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PERFORMANCE OF MUSICIANS AND NON-MUSICIANS, ON A BATTERY OF AUDIOLOGICAL CENTRAL AUDITORY PROCESSING TESTS: A COMPARATIVE STUDY

A REPORT ON A STUDY PRESENTED TO THE DEPARTMENT OF LOGOPAEDICS.

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ABSTRACT

'[T]his area of habilitation... ...the management of individuals with central auditory processing disorders... ...is indeed in its infancy and much clinical and research work remains to be done before any definitive statements regarding the efficacy of many of these procedures can be made' (Musiek, Baran and Schochat, 1999, 63).

The researcher did not seek to determine the efficacy of specific training programmes in the treatment of central auditory processing disorders. An analytic research design was adopted - using a cohort study - to provide objective evidence of the *potential role of musical training*, in the development of a variety of central auditory processes fundamental to the perception of speech and language. A more specific focus of the research was to determine whether 15 '*normal' adult listeners*, with a range of musical training (experimental group), would perform better on a *battery of central auditory processing tasks*, compared to 15 non-musicians (control group). Broadly, the researcher sought to determine whether exposure to listening tasks involving musical stimuli, was associated with improved performance on a variety of verbal and non-verbal auditory processing tasks. These central auditory processing tasks included: a two pair dichotic digit test, CVC Binaural Fusion test, Speech Masking Level Difference test, low pass filtered speech test, 45% Time Compressed Speech test, frequency pattern test, and duration pattern test (RSA CAPD Taskforce, Disc 1, 2001). It was thought that the findings of such research would form an objective foundation for future research into the development of music therapy programmes for individuals with deficits in the processing of verbal stimuli.

Following administration of the battery of central auditory processing tasks, significant differences in performance were found to exist - for tasks involving binaural fusion and auditory closure of verbal stimuli, as well as interhemispheric integration involving verbal labelling of non-verbal auditory stimuli - between the experimental group and control group. For these specific tasks, the experimental group performed better than the control group, furthermore, for all tasks the scores in the control group were generally more variable than those in the experimental group. These differences did not depend upon the years of training, age at start of training or the gender of the subject.

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1. INTRODUCTION

The following chapter seeks to define the nature of central auditory **processes**, the various tools used to assess these processes, as well as to provide an understanding of the nature and effects of central auditory processing disorders (CAPDs). A rationale for improved CAPD interventions will be established through a discussion of the multiple difficulties arising from this disorder. Finally, the researcher will outline previous recommendations for the use of music therapy in remediation of CAPDs, as well as past studies seeking to determine the effects of music training on the central auditory pathways. These studies will provide a foundation for the current research aim: To determine whether adult listeners with a range of musical training, perform better on a battery of central auditory processing tasks, compared to non-musicians.

1.1 DEFINING THE PROCESSES

Bellis (1996), defines the following central auditory processes, which may be used during the analysis of verbal and/or non-verbal stimuli:

- '**Auditory closure** refers to the ability of the normal listener to utilize intrinsic and extrinsic redundancy to fill in missing or distorted portions of the auditory signal and recognize the whole message' (Bellis, 1996, 173). For example, a listener may use auditory closure to fill in missing words, in a sentence which has been distorted by background noise.
- '**Auditory decoding** refers to deciphering the components of an auditory message' (Bellis, 1996, 173). Thus a listener may use auditory decoding to identify component words in a sentence, or component phonemes in a word.
- '**Binaural separation** refers to the ability of a listener to process an auditory message coming into one ear while ignoring a disparate message being presented to the opposite ear at the same time' (Bellis, 1996, 176). For example, an individual may wish to ignore background voices on the television while listening to someone on the telephone.
- '**Binaural integration** refers to 'the ability of a listener to process information being presented to both ears simultaneously, with the information presented to each ear being

different' (Bellis, 1996, 176). In this case, the individual may wish to watch his/her favourite television program while listening to someone on the phone.

- **Temporal patterning** 'refers to a listener's ability to recognize acoustic contours' (Bellis, 1996; 178). This process depends on a person's ability to 'discriminate differences' and sequence auditory signals. It also makes use or 'gestalt perception, and trace memory' (Bellis, 1996, 178). Temporal patterning affects one's ability to comprehend and produce 'prosodic aspects of speech, such as rhythm, stress, and intonation' (Bellis, 1996, 178).
- **Binaural interaction** underlies 'localization and lateralization of auditory stimuli, binaural release from masking, detection of signals in noise, and binaural fusion' (Bellis, 1996, 179). The primary function of binaural interaction is to allow the listener to detect specific auditory stimuli in background noise (Bellis, 1996).

In normally functioning individuals, the above processes interact with each other during the perception and analysis of auditory signals. The nature of this complex interaction has been and continues to be debated.

1.2 AN OVERVIEW OF CENTRAL AUDITORY PROCESSING

On entering the auditory system, sound stimuli are transformed into patterned electrical signals, which are then passed up the brainstem, to the cortex (Chermak & Musiek, 1997). A number of models have been proposed for the way in which information is transferred and analysed, at various levels within the central auditory system (CANS). Recently emphasis has shifted to a **'network' model**, involving both **serial and parallel processing** mediated by several anatomical structures, as well as physiological processes, within the brain (ASHA, 1996; Undgerleider, 1995; in Chermak & Musiek, 1997). Identification and interpretation, of auditory stimuli, is facilitated by the combined operations of **bottom-up processing** (identifying component parts of the signal as they enter the auditory system) and **top-down processing** (using context to facilitate recognition and understanding of component parts), with different weighting dependant on the nature of the listening condition (Churchland & Sejnowski, 1988; Elman, 1989, 1993; Elman & McClelland, 1986; Massaro, 1987; McClelland & Elman, 1986; in Chermak & Musiek, 1997). **Executive functions** refer specifically to those top-down processes which allow an individual to actively adapt to incoming stimuli in order to meet specific goals which are beneficial to that person (Borkowski, Milstead, & Hale, 1988; Brown, Bransford, Ferara, & Campione, 1983; Denckla, 1996; Sternberg, 1985; Torgesen, 1996; in Chermak & Musiek, 1997). These processes are fundamental to problem solving and learning (Borkowski & Burke, 1996; Welsh & Pennington, 1988; in Chermak & Musiek, 1997), as well as the development of pragmatic and metacognitive aspects of language (Westby & Cutler, 1994 in Chermak & Musiek, 1997). Executive functions involve parallel processing across a number of structures and place large demands on **memory and attention**.

This model of bottom-up and top-down processing requires the active participation of the individual, in all listening activities. It implies that a lack of such active participation may lead to serious breakdowns in the construction of meaning from auditory input (Chermak & Musiek, 1997).

1.3 PROCESSING OF AUDITORY-VERBAL STIMULI

Processing of speech signals may be the most complex and demanding task fulfilled by the peripheral and central auditory system. In addition, processing of real-time spoken language may be different to that involved in written language and reading, suggesting that these processing mechanisms may be modality specific (Craig, 1997).

Real-time speech recognition refers to the processing of rapidly changing speech signals, and relies upon the implementation of highly sophisticated temporal processing skills (bottom-up processing). However, the presence of linguistic-contextual cues aids recognition, and may even allow for identification of words before all the acoustic-phonetic features have been perceived (through top-down processing). The type of speech recognition processing thus changes depending upon the level of linguistic-contextual information, i.e. words versus sentences (Craig, 1997).

Models of spoken language processing incorporate several phases (Craig, 1997):

1) Perceptual encoding of auditory stimuli
2) Complex analysis of the signal, allowing for recognition of patterns.
3) The matching of recognised patterns to internal representations (lexical access).
4) Deriving meaning from sequences of linguistic representations.
5) Determining the overall message from these sequences.

1.3.1 Word Recognition Based Primarily On The Cohort Model
by (Marslen-Wilson, 1978; Marslen-Wilson & Welsh, 1978; Slowiaczek, Nusbaum, & Pisoni, 1987; in Craig, 1997, 78)

The Cohort model described by Craig (1997), was developed solely from observations of behavioural performance. It may provide a satisfactory explanation for real-time spoken language processes, and may be used as a solid theoretical foundation for compiling and understanding the nature of different assessment procedures as well as planning future remediation (Craig, 1997).

- The acoustic-phonetic characteristics of an input stimulus are matched with internal representations of the phoneme, syllable and/or phonological word forms. The activation level of perceptual representations may vary according to factors such as the stimulus, listener and listening environment (Warren, 1981 in Craig, 1997). A cohort of representational candidates is simultaneously selected, and activated. In the case of word representations, activation is based primarily on the initial sounds of the input stimulus (Craig, 1997).
- Certain models of lexical access, propose that lexical candidates are stored in memory in a similarly segmented fashion (based on a hierarchy of language structures) (Craig, 1997).
- With the addition of each new representation, a higher-level conceptual representation is assembled. The lexical, semantic and syntactic information, contained within and across representations, is accessed.
- Top-down processing (based on conceptual representations), in conjunction with bottom-up processing, is used to narrow down the cohort of word candidates, and reassign word

activation levels. Top-down processing involves the application of linguistic contextual cues to aid word recognition. The more linguistic-contextual information is available, the more the acoustic-phonetic characteristics of a signal may be disrupted before a listener becomes unable to locate a target representation (Craig, 1997). Code (1987), proposed that bottom-up language processing occurs primarily in the left-hemisphere, while top-down language processing (involving semantic and conceptual information) occurs primarily in the right hemisphere.

