ear deficit on the SSW and he presented with poor scores for the labelling and hummed responses on the PPS. He further obtained bilaterally poor scores on the NU 6 TC. These scores do not allow for classification into the Bellis/Ferre model and may also suggest a more global delay.

Subject 15 presents with poor listening in noise skills. His academic report indicated generally poor progress regarding his reading, spelling and arithmetic skills. Poor phonological skills and auditory discrimination skills were also reported.

The reason that these subjects present with a global delay is unknown. A possible explanation could be an underlying attention deficit disorder or a possible learning difficulty. Furthermore, poor memory skills may also account for the suspected global delay. The relationship between these deficits and auditory processing is complex, hence a brief discussion is undertaken.

The CANS is critical to auditory functions such as processing of spoken language and complex signals. The simplest auditory task may be influenced by higher level factors such as attention, memory, learning and motivation (ASHA, 1996 ; Silman, Silverman and Emmer, 2000). When the pathology of the CANS is clear it is easier to presume that the neuropathology is responsible for the observed CAPD (ASHA, 1996). However, the relationship with pathologies such as ADD/ADHD or language disabilities is more complex as the CANS pathology is uncertain, thus the relationship between CAPD and co-existing disorders is unclear and not well understood (ASHA, 1996, Bellis, 1996).

Children diagnosed with ADHD often show difficulty performing tasks that assess the central auditory nervous system (Chermak et al., 1999). As stated previously, numerous studies have investigated the complex nature of ADHD and CAPD, thus highlighting the complexity of this area.

CAPD deficits are also characteristic in children with learning disabilities. Gomez and Condon (1999) found that children with ADHD and LD performed much poorer on CAPD tests than subjects presenting with only an ADHD. This implies that CAPD may be associated with LD rather than with ADHD.

Memory is also crucial in auditory processing as it provides the knowledge of a previous sound, which can be matched against the new stimulus (Baddeley, 1986; Wirz, 1995). Fully developed auditory memory skills are vital to learning and learning success. The child with CAPD may exhibit underdeveloped short-term memory skills (Page, 1985).

Although subjects presenting with ADHD/ADD were attempted to be excluded from this study, Subject 5 and 15 may present with subtle attention deficits. It is also possible that Subject 5 and 15 present with auditory memory deficits or learning disabilities that may account for their global delay.

3.7 Management Strategies as Suggested by Bellis (2001)

The primary aim of sub-profiling CAPD is to provide intervention recommendations that will allow for individualised CAPD management (Bellis, 1999). CAPD management needs to be comprehensive and it should integrate specific skills and provide general problem solving skills (Chermak and Musiek, 1992). Furthermore, like the assessment of CAPD, management should be multidisciplinary in nature (Bellis, 2001).

Management of CAPD should involve three principles: environmental modifications, remediation (direct therapy) techniques, and compensatory strategies. The management should be deficit- specific and be devised specifically for the individual with CAPD and the unique circumstances of their learning or communicative difficulties (Bellis, 2002). In addition, CAPD management should focus on changing the environment, remediating the disorder and improving the individual's learning and listening skills (Bellis, 1996).

Environmental modifications consist of changing the learning environment so that access to verbally presented information is maximised (Bellis, 2002). This can be achieved through reduction of noise, changing seating in the class room, consideration of assisstive listening devices, pre-teaching new information or vocabulary, frequent checks of understanding and the repetition or rephrasing of instructions (Bellis, 2001).

Remediation or direct therapy techniques should be challenging and should focus on the auditory deficit itself. This aims to train specific auditory and listening skills and change the way the brain processes auditory information (Bellis, 2002).

Some examples of direct therapy techniques are as follows:

- Auditory closure activities aim to help the child fill in missing components of the acoustic message. Such exercises include improving listening skills in noise, missing word, syllable and phoneme exercises (Bellis, 2001).
- Phoneme training aims to develop accurate phoneme discrimination and improve phonological awareness skills. Such tasks include minimal pair discrimination, vowel training and segmentation and blending of phonemes (Bellis, 2001).
- Prosody training aims to aid recognition and use of prosodic aspects of speech especially intonation, rhythm and stress. Examples include non-verbal cues, key word extraction and reading aloud with exaggerated prosodic features (Bellis, 2001).
- Temporal patterning training aims to aid in discrimination of the differences of auditory stimuli. This includes detection of differences in speed, loudness and rhythm (Bellis, 2001).
- Interhemispheric exercises aim to stimulate the corpus callosum and improve interhemispheric transfer of information. Such exercises include verbal to motor transfer activities namely: music activities, art and pattern recognition activities (Bellis, 2001).