- The word representation with the highest level of activation will be accepted. The level of confidence, with which a listener accepts a word, may vary according to the nature of the stimuli and linguistic-contextual factors.

There are thus a number of processes which may be involved in the processing of auditory stimuli: specific central auditory processes (Bellis, 1996), top-down processing (including executive processing), and bottom-up processing. *Are these processes similar for all complex auditory stimuli? Does the processing of speech require processes, or models of processing, similar to those required for the perception of music?*

To answer these questions, one must first identify valid and reliable assessment procedures, which are able to assess such processes.

1.4 ASSESSING CENTRAL AUDITORY PROCESSES

In October 1999, a group of leading South African audiologists and speech-language pathologists convened to address issues concerning the assessment and remediation of central auditory processing disorders (CAPDs), within a specifically South African context. The primary concern, of this convention, was the need to develop or compile a battery of assessment procedures which would increase understanding regarding the interaction between learning difficulties and central auditory processing disorders; guiding compensatory or therapeutic intervention. In order to fulfil the primary objective, the convention assembled what is now referred to as the RSA CAPD Taskforce (Campbell & Wilson, 2000).

As a foundation for future research, the convention laid out a framework for the compilation of a central auditory processing test battery which incorporated all phases of the referral and assessment procedure, from initial screening to final diagnostic testing (including both behavioural and electrophysiological measures) (in Campbell & Wilson, 1999):

1.4.1 Assessment Framework

- **Initial Screening**

Use of teacher and parent checklists to identify possible auditory difficulties. Suggested Checklists included Fisher's Auditory Problems checklist, and the CHAPPS (Children's Auditory Processing Performance Scale) (Smoski, 1987 in Campbell & Wilson, 1999). Children identified in this phase were to be referred for secondary screening (Campbell & Wilson, 1999).

- **Secondary Screening**

Secondary screening involves the administration of behavioural auditory processing tasks, specifically designed for screening purposes. Suggested tasks included the SCAN (Screening Test for Auditory Processing Disorders), SCAN-A (SCAN for Adolescents) or SAAT (Selective Auditory Attention Test). Children identified in this phase were to be referred for full diagnostic testing (Campbell & Wilson, 1999).

- **Diagnostic Testing**

Both behavioural and electrophysiological test procedures were recommended for the diagnostic phase of testing.

1 Behavioural Testing

It was suggested that one test be selected to represent each of the following processing categories:

- Dichotic tasks (both linguistically loaded and non-linguistically loaded tasks)
- Temporal Ordering
- Monaural low-redundancy
- Binaural fusion

2 Electrophysiological Testing

Auditory Brainstem response, Middle Latency Response, Late Response Evoked Potentials (P300), Mismatched Negativity Response, and Otoacoustic Emmissions were recommended as part of the electrphysiological assessment.
(Campbell & Wilson, 1999)

Based on the above framework, the RSA CAPD Taskforce assembled a battery of *behavioural diagnostic* central auditory processing tests using low linguistically loaded materials from the *Tonal and Speech Materials for Auditory Perceptual Assessment, Disc 2.0 compact audio disc (1998)* (RSA CAPD Taskforce, 2001). With permission, materials were re-recorded onto a new compact disc (RSA CAPD Taskforce Disc 1 – 2001), which has since been made available for purposes of South African-based research (RSA CAPD Taskforce, 2001).

The Taskforce disc materials, although originally developed in the United States, allow for assessment of all the primary central auditory processes described by Bellis (1996) (see section 1.1), and may 'provide a basis from which to work within the RSA', prior to development of RSA specific test material (RSA CAPD Taskforce, 2001, 3). The following is a list of assembled test procedures and the central auditory processes, which they were designed to assess:

- *Two pair dichotic digit test*: Binaural integration
- *Frequency pattern test* and *Duration pattern test*: Temporal ordering
- *Low pass filtered speech test* and *45% Time compressed speech*: Auditory closure
- *Speech Masking Level Difference test*: Binaural interaction
- *CVC binaural fusion test*: Binaural fusion

(RSA CAPD Taskforce, 2001)

Why is it important to assess and understand the relationship between various central auditory processes, and the variables which affect them? This question requires an in-depth consideration of the nature of central auditory processing disorders, and their wide-reaching effects.

1.5 CENTRAL AUDITORY PROCESSING DISORDERS – A RATIONALE FOR IMPROVED INTERVENTIONS

1.5.1 Defining the Disorders

For the past twenty years, the true nature of central auditory processing disorder (CAPD) has remained elusive to the fields of audiology and speech-language pathology. Many studies have sought to clarify aspects of this seemingly immeasurable disorder, but with varying degrees of success (Chermak & Musiek, 1997). Consequently, an all-encompassing, yet sufficiently specific, definition of CAPD has yet to be developed, or verified, through well-developed and theoretically grounded assessment protocols. Nevertheless, ASHA (1996) used a **'process' orientated approach** - similar to that described by Bellis (1996) (see section 1.1) - to define CAPD as a 'deficiency in one or more of the following: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects (resolution, masking, integration, ordering) of audition; and auditory performance decrements with competing and degraded acoustic sounds' (Gomez & Condon, 1999, 150).

The involvement and interaction of several complex processes (see section 1.2) - with information processing occurring across a many different regions in the brain - allows for the co-existence of CAPD with a variety of other disorders, including **developmental language disorder, learning disabilities (LD), and attention deficit disorder (ADD)** (Chermak & Musiek, 1997). However, the causal relationship between various concomitant disorders, as well as their differential contribution to performance deficits remains obscure (Chermak & Musiek, 1997). In fact, some may argue that these disorders are indistinguishable from each other (Grundfast et al, 1991 In Cacace & McFarland, 1998).

CAPDs involve perceptual dysfunction specific to the perception of auditory stimuli, excluding disorders of the peripheral hearing mechanism (Cacace & McFarland, 1998). By definition, CAPDs cannot exist alongside comparable processing deficits in other modalities (i.e. visual or tactile), and must be distinguished from supramodal disorders such as attention, motivation, memory and motor skills (McFarland & Cacace, 1995). CAPDs can, however, be comprised of **modality specific** attention difficulties, involving selective and divided auditory attention (Cherry, 1980; Jerger & Jerger, 1984; Katz & Illmer, 1972; Keith, 1986; Lasky & Tobin, 1973; in Chermak & Musiek, 1997). CAPDs can also occur alongside non-comparable visual or tactile processing deficits, as well as supramodal disorders.

Due to the widespread processing involved, as well as links with **learning, memory and attention; disorders of executive functioning** have been linked to academic difficulties in both ADHD, and LD (Denckla, 1996; Fletcher, Taylor, Levin & Satz, 1995; Graham & Harris, 1996; Pennington, 1991; Stanovich, 1986; Torgensen, 1994; in Chermak & Musiek, 1997). In turn, there are significant links between central auditory processing and processes related to attention and memory (Chermak & Musiek, 1997), although no conclusive decision has been reached regarding explanation of the above interrelationships (Gascon, Johnson, & Burd, 1986; Keith, 1981; Rees, 1981; Sloan, 1986; in Chermak & Musiek, 1992). Secondary deficits, involving executive dysfunction, may contribute to the performance deficits resulting from central auditory processing dysfunction. Secondary deficits may also give rise to metacognitive difficulties (as a result of repeated task failure), leading to a lack of 'generalisation of strategic listening behaviours across settings' (Borkowski & Burke, 1996 in Chermak & Musiek, 1997, 18). Reduced motivation may contribute to a lack of implementation of executive functions (Chermak & Musiek, 1997). The identification of executive dysfunction, in children with CAPD, may thus be essential to the planning and implementation of effective intervention strategies, incorporating auditory, metalinguistic and metacognitive training (Chermak & Musiek, 1997).

The following definition may provide a summary and aid understanding of the role of executive functions in central auditory processing disorder:

'Individuals with CAPD do not seem to exert executive control in deploying strategies to aid in organizing, monitoring, and understanding the acoustic signal, strategies that might facilitate information processing and enable them to compensate to some extent for the deficient central auditory processes that characterize the disorder' (Chermak & Musiek, 1992; Gerber, 1993; Pressley & Levin, 1987; Suiter & Potter, 1987; Torgesen & Houck, 1980; Wong, 1987; in Chermak & Musiek, 1997, 19). They show a 'passive and inefficient approach to problem solving' (Swanson, 1989; Torgesen, 1979; in Chermak & Musiek, 1997, 19)

1.5.2 Defining the Effects of CAPD

Despite its intangible nature, CAPD may be at the heart of a number of lifelong learning, language, and social dysfunctions, having far reaching effects in the lives of those who suffer with the condition (Chermak & Musiek, 1997).

Cacace & McFarland (1998), suggest that central auditory processing disorders may be the cause of many learning difficulties in the school-aged child. Deficiencies may affect performance on tasks involving both verbal and non-verbal input stimuli, and lead to functional difficulties in the areas of speech and language (including spelling and reading), and hence academic performance (Ormson & Williams, 1975; Stubblefield & Young, 1975; Orchik & Oeschlager, 1974; in Lukas & Eschenheimer, 1982; Gomez & Condon, 1999; Chermak & Musiek, 1997; Campbell, 1996). The learning of second or third languages may be particularly difficult (Baran & Musiek, 1995). Individuals with CAPD may frequently and inappropriately take the literal meaning of words and sentences and have difficulty dealing with abstract information, riddles and verbal math problems. They may have difficulty identifying and manipulating speech segments, discriminating between similar sounding words or sounds and experience great difficulty understanding rapid speech, or speech in the presence of background noise (Baran & Musiek, 1995). They may be more sensitive to sounds than 'normals', while not responding to verbal signals when concentrating on something else. Auditory perceptual difficulties may thus lead to misunderstandings or delayed response to auditory instructions and frequent requests for repetition (Campbell, 1996). In summary, children with CAPD are unlikely to become effective communicators (Paton, 1999).

Having established the potentially devastating effects of central auditory processing disorders, how can the speech-language therapist provide effective treatment? More specifically, *what role does music training play*, in the remediation of various central auditory processing disorders?

1.6 MUSIC TRAINING AND REMEDIATION OF CENTRAL AUDITORY PROCESSES

Different Authors adopt different approaches to the assessment and remediation of central auditory processing; including varying focus on 1) subprofiling systems involving specific deficits, and/or 2) general concepts for remediation of auditory perceptual deficits.

1.6.1 Remediation of the Subprofiles of CAPD

The 'use of subprofiles of central auditory processing deficits has begun to gain wider acceptance clinically', providing an effective basis for planning interventions (Ferr, 1992; Katz, 1992; Katz, Stecker & Masters, 1994; Musiek, Gollegly, & Ross, 1985; in Bellis, 1996, 185). Bellis (1996, 193) provides the following summary (see table 1.1) of four primary central auditory processing subprofiles, based on the dysfunction of specific central auditory processes:

Table 1.1: Subprofiles of Central Auditory Processing Disorders

Type	Primary Sequelae	Central Test Findings	Management
Auditory Decoding Deficit	Sound recognition, blending, reading, and writing skills adversely affected. Poor auditory closure abilities.	Poor performance on **monaural low redundancy speech** tests and **speech-in-noise.** Site of dysfunction: primary auditory cortex.	Phoneme training, preteach new information, improve acoustic clarity of the signal.
Integration Deficit	Difficulty in multimodality tasks, reading, spelling, writing, and use of symbolic language and prosody. Poor music skills.	Left ear deficit on **dichotic speech** tasks combined with bilateral deficit on tests of **temporal patterning** requiring verbal report. Site of dysfunction: corpus callosum.	Interhemispheric exercises, reduce use of multimodality cues, prosody training, key word extraction, **music training.**

Table 1.1 (cont.)

Associative Deficit	Receptive language deficits, pragmatic skills may be poor. Academic difficulties may not become apparent until the 3rd grade.	Bilateral deficit on **dichotic speech** tasks, poor word recognition skills. Site of dysfunction: primary and associative cortical regions.	Language intervention combined with compensatory strategies.
Output-Organization Deficit	Deficit in sequencing, planning, and organizing responses. Poor organizational skills, reversals, poor recall and sequencing abilities. Motor skills often affected.	Difficulty on any task requiring report of more than two critical elements. Site of dysfunction: efferent system.	Similar to associative deficit, including training of organizational skills and language intervention.

From table 1.1 it can be seen that **music training** (including singing and dancing) is only recommended as an intervention in one of the four central auditory processing subtypes - Integration deficit – identified by poor performance on temporal processing tasks requiring verbal report, and dichotic listening tasks (Bellis, 1996). Could music training possibly be applied to perceptual deficits present in other subtypes of central auditory processing deficit?

1.6.2 Decreasing Perceptual Deficits

Chermak and Musiek (1997) rarely mention music training as a specific form of remediation, and do not overtly associate particular forms of remediation with specific CAPD subprofiles (as determined by diagnostic CAPD tests). They do, however, provide guidelines for the remediation of a number of perceptual deficits, which may be present in various CAPD subprofiles (see table 1.2).

Table 1.2: Decreasing Perceptual Deficits

Skill	Procedures used for training – as described by Chermak and Musiek (1997, 190-193)
1) Detection of temporal gaps	Detection of 'brief bursts of white noise which are progressively shortened approaching the criterion of 1-5 msec gap detection.'
2) Discrimination of frequency	Discrimination of frequency differences of 5-10 Hz. 'Determine the upward or downward direction of a frequency sweep for tone bursts of a few milliseconds.'
3) Discrimination of temporal gaps	Comparison of a gap of about 20msec (necessary for 'phonetically meaningful distinction[s]') to one of 30-40msec. Discrimination between steady state noise and noise with an interruption rate of 5-15 per second.
4) Discrimination of temporal order	The client is required to identify whether tone sequences are the same or different.
5) Sustained attention (vigilance)	Auditory continuous performance tasks, which involve attending to and identifying a target stimuli from a 'continuous stream of auditory stimuli, such as environmental sounds, syllables, or words.'
6) Interhemispheric interaction This is the only deficit for which the authors (Chermak & Musiek, 1997) overtly recommend music training – a view supported by Bellis (1996, 216): 'Music therapy is a fun, repetitive way in which to facilitate interhemispheric communication.'	Verbal labelling of an object recognised through tactile cues. **Singing and other musical activities**. Motor response (involving the left side of the body) to verbal directions.

As can be seen from table 1.2, the remedial activities which Chermak and Musiek (1997) describe, involve very well graded and well-controlled stimuli. However, for the client with CAPD, many of these tasks may possess low levels of meaningfulness and task novelty, particularly after repeated presentation. The researcher proposes that, if music training was found to be instrumental in the development and enhancement of various central auditory processes, such training may provide a suitable compromise between interest, enjoyment and motivation, and the need for structured presentation of auditory stimuli.

Supporting this view, various authors have linked music therapy to the development of several verbal and non-verbal auditory perceptual skills, some of which may correspond with those outlined by Chermak and Musiek (1997) (see table 1.2). Musiek, Baran and Schochat (1999, 67) reported that 'replicating or describing sequences of notes played on the piano or sequences of simple finger tapping', with variation in 'pitch, interstimulus interval, loudness' or 'number of elements in the sequence', may develop temporal processing skills informally. Bellis (1996) sited discrimination, analysis and imitation of the rhythmic patterns of **non-verbal auditory stimuli** as a foundation step in the training of auditory-verbal temporal patterning skills (corresponding to skills 1-4 in table 1.2) – as assessed by behavioural temporal processing tests. Barr (1976) provided detailed guidelines for a graded approach, to the remediation of central auditory processing deficits, which incorporates musical and environmental as well as speech stimuli. He advised the **graded introduction of non-speech stimuli** (i.e. environmental and later musical stimuli), prior to tasks involving auditory-verbal stimuli. Areas incorporating musical training included 'awareness' (corresponding to skill 5 in table 1.2), localisation (identifying the direction of a sound), rhythm (skills 1-4 in table 1.2), memory (incorporating skills 1-4), decoding (understanding the meaning of auditory input), association (linking concepts and symbols) and encoding (translating concepts into verbal output) (Barr, 1976). The above authors were obviously convinced of the value of music training in remediation of central auditory processing disorders (broadly). However, they fail to provide conclusive scientific evidence of the specific processes which are affected or improved by music training – as evidenced by performance on specific diagnostic CAPD tests (see section 1.4).

Different authors have approached CAPD interventions from different standpoints. There are thus a number of seemingly asynchronous views which, in isolation, do not inclusively define the role of music therapy in the development and remediation of specific processing deficits, as defined by diagnostic CAPD tests (see section 1.4). The questions, which must then be asked, follow: *How does music training affect specific auditory processes?* and *How might one ethically determine the possible applications of music training, to deficits involving specific central auditory processes?* One solution may be to determine the effect of long-term music training (and lack thereof) on individuals whose intellectual and central auditory processing abilities fall within the range of normal. Such an approach may eliminate the confounding effects of past and present perceptual interventions, and the influence of disorders involving executive dysfunction.

1.7 THE EFFECT OF MUSIC TRAINING ON THE CENTRAL AUDITORY PATHWAYS AND CENTRAL AUDITORY PROCESSING – PAST STUDIES

'The plasticity of the human auditory system is inherent', with changes being observed in predominantly in the non-primary, but also in the primary, auditory pathways (Kraus, McGee, & Koch, 1998, 12). Many studies have shown that structures, along these pathways, may be altered in response to varying auditory stimulation, and that auditory training may 'enhance various auditory processes' (Musiek, Baran, & Schochat, 1999, 64). The following studies may provide rationale for further research into the association between music training and central auditory processing:

1) Schlaug, Jancke, Huang, and Steinmetz (1995), found that the planum temporale of the left hemisphere was larger for musicians compared to non-musicians (Pantev, Oostenveid, Engelien, Ross, Roberts & Hoke, 1998).