Compensation strategies are important as the person will continue to experience symptoms of their disorder even after remediation (Bellis, 2002). Active listening is an important strategy as a child should be taught to become an active listener rather than only being a passive listener. The child needs to become responsible for their own listening comprehension and use strategies to ensure they understand verbal instructions. In addition, metalinguistics such as discourse cohesive devices and metamemory tasks such as chunking and paraphrasing are important (Bellis, 2001).

Table 3.9 presents some suggested management strategies for each subprofile (Bellis, 1999, 2001). Subjects 4 and 12 would benefit from remediation strategies for both the Auditory Decoding Deficit and Integration Deficit as they present with this mixed subprofile.

Subjects 5 and 15 presented with a possible global delay and would need further investigation to determine whether there is an additional underlying deficit, such as an ADHD/ADD or learning disability. These subjects also performed poorly across three CAPD tests and would possibly benefit from training aimed at improving their individual CAPD difficulty.

The following Table 3.9 presents some management strategies for each subject, as suggested by Bellis (1999).

Table 3.9 Suggested Management Strategies for each Subtype of CAPD (Bellis, 1999)

Subj. No.	Subprofile	Environment	Remediation	Compensatory Strategies
8, 11, 14	**Auditory Decoding Deficit**	Preferential seating, Auditory training, Repetition	Phoneme training, Auditory closure activities	Identification of adverse listening situations
6	**Prosodic Deficit**	Placement with animated teacher	Prosody training	Key word extraction
2, 3, 9 13, 16	**Integration Deficit**	Reduce use of multi-modality cues	Intehemispheric activities	Avoid division of attention

7	**Associative Deficit**	Pre-teach new information, Rephrase in smaller linguistic units	Receptive speech and language therapy	Memory tasks, Verbal rehearsal, Chunking, Organisational aids
1, 10	**Output-Organisation Deficit**	Pre-teach new information, Rephrase	Expressive speech and language therapy	Memory tasks, Organisational aids

This chapter presented the findings of the behavioural, audiological central auditory processing test battery, which allowed for the diagnosis of each subject's suspected CAPD.

Furthermore, twelve out of the sixteen subjects were easily subprofiled into the Bellis/ Ferre model according to their test scores on the SSW, PPS and NU 6 TC. These subjects' academic difficulties were related to the findings of each subprofile and similarities were noted.

Two subjects, presented with a mixed subprofile, namely an Auditory Decoding Deficit and an Integration Deficit.

Finally, two subjects could not be classified according to the Bellis/Ferre model as they performed poorly across all three measures used to assess CAPD. It is suspected that a more global deficit is present.

In the following chapter, a more general discussion of CAPD and the clinical implications of this study are presented.

4. GENERAL DISCUSSION AND CONCLUSION

"The act of hearing does not end with the mere detection of an acoustic stimulus."

Bellis (1996 pg. 31)

The findings of this study clinically support the use of behavioural audiological testing in the area of CAPD in South Africa particularly for the purpose of diagnosing, subprofiling and providing more deficit specific management strategies.

The test battery selected in this study has shown to be effective in the diagnosis and categorisation of CAPD into subprofiles suggested by Bellis (1999). A test was selected from each of the categories highlighted by ASHA (1996), namely dichotic listening , monaural low redundancy, temporal processing and binaural interaction. In addition, Bellis (1999) states that only a dichotic test, temporal processing test and monaural low redundancy tests are needed when subprofiling CAPD.

The following tests were selected according to their availability in South Africa. Dichotic listening was measured by the Staggered Spondaic Word Test (SSW), temporal processing was assessed by the Pitch Pattern Sequence Test, monaural low redundancy was measured by the NorthWestern University Word List, time compressed to 60%. The binaural interaction test, Masking Level Difference, which has been shown to be effective for identifying lower brainstem dysfunction, was not needed for subprofiling according to Bellis (1999). However, the MLD was still employed in the test battery to exclude lower brainstem dysfunction in each subject.