2) Similarly, Pantev, Oostenveid, Engelien, Ross, Roberts and Hoke (1998), reported regular differences in cortical representations for musicians compared to non-musicians, with representations being affected by the age at which musicians commenced practise. Enhanced cortical representations were found in 'subjects who began to practise before the age of 9 years', corresponding to previous reports of enhanced somatosensory

representations in subjects who began to practise before the age of 10 years (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1996 in Pantev, Oostenveid, Engelien, Ross, Roberts & Hoke, 1998). Musiek, Baran, and Schochat, (1999) also reported increased brain plasticity in younger individuals.

3) Lynch and Eilers (1992) showed that certain complex non-verbal auditory perceptual functions may develop in parallel to corresponding verbal auditory perceptual functions. They found that 'the development of culturally specific perceptual reorganization for music occurs in a developmental period similar to that for the perceptual reorganization of native speech contrasts' (Lynch and Eilers, 1992, 606).

4) Studies by Winitz and Bellerose (1963 in Katz & Wilde, 1994) as well as Kraus, McGee and Koch (1998), provide scientific proof that training of specific auditory processing skills may be generalised to related skills. They found that the skills developed during discrimination training for specific speech stimuli may be generalised to non-trained speech stimuli, supporting Musiek, Baran, and Schochat's (1999) assertion regarding the interdependance of various auditory processes. This study, in conjunction with Lynch and Eiler's (1992) findings, provides the grounds for proposing the existence of a possible link between the central processing of complex verbal and non-verbal auditory stimuli.

5) **Hillenbrand, Canter and Smith (1990)**, reported on a number of studies in which specific phonetic training lead to significant improvement in the perception and labelling of intraphonemic differences for speech stimuli, both within and across categories of stimuli (For example: fricatives, plosives or vowels). One study showed that musicians may be 'more reliable in providing labels for subphonemic categories in an open-set identification task', compared to non-musicians (Chandler & Strange, 1984 in Hillenbrand, Canter & Smith, 1990, 656). Based on these studies, the authors sought to determine whether adult 'listeners with extensive experience in phonetics and music are better able to perceive intraphonemic differences than inexperienced listeners, in the absence of specific identification or discrimination training on the synthetic speech sounds being tested (Hillenbrand, Canter, & Smith, 1990, 656). A specific aim of their study was to determine whether any advantage in the perception of speech stimuli, resulted from continued exposure to listening tasks involving

speech stimuli specifically (in the case of phoneticians), and whether exposure to listening tasks involving musical stimuli (in the case of musicians) would generalise to improved performance on speech discrimination tasks. Hillenbrand, Canter, and Smith (1990, 656) made use of verbal stimuli on a [bi]-[p^hi] continuum ('cued by variation in voice onset time'), and a [wei]-[rei] continuum ('cued by variation in second- and third-formant starting frequencies'). The following results were reported:

- Subjects with long-term phonetic training - who did not receive training on the specific stimuli used in the study – performed significantly better on certain speech identification and discrimination tasks, compared to musicians and inexperienced listeners (who had undergone a 10-week introductory phonetics course). Therefore, 'the performance advantage that was seen for the phonetically trained listeners is not related to any general auditory ability that might be common to musicians and phoneticians', but rather to specific exposure to the listening and labelling tasks involved in phonetic transcription of speech stimuli (Hillenbrand, Canter & Smith, 1990, 662).
- It was also found that several inexperienced listeners obtained scores comparable to those of phonetically trained subjects. This suggests that long-term phonetic training may enhance skills already existing in the latter.
- Inexperienced listeners showed no improvements in identification or discrimination, following the 10-week phonetics course; suggesting that long-term training may be required to improve these processes. This conclusion is supported by a number of other authors: 1) Bryan and Harter (1899), 2) Meyer (1899) who reported a 24-28 week training period for asymptotic performance on musical pitch identification tasks, and 3) Watson (1980) who concluded that long training periods were required for complex stimuli involving identification rather than discrimination or detection (Hillenbrand, Canter & Smith, 1990).

1.8 THE PURPOSE AND PRIMARY AIMS OF STUDY

In their study, Hillenbrand, Canter and Smith (1990), made use of very specific auditory discrimination and labelling tasks. They did not, however, assess performance on a battery of central auditory processing tasks. Furthermore, subjects from the 'musically trained' listening group had all undergone intensive long-term musical training, with formal training commencing before 12 years of age. If future research can attribute improved performance, on specific speech tasks, to musical training, it is important that the length of the training period used during research be practically applicable to the development of music therapy programmes (to be used in the treatment of central auditory processing).

Based on inadequacies identified in the Hillebrand, Canter and Smith (1990) study, the purpose of this study was as follows:

Through the study of non-disordered adult subjects, to provide objective evidence of the potential role of musical training – in the development of a variety of central auditory processes fundamental to the perception of speech and language.

The primary aims of the study were as follows:

- To determine whether adult listeners with a range of musical training, perform better on a battery of central auditory processing tasks, compared to non-musicians (in the absence of specific training with selected processing tasks). Hence, to determine whether exposure to listening tasks involving musical stimuli, would generalise to improved performance on a variety of verbal and non-verbal auditory processing tasks.

It would be extremely difficult to conduct a long-term study on the effects of music intervention in populations with central auditory processing disorders for the following reasons:

- The inherent difficulty in matching subjects (musical training) with controls (no musical training), when the population of individuals with central auditory processing disorders is so heterogeneous
- It would be difficult to standardise music training as well as other forms of intervention, with such widely divergent disorders
- It may be impossible to control for the effects of co-existing disorders of perception and executive functioning.

It was thought that the findings of such research - assessing the effect of musical training on non-disordered adult populations - would form an objective foundation for future research into the development of music therapy programmes for adults (and potentially children) with deficits in the processing of verbal stimuli.

To quote Musiek, Baran and Schochat (1999, 63): 'this area of habilitation... ...the management of individuals with central auditory processing disorders... ...is indeed in its infancy and much clinical and research work remains to be done before any definitive statements regarding the efficacy of many of these procedures can be made.'

2. METHODOLOGY

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

2.1 AIMS

The primary aim of this study was as follows:

- To determine whether individuals who regularly sing or play a musical instrument (experimental group) show significantly better performance, on tasks involving the processing of verbal and non-verbal auditory stimuli, compared to individuals who do not regularly sing or play a musical instrument (control group) - in the absence of specific training with selected auditory tasks.

2.2 SUBSIDIARY OBJECTIVES

1. To determine the existence of significant difference in mean score – between the experimental and control group - for the following behavioural tests of central auditory processing:
   - Two pair dichotic digit test
   - Binaural fusion test
   - Low pass filtered speech test
   - Speech Masking Level Difference Test
   - Frequency pattern test
   - Duration pattern test
2. To determine the existence of significant difference in the variance – between the experimental and control group - for the above behavioural tests of central auditory processing.

3. To determine the existence of significant difference in performance, between left and right ear presentations for the above behavioural tests of central auditory processing. The researcher sought to determine whether 'practise effects' would significantly affect results on these tests.
4. To determine whether performance on central auditory processing tests is related to the total number of years of exposure to musical training. The researcher sought to determine whether increased years of exposure would lead to improved performance on tests of central auditory processing.
5. To determine whether performance on central auditory processing tests is related to the total number of years of musical training within the past 10 years. The researcher sought to determine whether recent exposure to musical training may be fundamental to improved performance on central auditory processing tests, due to continuous cortical reorganisation in response to exposure or reduced exposure to various stimuli (Musiek, Baran & Schochat, 1999).
6. To determine whether age at which musical training commenced is related to performance on central auditory processing tests. The researcher sought to determine whether a critical period existed, for exposure to musical training, after which the introduction or further provision of training would no longer significantly affect performance on central auditory processing tests.
7. To determine whether gender has a significant effect on performance, for the above behavioural tests of central auditory processing. The researcher sought to determine whether recommendations, for the use of musical training to develop central auditory processes, could be applied to both genders.

2.3 METHODS

2.3.1 Study Design

This study adopted an **analytic** research design. A cohort study was used to evaluate the effect of regular singing or practise of a musical instrument (exposure) on interhemispheric processing and the processing of auditory-verbal information. Quantitative measures were employed.

2.3.2 Sample – based on the study by Hillenbrand, Canter and Smith (1990)

Thirty adult English-first-language speakers, with normal peripheral and central hearing, living in Cape Town.

Experimental group : 15 individuals

Control group : 15 individuals

2.3.3 Sampling Method

For both the experimental and the control groups, subjects selected using the following non-random sampling techniques:

- Quota sampling: Participants were recruited based on the researchers prior knowledge of their exposure/non-exposure to musical training.
- Networking: Participants were recruited by word of mouth.

2.3.4 Subject Consent

Each subject was required to give written and informed consent prior to participation in the study (see Appendix A and B).

2.3.5 Subject Selection Criteria

The following selection criteria were based on those used, by the RSA CAPD Taskforce (2001), during the collection of normative data for CAPD tests used in the current study. Principles outlined by Bellis (1996) were also used in the selection process.

The following selection criteria were applied to both the experimental and the control group:

- **Normal peripheral hearing** (pure-tone air conduction thresholds of between 0 and 20dB for the frequency range of 125-8000 Hz) (RSA CAPD Taskforce, 2001). Scores on the monaural low-redundancy speech tests may be significantly affected by peripheral hearing loss (Mueller & Bright, 1994). Furthermore, masking level differences are significantly effected by conductive, cochlear, and peripheral retrocochlear hearing losses (Noffsinger, Martinez, & Schaefer, 1985; Schoeny & Talbott, 1994). In addition, peripheral hearing loss has been shown to lead to anatomical and functional changes of the central auditory nervous system; involving both the brainstem and cortex (Morest & Bohne, 1983; Schwaber et al., 1993; in Baran & Musiek, 1995).

- **English** as a mother-tongue language (RSA CAPD Taskforce, 2001). The RSA CAPD Taskforce cited assessment of proficient English and non-proficient English speakers, as primary objectives to be completed within the next two years. However, the latter objective may only be reached once test material, representing the ten national languages, has been developed (Campbell & Wilson, 2000). As available test material contained normative data for English populations only, and the researcher was an English first-language speaker, subjects were required to be English mother-tongue speakers.

- **No history of learning disability, Attention Deficit Disorder, head injury, or known central auditory processing deficits,** all of which may negatively affect central auditory processing test results (Bellis, 1996; RSA CAPD Taskforce, 2001).
- **Not currently on any long-term medications** which may have central nervous system effects (RSA CAPD Taskforce, 2001).

- **Normal intellectual abilities** - having received mainstream schooling and some form of tertiary education (RSA CAPD Taskforce, 2001). Poor cognitive functioning may lead to poor performance on certain auditory processing tasks; regardless of true auditory processing abilities (Bellis, 1996).

- **Adults** (either male or female) between the ages of 18 and 30 years. Elderly adults were excluded from the sample as CAPD has been found to be prevalent in these populations (Chermak & Musiek, 1997). Furthermore, Wilson and Jaffe (1996) found significantly better performance on a dichotic digits test, for subjects younger than 30 years, compared to older subjects (Hallgren, Johansson, Larsby & Arlinger, 1998).

The following selection criteria were specific to each cohort:

- **The Experimental group**: Regular singing (in a band or choir) and/or practise of a musical instrument (either alone or in a band/orchestra) at least once a week for five consecutive years in the past 10 years - as a lengthy training period is required prior to improved performance on tasks involving the perception of complex auditory stimuli such as speech or music (Hillenbrand, Canter, and Smith, 1990) (see table 2.1).

- **The Control group**: Subjects from the control group were selected on the basis of their exclusion from the experimental group (i.e. they did not qualify according to the criteria mentioned above) (see table 2.2).

2.3.6 Description of Subjects

Table 2.1: Experimental Group

SUBJECT	DOB	GENDER	TOTAL MUSICAL TRAINING	MUSICAL TRAINING IN THE PAST 10 YEARS (1992-2001)	AGE TO COMMENCE TRAINING
1	14.10.78	Female	Recorder: 1985-1991 (1x weekly) Piano: 1991-1995 (2x weekly) Oboe: 1992-1996 (3x weekly) **Total: 12 years**	6 years	7 years
2	19.04.78	Male	Guitar: 1992-2001 (almost everyday) Piano: 1987-2001 (1x every 2 weeks) **Total: 15 years**	10 years	9 years
3	19.09.79	Female	Violin: 1986-2001(2-3x weekly) Aural & harmony: 1991-1996 Choir: 1985-1997, 2000-2001 (1x weekly). **Total: 16 years**	10 years	6 years
4	07.11.76	Female	Recorder: 1979-1994 (2x weekly) Violin: 1982-1988 (3x weekly) Viola: 1988-2001 (2x weekly) Piano: 1979-2001 (1x every 2 weeks) **Total: 23 years**	10 years	3 years

Table 2.1 (cont.)

5	07.01.79	Female	Piano: 1985-2001 (2x weekly) Guitar: 1990-2001 (1x weekly) Choir: 1987-1996 (1x weekly) **Total: 17 years**	10 years	6 years
6	24.02.81	Female	Piano: 1989-1999 (4x weekly) Choir: 1996-1999 (1x weekly) **Total: 11 years**	8 years	8 years
7	15.10.82	Female	Recorder: 1993 (1x weekly) Choir: 1995-1999 (1x weekly) Piano: 1995-2001 (3x weekly) Singing lessons: 2001 (1x weekly) **Total: 8 years**	7 years	11 years
8	14.08.81	Female	Choir: 1995-1999 (1x weekly) Church choir: 2001 (1x weekly) Recorder: 1993-1994 (1x weekly) Piano: 1995-2001 (1x weekly) **Total: 9 years**	8 years	12 years
9	18.07.78	Female	Choir: 1992-2001 (1x weekly) Piano: 1988-1996 (2x weekly) **Total: 14 years**	10 years	10 years
10	06.01.81	Female	Choir: 1991-1994 (1x weekly) Piano: 1989-2001 (2x weekly) Violin: 1994-1997 (1x weekly) **Total: 13 years**	10 years	8 years
11	28.12.76	Male	Piano: 1985-1986 (1x weekly) Violin: 1994-2001 (everyday) Bass: 1999-2001 (2x weekly) Mandolin: 1995-2001 (4x weekly) **Total: 10 years**	8 years	9 years

Table 2.1 (cont.)

12	08.10.82	Male	Piano: 1995-1997 (1x weekly) Trumpet: 1994-2000 (3x weekly) **Total: 7 years**	7 years	12 years
13	12.05.76	Male	Piano: 1985-2001 (3x weekly) Guitar: 1994-2001 (3x weekly) Percussion: 2000-2001 (1x weekly) **Total: 16 years**	10 years	9 years
14	01.05.79	Male	Piano: 1989-1991 (1x weekly) Guitar: 1993-2001 (daily) Choir: 1990-1993 (1x weekly) **Total: 13 years**	10 years	10 years
15	26.07.78	Female	Recorder:1984-1988 (2x weekly) Clarinet: 1991-1996 (4x weekly) **Total: 11 years**	5 years	6 years

Table 2.2: Control Group

SUBJECT	DOB	GENDER	TOTAL MUSICAL TRAINING	MUSICAL TRAINING IN THE PAST 10 YEARS (1992-2001)	AGE TO COMMENCE TRAINING
16	03.02.79	Male	None **Total: 0 years**	0 years	-
17	02.11.79	Male	Percussion: 1989-1992 (2x weekly) Recorder: 1989-1992 (2x weekly) **Total: 4 years**	1 year	10 years
18	21.11.80	Male	Choir: 1987-1988 (1x weekly) **Total: 2 years**	0 years	7 years
19	07.01.82	Male	Sax: 1998 for 1 month Piano: 1993 (2x weekly) **Total: 1 year**	1 year	16 years
20	07.01.82	Male	Trumpet: 1998 for 1 month Piano: 1993 (2x weekly) **Total: 1 year**	1 year	16 years

Table 2.2 (Cont.)

21	22.02.79	Male	Piano: 1987 (1x weekly) **Total: 1 year**	0 years	8 years
22	24.01.78	Male	Guitar: 1991 (1x weekly) **Total: 1 year**	0 years	13 years
23	02.04.79	Female	None **Total: 0 years**	0 years	-
24	09.08.76	Female	Choir: 1985-1987 (2x weekly) Piano: 1990 (1x weekly) **Total: 4 years**	0 years	9 years
25	10.09.77	Female	None **Total: 0 years**	0 years	-
26	06.06.79	Female	None **Total: 0 years**	0 years	-
27	28.12.78	Female	None **Total: 0 years**	0 years	-
28	16.12.79	Female	Piano: 1992-1993 (2x weekly) **Total: 2 years**	2 years	13 years
29	17.03.76	Female	None **Total: 0 years**	0 years	-
30	12.03.80	Male	None **Total: 0 years**	0 years	-

2.4 DATA COLLECTION

2.4.1 Principals Adopted In The Compilation Of The Test Battery

This study endorsed a primarily audiological approach, in the assessment of central auditory processes, for the following reasons (Chermak & Musiek, 1997):

- Audiological testing allowed for better control of presented acoustic stimuli, and provided good control over the acoustic environment during testing – leading to improved reliability and validity of measures.
- Testing could involve either binaural or monaural presentation of stimuli, in various listening conditions.

The use of a number of central auditory processing tests, with diverse constructions, is essential in assessing many different auditory processes (Chermak & Musiek, 1997). At least one audiologically-based behavioural procedure was chosen for assessment of each of the following central auditory processes:

- Binaural separation
- Binaural fusion
- Binaural Release from masking
- Auditory closure
- Temporal processing

All test procedures were selected from the battery of assessment tools recommended by the RSA CAPD Taskforce, so as to ensure the availability of appropriate normative data. Furthermore, the sensitivity/specificity, reliability and validity of each assessment tool was carefully evaluated, and compared to other available tools (Chermak & Musiek, 1997). All chosen tests were relatively easy to administer, score and interpret, limiting the possibility of tester error.