Although the scoring for the SSW is highly complex, the audiological data gained from scores on the SSW was felt to be useful in diagnosing CAPD. The inclusion of the PPS and NU 6 TC was felt to be effective as the administration and interpretation of scores obtained on these tests is fairly straightforward. In summary, the tests selected for the behavioural audiological CAPD battery adopted in this study were felt to be effective as clear patterns were easily indicated, allowing for subprofiling of each subject's CAPD.

Bellis (2001) states that it is useful to include two dichotic tests in a CAPD test battery. One test can to be heavily linguistically loaded, such as the SSW, whereas the other dichotic test can have a lighter linguistic load, such as the dichotic digits test. This will improve test reliability as children may perform differently on tasks with different degrees on linguistic load. In addition, the inclusion of a speech in noise test may have been useful for subprofiling each subjects CAPD as it is a common difficulty seen in most of the subprofiles described by Bellis (199).

The findings in this study highlight the role of the audiologist and the important role they may play in the diagnosis of CAPD. Typically, the audiologist has the practical and theoretical knowledge needed to administer and interpret the behavioural audiological CAPD test battery (ASHA, 1996).

The role of the speech-language pathologist is to provide measures of the individual's speech, language abilities and communicative function, which may assist in the differential diagnosis of a CAPD (Chermak and Musiek, 1997). This enforces the need for collaboration across disciplines as the speech-language pathologist plays an important role in the diagnosis and remediation of a CAPD (ASHA ,1996). However, speech and language measures do not provide information about the underlying auditory processing deficits of CAPD (Bellis, 2001). It is important to identify these deficits as it will allow for deficit specific management to be provided, which is vital in the correct management of children with CAPD. Hence, collaborative assessment including test batteries conducted by both audiologists and speech pathologists should be sought wherever possible.

A team approach to is the best practise to ensure a holistic approach to the assessment and management of CAPD (ASHA, 1996; Bellis 2001). The integration of academic performance, auditory behaviour, performance on CAPD tests and language abilities are crucial to the diagnosis and management of CAPD (Chermak and Musiek , 1997). Speech-language pathologists, psychologists, audiologists, social workers, teachers and parents may all be involved in the individuals overall care however, the extent of each members involvement depends on the nature of the disorder (Bellis, 1996).

The role of the educator is important as they identify the difficulties presenting in the classroom. It is becoming more widely known that central auditory processing disorders may be the cause of many cases of classroom difficulties (Katz et al., 1992; Silman et al., 2000).

In summary, subprofiling and identifying the underlying auditory processing deficits is believed to be an integral and critical part of CAPD assessment. The subprofiles in themselves are the link between speech and language measures and behavioural auditory CAPD measures as they assist in the interpretation of the assessment results obtained by speech and language pathologists. The subprofiles relate the speech and language difficulties to the underlying disordered auditory process and furthermore relate the disordered auditory processes to academic performance in the classroom. In addition, the subprofiles provide clearer guidelines for remediation.

The clinical applicability of an assessment similar to the one adopted in this study raises numerous questions.

At present very few formal behavioural, audiological measures of CAPD are being used in a clinical context in South Africa (Campbell, 2003, personal communication). A small number of practitioners may be using CAPD tests in their clinics, however there is no clarity on the type of assessment battery or management strategies to use.

At present the equipment required for behavioural, audiological CAPD testing is restricted primarily to tertiary hospitals and Audiology Departments at universities in South Africa. This obviously limits the accessibility of a comprehensive assessment battery to the majority of the population. Furthermore, theory relating to the assessment and management of CAPD is taught to the undergraduate audiological students at tertiary universities. However, these universities rarely provided clinical practise for their students. Students need to be taught to be clinically competent in the administration of behavioural, audiological CAPD tests.

University educators are starting to recognise central auditory processing disorders as a core disability area and according to Campbell (2003, personal communication) are aiming to develop clinical experience and skills in this field, towards the end of 2003.