Electrophysiological tests, as well as behavioural measures, may be used effectively in the assessment of central auditory processing (Bornstein & Musiek, 1992; Ferre & Wilbur, 1986; Jerger, Martin, & Jerger, 1987; Jirsa, 1992; Ludlow, Cudahy, Bassich, & Brown, 1983; in Chermak & Musiek, 1997). It would have been ideal to include electrophysiological procedures in the central auditory battery (Chermak & Musiek, 1997), however time considerations, and the lack of specialist equipment precluded the use of such measures.

2.4.2 The Test Battery and Administration Procedures

The complete battery, of peripheral hearing (see section 2.3.5: subject selection criteria) and central auditory processing measures, took approximately 1 hour to administer to each individual. Tests were administered to individual subjects (from both the experimental group and the control group), in the following order:

i. Assessment of Peripheral Hearing

Pure-tone and Speech Recognition tests (SRT) were conducted within sound proof audiometric booths (as specified by Industrial Acoustics Company, INC.), in the Department of Communication Sciences and Disorders, at Groote Schuur Hospital, using a calibrated Orbiter 922 clinical audiometer (version 2).

- **Air-conduction pure-tone thresholds** were determined, bilaterally, using the Carhart-Jerger Modified Hughson-Westlake (1959) method, as outlined in Silman and Silverman (1991). Stimuli were presented via earphones, specially calibrated for use with the particular audiometer in question. Pulsed pure-tones were used, and testing was conducted at 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. Subjects were considered to have normal peripheral hearing if their pure-tone thresholds fell between –10 and +20 dB's at all test frequencies (RSA CAPD Taskforce, 2001).

- **SRTs** were used to confirm pure-tone thresholds and were also required to calculate presentation levels for several central auditory processing tests (those making use of speech stimuli). SRT refers to the minimum threshold of hearing for speech stimuli. According to Silman and Silverman (1991, 30), 'SRT is the lowest hearing level at which a person correctly recognizes the speech stimuli 50% of the time.' SRTs were determined, bilaterally, using the technique outlined by Chaiklin and Ventry (1964) (Silman & Silverman, 1991, 35). Spondees were presented using live voice, as a number of researchers have reported this method to be reliable (Beattie, Forrester, & Ruby, 1976; Carhart, 1946; Creston, Gillespie, & Krahn, 1966; in Silman & Silverman, 1991), with subjects being required to verbally repeat the presented word. Subjects were familiarised with the word stimuli prior to testing. According to Ventry and Chaiklin (1965), SRT's were considered normal if they fell within 12 dB's of the pure-tone average of 500, 1000 and 2000 Hz (Silman & Silverman, 1991).

ii. Assessment of Central Auditory Processes

Behavioural tools were used to assess 1) dichotic listening, 2) binaural release from masking, 3) auditory closure and 4) temporal processing (see table 2.3), in both the experimental and the control group. All tests were conducted within sound proof audiometric booths (as specified by Industrial Acoustics Company, INC.), in the Department of Communication Sciences and Disorders, at Groote Schuur Hospital. Tests made use of recorded tonal and speech materials from the RSA CAPD Taskforce Disc 1 – 2001 (used with permission of the Taskforce). A calibrated Orbiter 922 clinical audiometer (version 2) was used in conjunction with a Toshiba Tecra 730XCDT computer (with CD player).

Table 2.3: Central Auditory Processing Tests within the Battery

Test Category	**Test Name**
Dichotic listening: Binaural separation	1. Two pair dichotic digit test
Dichotic listening: Binaural fusion	2. CVC Binaural Fusion Test
Binaural Release From Masking	3. Speech Masking Level Difference Test
Auditory Closure	4. Low pass filtered speech test 5. 45% Time Compressed speech test
Temporal Processing	6. Frequency pattern test 7. Duration pattern test

- **Two Pair Dichotic Digit Test**

  Rationale: Dichotic listening tasks involve simultaneous presentation of sound stimuli to both ears, in which the stimuli to the right ear will differ from that to the left ear. Dichotic tests have been shown to be sensitive to dysfunctions of the central auditory nervous system and their inclusion, during assessment of central auditory processing, has been strongly recommended (Musiek, Baran, & Pinheiro, 1994; Musiek & Pinheiro, 1985; in Chermak & Musiek, 1997). The dichotic digits test has a sensitivity of 75-80% and false-positive rate of less than 15% (Musiek, 1983; Musiek et al., 1991; in Chermak & Musiek, 1997). Furthermore, it is sensitive to lesions of the cortex, brainstem and corpus callosum (Musiek, 1983 in Chermak & Musiek, 1997).

Administration: 25 sets of 2-pair dichotic digit stimuli were presented binaurally, at a level of 50dB above the SRT of the better ear. For each set, the subject was asked to repeat all four digits, in any order (RSA CAPD Taskforce, 2001). Responses were recorded on a sheet provided by the RSA CAPD Taskforce (2001).

Scoring: The first 5 sets of digits were counted as practise items, and excluded from scoring. For each ear, the percentage of correct responses, out of a total of 40 digits, was calculated. A total percentage, out of 80 digits, was also calculated.

- **CVC Binaural Fusion Test**

Rationale: Binaural fusion tasks also require dichotic listening skills, and are highly sensitive to cortical lesions affecting auditory areas of the brain (Bellis, 1996). CVC binaural fusion tests in particular, have been shown to possess between 78-93% sensitivity to lesions of the temporal lobe (Olsen, 1977; Mueller et al, 1987; in Chermak & Musiek, 1997).

Administration: Monosyllabic words from List 4 of the North Western University Test no.6, were presented, at 50dB above the SRT of the better ear. Words were presented dichotically, with the low-pass filtered version to the right ear, and high-pass filtered version of the same word to the left ear. A total of 50 words were presented and subjects were required to repeat each word as they heard it (RSA CAPD Taskforce, 2001). Responses were recorded on a sheet provided by the RSA CAPD Taskforce (2001).

Scoring: The first five words were counted as practice items and were excluded from scoring. For each subject the percentage of correct responses, out of a total of 45 CVC words, were calculated (RSA CAPD Taskforce, 2001).

➢ **<u>Speech Masking Level Difference Test</u>**

<u>*Rationale*</u>: Masking level differences (MLDs) represent an important component of auditory processing, involving the central auditory process of binaural interaction (i.e. interaction between the two ears) (Schoeny & Talbott, 1994; Bellis, 1996). A binaural interaction task was chosen due to the emphasis which Musiek and Lamb (1994) placed on assessment of both cortical/hemispheric, interhemispheric and brainstem function (Bellis, 1996). The MLD procedure is the only binaural interaction task whose worth has not been questioned due to poor sensitivity or lengthy and complex administration procedures (Bellis, 1996). Furthermore, the processes underlying MLD's are relatively well understood, allowing for more reliable interpretation of test results (Schoeny & Talbott, 1994). MLDs have frequently been used in clinical and research settings, and are both valid and reliable in the detection of brainstem dysfunction (Chermak & Musiek, 1997; Noffsinger, Martinez, & Schaefer, 1985). In fact, the MLD task may be comparable to Auditory Brainstem Response assessments (Hannley et al., 1983 in Noffsinger, Martinez, & Schaefer, 1985).

<u>*Administration*</u>: Binaural masking level difference (MLD) refers to the release from masking, which occurs as a result of changes in phase involving either the test signal or its masker. A test stimulus and masking noise may be presented binaurally and in phase (via earphones), at such a level that the noise just masks the test stimulus. By shifting the phase of either the test stimulus or the noise, at one earphone, the former becomes binaurally audible (Hirsh, 1948 in Noffsinger, Martinez, & Schaefer, 1985). Thus a shift in phase resulting in the test stimulus or the masker being out of phase (at the two ears) results in improved thresholds for the test stimulus, compared to the in-phase condition (Chermak & Musiek, 1997). For 'speech masking level differences', the stimuli are a closed set of ten spondees, which the listener is given on a printed sheet. In this study, spondees were first presented binaurally in the in-phase condition (S_oN_o), and then in the out-of-phase condition (S_nN_o), starting at a level of 50dB above the SRT of the better ear. 'Four words were automatically presented for each of 16 signal-to-noise ratios, beginning at the 0dB S/N and ending at the –30dB S/N (Taskforce, 2001, 10). The subject was required to repeat all spondees, at the various levels. Response ceiling was reached when the subject failed to respond to all spondees at two consecutive S/N ratios (RSA

CAPD Taskforce, 2001). Responses were recorded on a sheet provided by the RSA CAPD Taskforce (2001).

Scoring: The final MLD threshold, for each subject, was calculated by subtracting the S_nN_o threshold from the S_oN_o threshold (RSA CAPD Taskforce, 2001):

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

S_nN_o threshold = (dBHL of audiometer) + 1 – (total number of words repeated correctly/2)

- **Low Pass Filtered Speech Test**
- **45% Time Compressed Speech Test**

Rationale and Utility: Low redundancy monaural speech tasks are not highly sensitive or specific, but they are able to assess processing skills which are qualitatively different from temporal and dichotic listening (i.e. auditory closure) (Musiek, Baran, & Pinheiro, 1994 in Chermak & Musiek, 1997). Low pass filtered speech has been shown to have 74% sensitivity and specificity to temporal or parietal lobe lesions (Lynn & Gilroy, 1977 in Chermak & Musiek, 1997). Time compressed speech was also included in the battery as such tests may assess a subject's auditory closure skills more adequately than filtered words tests (Bellis, 1996; Chermak & Musiek, 1997). Time compressed speech differs from standard speech recognition tests in that, through the method of compression, the temporal duration of the word stimuli are altered. For example, a compression rate of 45% results in 45% of the signal being extracted in small acoustic components (Mueller & Bright, 1994). This process results in minimal distortion of the frequency characteristics of each word (Fairbanks, Everitt, & Jaeger, 1954 in Bellis, 1996). Time-compressed speech is 67% sensitive to pathology of the central auditory nervous system (Baran, Verkest, Gollegly, & Kibbe-Michael, 1985 in Chermak & Musiek, 1997), and 80% sensitive to temporal lobe lesions (Karlsson & Rosenhall, 1995 in Chermak, Musiek, & Craig, 1997).

Administration: For the low pass filtered speech, monosyllabic words from List 3 of the North Western University Test no. 6, were presented, through a low-pass filter, at 50dB above the SRT for each ear. For the 45% time compressed speech test, monosyllabic words from List 5 of the North Western University Test no. 6, were presented at 50 dB above the SRT for each ear. In both tests, 25 words were presented to the left ear and then another 25 words were presented to the right ear. Subjects were required to repeat each word, as they heard it (RSA CAPD Taskforce, 2001). Responses were recorded on sheets provided by the RSA CAPD Taskforce (2001).

Scoring: For both tests, the first five words (in each ear) were considered practise items and excluded from scoring. For both left and right ear presentations, the percentage of correct responses out of 20 was calculated. The left and right ear scores were then combined to determine the total percentage of correct responses out of 40 presentations.

- **Frequency Pattern Test**
- **Duration Pattern test**

Rationale: Both animal and human studies have shown the diagnostic value of temporal processing tasks, and thus support their inclusion in most central auditory processing batteries; for clinical and/or research purposes (Colavita, 1972; Musiek, 1984, 1986; Musiek & Baran, 1987; Neff, 1961; in Chermak & Musiek, 1997). Temporal processing tasks have been shown to possess a high degree of efficacy and sensitivity (Tallal & Piercy, 1973; Tallal, 1985; Musiek, Baran & Pinheiro; in Chermak & Musiek, 1997; Schoeny & Talbott, 1994). Tests involving the verbal labeling of sequenced tones may be sensitive to those lesions affecting sites involved in interhemispheric transfer of auditory information (Baran & Musiek, 1991 in Baran & Musiek, 1995), and can be used to provide neuromaturational information (i.e. degree of myelination of the corpus callosum) (Campbell & Wilson, 1999). Based on reported uses of similar tests [i.e. the pitch pattern sequence test; Ptacek and Pinheiro, 1971 (Chermak & Musiek, 1997)], the frequency and duration pattern tests were used in the evaluation of both temporal sequencing and interhemispheric interaction (involving auditory input) (Smoski, Brunt & Tannahill, 1992).

Administration: The frequency and duration pattern tests were presented monaurally, and required the subject to correctly sequence and verbally label sets of three tone bursts. In the frequency pattern test, these tone bursts were either 'high' (1122Hz) or 'low' (880Hz) in pitch (requiring a degree of frequency discrimination). In the duration pattern test, the tone bursts were either 'short' (250ms) or 'long' (500ms). For both tests, a total of 30 items were presented (first to the left and then to the right ear), at a level of 50dB above the 1000 Hz pure-tone threshold for each ear (RSA CAPD Taskforce, 2001). Responses were recorded on a sheet provided by the RSA CAPD Taskforce (2001).

Scoring: For both tests, the first five presentations (in each ear), were counted as practice items and were thus excluded from scoring. For both left and right ear presentations, the percentage correct responses out of 25 were calculated. The left and right ear scores were then combined to determine the total percentage of correct responses out of 50 presentations. Reversals (where the subject maintained the correct sequence, but inverted verbal labels (i.e. high-low-high instead of low-high-low) were counted as correct responses. The percentage of reversals, for both left and right ear presentations and the total score out of 50, were calculated.

2.5 MEASUREMENTS

2.5.1 Subject Description

The following descriptive information was obtained for each subject (see table 2.1 and 2.2):

- Gender
- Total years of music training
- Total years of music training in the past 10 years (recent training)
- Age at which music training commenced

2.5.2 Outcome Variables

The following outcomes were calculated for each subject (see table 2.4 and 3.1):

Table 2.4: Subject Outcomes

Test	Description of 'Subject Outcome' Variables	Label	Type of Variable
Dichotic Digits Test	**Total % correct digits** = 100(correct responses /80)	TPDDT	Numerical
	% correct digits for left ear presentations = 100(correct responses /40)	TPDDL	
	% correct digits for right ear presentations = 100(correct responses /40)	TPDDR	
CVC Binaural Fusion Test	**Total % correct binaural words** = 100(correct responses /45)	CVCBFT	Numerical
Speech Masking Level Difference Test	**Final Masking level difference** = SoNo threshold – SnNo threshold	SMLDFIN	Numerical
	SoNo threshold = (dBHL of audiometer) + 1 – (total number of words repeated correctly/2)	SMLD SONO	
	SnNo threshold = (dBHL of audiometer) + 1 – (total number of words repeated correctly/2)	SMLD SNNO	
Low Pass Filtered Speech Test	**% correct filtered words** = 100(correct responses /40)	LPFSTT	Numerical
	% correct words for left ear presentations = 100(correct responses /20)	LPFSTL	
	% correct words for right ear presentations = 100(correct responses /20)	LPFSTR	
45% Time Compressed Speech	**% correct filtered words** = 100(correct responses /40)	TCST45	Numerical
	% correct words for left ear presentations = 100(correct responses /20)	TCSL45	
	% correct words for right ear presentations = 100(correct responses /20)	TCSR45	

Table 2.4 (Cont.)

Frequency Pattern Test	**% correct pitch sequences** = 100(correct responses /50)	FPTTOTC	Numerical
	% correct pitch sequences for left ear presentations = 100(correct responses /25)	FPTLC	
	% correct pitch sequences for right ear presentations = 100(correct responses /25)	FPTRC	
	% pitch reversals = 100(reversals/50)	FPTTOTR	
	% pitch reversals for left ear presentations = 100(correct responses /25)	FPTLR	
	% pitch reversals for right ear presentations = 100(correct responses /25)	FPTRR	
Duration Pattern Test	**% correct duration sequences** = 100(correct responses /50)	DPTTOTC	Numerical
	% correct pitch sequences for left ear presentations = 100(correct responses /25)	DPTLC	
	% correct pitch sequences for right ear presentations = 100(correct responses /25)	DPTRC	
	% duration reversals = 100(reversals/50)	DPTTOTR	
	% pitch reversals for left ear presentations = 100(correct responses /25)	DPTLR	
	% pitch reversals for right ear presentations = 100(correct responses /25)	DPTRR	

2.6 DATA ANALYSIS

2.6.1 Treatment of variables

Subject outcome measures were tabulated and then used to determine descriptive measures for both the experimental and the control groups (see table 3.2). Descriptive measures were also displayed graphically, using boxplots (see figures 3.1 –3.9)

The following descriptive measures were calculated, for all subject outcomes, within and across exposure groups:

- Mean
- Standard deviation
- Variance

2.6.2 Statistical Analysis Procedures

The null hypotheses – according to stated research objectives (see section 2.2) – were as follows:

1. There is no significant difference in mean score – between the experimental and control group - for the following behavioural tests of central auditory processing:
   - Two pair dichotic digit test
   - Binaural fusion test
   - Low pass filtered speech test
   - Speech Masking Level Difference Test
   - Frequency pattern test
   - Duration pattern test
2. There is no significant difference in the variance – between the experimental and control group - for the above behavioural tests of central auditory processing.
3. There is no significant difference in performance, between left and right ear presentations for the above behavioural tests of central auditory processing.
4. Performance on central auditory processing tests is not related to the total number of years of exposure to musical training.
5. Performance on central auditory processing tests is not related to the total number of years of exposure to musical training, in the past 10 years.
6. Age at which musical training commenced is not related to performance on central auditory processing tests.
7. Gender does have a significant effect on performance, for the above behavioural tests of central auditory processing.

The test scores of the music and the non-musically trained groups were compared using F tests for the variances and t-separate tests for the means of numeric variables. This modified t-test allowed means to be compared where the variances of the two groups differed (Hicks 1982, 29). Differences between the scores, for left and right ear presentations, were investigated using paired t-tests. Two-way multivariate analysis of variance (Morrison, 1976) was used to test for overall differences in the mean scores of the experimental and control group, and to investigate the effect of gender on test performance. The effects of 'years of training' and 'age to commence training', on test performance, were investigated (separately) using correlations. All calculations were done using Statistica.