It could be argued that although the CAPD assessment battery used in this study may be lengthy, in the long term providing the correct management would increase the efficacy of therapy and in turn be more cost effective. Furthermore with a direct management plan, therapy could be given to teachers or listening and language teachers to employ in the classroom, thus increasing the accessibility of management to children with CAPD in communities where speech-language therapists are not easily available. This increases the number of people who can deliver this service to children diagnosed with CAPD, and not limit service delivery to specialised professionals.

Due to the limited use of behavioural audiological CAPD testing in South Africa many children with a suspected CAPD that has not been formally diagnosed may or may not be receiving the appropriate therapy. Those who are fortunate enough to be receiving therapy may not be receiving the correct management aimed at treating the underlying auditory processing deficit. Those who are undiagnosed may be in an environment that is preventing learning success and are not reaching their full academic potential. As shown in this study, the Bellis/ Ferre model provides management strategies that are mostly different to traditional speech and language management strategies.

4.1 Conclusion

In conclusion, this study set out to select a test battery for diagnosing CAPD and furthermore to determine whether the selected behavioural audiological CAPD test battery could in fact diagnose CAPD. The findings in this study revealed that by using the selected behavioural audiological CAPD test battery all subjects could be diagnosed with CAPD.

Furthermore, this study aimed to subprofile each subject's CAPD into the Bellis/Ferre model. The findings in this study also indicated that the selected test battery allowed twelve out of sixteen subject's CAPD to be subprofiled according to the Bellis/Ferre model. Two out of the sixteen subjects were classified as presenting with a mixed subprofile. In addition, two subjects could not be subprofiled as they presented with scores that may indicate a global delay. The possible role of deficits in cognitive processes involving attention, memory and learning within a more global delay would be suggested. The complex nature of the relationship of these disorders is well recognised.

Once CAPD subprofiles were determined for each subject, their subprofiles were related to their respective academic and language difficulties. A number of similarities were noted for each subject. In addition, using the Bellis/Ferre profiles, management strategies were provided based on Bellis (1999) management guidelines. As was shown, once subprofiles were determined, the management strategies were more clearly defined for each subject.

The findings in this study highlight the importance of including a behavioural audiological CAPD test battery in the diagnosis, assessment and management of CAPD. Furthermore, these findings outline the crucial information these tests provide regarding underlying auditory processing deficits, which impact on language and learning skills and manifest in academic difficulties in the classroom.

It is believed that a limitation of this study was that although an attempt was made to exclude subjects presenting with general ADD/ADHD, more stringent pre-assessment for ADD /ADHD needs to be conducted in order to determine whether the subject presents with such a disorder. Hence this may have accounted for two of the subjects in this study, who were unable to be subprofiled. The co-morbidity of ADD/ADHD and other cognitive deficits, such as learning and memory difficulties are well acknowledged.

This study obviously has numerous clinical implications and as discussed previously it is strongly believed that there is a dire need to address the assessment and management of CAPD in children with academic, language and learning difficulties in a comprehensive and systematic fashion. For too long, clinicians working with children in CAPD have not included a comprehensive approach to assessment and management of CAPD and have mostly relied on speech and language measures alone. While speech language measures provide valid information on the impact of CAPD, however they do not provide information on the underlying auditory processing deficit. This study shows that the Bellis/Ferre model is a link between professionals working in the filed of CAPD, as it links speech and language difficulties and academic difficulties with underlying auditory processing deficits.

Therefore, it is hoped that the use of subprofiling and the use of models such as Bellis/ Ferre model will be adopted more widely in South Africa. Universities and tertiary hospitals can play a larger role in the assessment and management of CAPD. However the challenge to meet the greater community of children with CAPD still needs to be met. The limited access to these services obviously still needs to be addressed.

This study has important clinical implications for clinicians practicing in South Africa. It shows that a minimal behavioural audiological CAPD assessment battery allows for diagnosis and subprofiling CAPD and furthermore suggests clear and appropriate management strategies.

Two clear future research implications have emerged from this study:

- The inclusion of an ADD/ADHD assessment in the test battery used in this study. This will provide a more comprehensive means of excluding subjects with general or modality specific ADD/ADHD.
- Piloting the implementation of therapy activities in the classroom and assessment of whether this is a viable means of managing children with CAPD in the community may be explored.

> *"If the true nature of this disorder is not known then it is difficult to make useful recommendations for effective remediation."*
>
> Cacace and McFarland, 1998

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