For the purposes of this study it was hoped that, each null hypothesis would be rejected ($p \leq 0.05$) in favour of the research hypothesis, allowing the researcher to infer that:

- Regular singing and practise of a musical instrument does significantly improve performance on tasks requiring 1) processing of auditory-verbal stimuli, and 2) tasks involving interhemispheric processing.
- There is significant difference in performance, between left and right ear presentations for the specified behavioural tests of central auditory processing.
- Gender does not have a significant effect on performance, for specified behavioural tests of central auditory processing.
- Performance on central auditory processing tests is related to the total number of years of exposure to musical training and/or years of training in the past 10 years.
- Performance on central auditory processing tests is related to the age at which one commences musical training, with performance improving as age decreases.

3. RESULTS AND DISCUSSION

This chapter presents the raw data, summary measures and statistical analysis of results, for specified audiological tests, in both the experimental and control groups. Discussion and interpretation of results are also presented. Refer to table 2.4 (pg 35) for a full description and explanation of the abbreviated variables found in tables 3.1-3.5, and figures 3.1-3.12.

3.1 SUBJECT OUTCOMES AND SUMMARY STATISTICS

Final subject outcomes, for each test, have been presented in table format (see Appendix C). The first two columns, on the left margin, specify the subject (by number) and his/her group assignment (experimental or control), while the horizontal axis lists specific outcome variables.

Individual subject outcome measures were used to determine summary statistics (mean, standard deviation and variance), within and across exposure groups (see table 3.1 and figures 3.1 – 3.9). Summary statistics were then analysed using the statistical methods discussed in section 2.6.2 (statistical analysis procedures)

Table 3.1: Summary Statistics (mean, standard deviation, variance)

Subject Outcome Variable	Summary Statistic	Control Group	Experimental Group	All Groups
TPDDL	Means	96.17	98.17	97.17
	Std.Dev.	5.97	2.91	4.72
	Variance	35.60	8.45	22.30
TPDDR	Means	96.00	99.33	97.67
	Std.Dev.	4.20	1.48	3.53
	Variance	17.68	2.20	12.47
TPDDT	Means	96.70	98.77	97.74
	Std.Dev.	4.20	2.16	3.44
	Variance	17.62	4.65	11.85
CVCBFT	Means	93.57	96.91	95.24
	Std.Dev.	4.68	2.89	4.18
	Variance	21.92	8.32	17.48
SMLDSONO	Means	42.90	43.17	43.03
	Std.Dev.	5.01	3.33	4.18
	Variance	25.11	11.06	17.48
SMLDSNNO	Means	35.93	35.17	35.55
	Std.Dev.	4.43	4.21	4.26
	Variance	19.60	17.74	18.18
SMLDFIN	Means	6.97	8.00	7.48
	Std.Dev.	1.88	2.45	2.21
	Variance	3.55	6.00	4.89
LPFSTL	Means	48.67	57.00	52.83
	Std.Dev.	15.29	19.25	17.60
	Variance	233.81	370.71	309.80

Table 3.1: (Cont.)

LPFSTR	Means	49.33	59.67	54.50
	Std.Dev.	16.99	19.04	18.49
	Variance	288.81	362.38	341.98
LPFSTT	Means	49.17	58.33	53.75
	Std.Dev.	15.28	17.41	16.76
	Variance	233.63	303.27	280.93
TCSL45	Means	90.00	96.00	93.00
	Std.Dev.	9.26	4.71	7.83
	Variance	85.71	22.14	61.38
TCSR45	Means	92.33	94.33	93.33
	Std.Dev.	4.58	5.63	5.14
	Variance	20.95	31.67	26.44
TCST45	Means	91.17	95.17	93.17
	Std.Dev.	5.97	4.06	5.41
	Variance	35.60	16.49	29.28
FPTLC	Means	94.40	100.00	97.20
	Std.Dev.	10.78	0.00	8.01
	Variance	116.11	0.00	64.17
FPTRC	Means	95.73	100.00	97.87
	Std.Dev.	9.85	0.00	7.18
	Variance	97.07	0.00	51.57
FPTTOTC	Means	95.07	100.00	97.53
	Std.Dev.	10.25	0.00	7.55
	Variance	105.07	0.00	57.02
FPTLR	Means	8.80	0.00	4.40
	Std.Dev.	6.79	0.00	6.51
	Variance	46.17	0.00	42.32
FPTRR	Means	8.27	0.27	4.27
	Std.Dev.	10.42	1.03	8.33
	Variance	108.50	1.07	69.44
FPTTOTR	Means	8.53	0.13	4.33
	Std.Dev.	7.87	0.52	6.95
	Variance	61.98	0.27	48.30

Table 3.1: (Cont.)

DPTLC	Means	83.73	96.53	90.13
	Std.Dev.	17.07	5.83	14.12
	Variance	291.35	33.98	199.43
DPTRC	Means	86.40	96.80	91.60
	Std.Dev.	19.41	5.70	15.02
	Variance	376.69	32.46	225.49
DPTTOTC	Means	86.00	96.80	91.40
	Std.Dev.	14.66	5.60	12.21
	Variance	214.86	31.31	149.01
DPTLR	Means	1.07	0.27	0.67
	Std.Dev.	1.83	1.03	1.52
	Variance	3.35	1.07	2.30
DPTRR	Means	1.60	0.27	0.93
	Std.Dev.	3.31	1.03	2.50
	Variance	10.97	1.07	6.27
DPTTOTR	Means	1.33	0.27	0.80
	Std.Dev.	2.23	0.70	1.71
	Variance	4.95	0.50	2.92
Summary Table of Means (scores.sta) N=30 (No missing data in dep. var. list)				

3.2 STATISTICAL ANALYSIS AND INTERPRETATION OF RESULTS

This section presents the statistical analyses and interpretation of the summary statistics in table 3.1, as well as clinical recommendations based on study findings.

3.2.1 Comparison of Mean Score and Variances between Groups

F-tests and modified t-tests were used to assess the significance of differences - between experimental and control groups – for variances and mean scores respectively. The complete results, from these statistical tests, are presented in table 3.2 and figure 3.10-3.12. The statistical results, for individual CAPD assessments, are then interpreted with the use of boxplots (see figures 3.1-3.9).

Table 3.2: Comparison of Mean Score and Variances between Groups

Outcome Variable	Mean for Control Group	Mean for Experimental Group	t separate Test variance est.	df	p 2-sided	Std. Dv. for Control Group	Std. Dv. for Experimental group	F-ratio Variances	p Variances
FPTLC	94.40	100	-2.01	14.00	0.06	10.78	0.00	no valid test for variances	
FPTRC	95.73	100	-1.68	14.00	0.12	9.85	0.00	no valid test for variances	
FPTTOTC	95.07	100	-1.86	14.00	0.08	10.25	0.00	no valid test for variances	
FPTLR	8.80	0.00	5.02	14.00	0.00	6.79	0.00	no valid test for variances	
FPTRR	8.27	0.27	2.96	14.28	0.01	10.42	1.03	101.71	0.00
FPTTOTR	8.53	0.13	4.12	14.12	0.00	7.87	0.52	232.43	0.00
TPDDL	96.17	98.17	-1.17	20.29	0.26	5.97	2.91	4.21	0.01
TPDDR	96.00	99.33	-2.90	17.43	0.01	4.20	1.48	8.03	0.00
TPDDT	96.70	98.77	-1.69	20.91	0.11	4.20	2.16	3.79	0.02
DPTLC	83.73	96.53	-2.75	17.22	0.01	17.07	5.83	8.57	0.00
DPTRC	86.40	96.80	-1.99	16.39	0.06	19.41	5.70	11.61	0.00
DPTTOTC	86.00	96.80	-2.67	18.00	0.02	14.66	5.60	6.86	0.00
DPTLR	1.07	0.27	1.47	22.09	0.15	1.83	1.03	3.14	0.04
DPTRR	1.60	0.27	1.49	16.70	0.16	3.31	1.03	10.29	0.00
DPTTOTR	1.33	0.27	1.77	16.77	0.09	2.23	0.70	10.00	0.00
LPFSTL	48.67	57.00	-1.31	26.63	0.20	15.29	19.25	1.59	0.40
LPFSTR	49.33	59.67	-1.57	27.65	0.13	16.99	19.04	1.25	0.68
LPFSTT	49.17	58.33	-1.53	27.54	0.14	15.28	17.41	1.30	0.63
CVCBFT	93.57	96.91	-2.35	23.29	0.03	4.68	2.89	2.63	0.08
TCSL45	90.00	96.00	-2.24	20.78	0.04	9.26	4.71	3.87	0.02
TCSR45	92.33	94.33	-1.07	26.89	0.30	4.58	5.63	1.51	0.45
TCST45	91.17	95.17	-2.15	24.68	0.04	5.97	4.06	2.16	0.16
SMLDSONO	42.90	43.17	-0.17	24.33	0.87	5.01	3.33	2.27	0.14
SMLDSNNO	35.93	35.17	0.49	27.93	0.63	4.43	4.21	1.11	0.85
SMLDFIN	6.97	8.00	-1.29	26.27	0.21	1.88	2.45	1.69	0.34
Grouping: GROUP! (scores.sta). Group 1: Control. Group 2: Experimental.									

* Std. Dv = standard deviation; df = degrees of freedom; p = significance level (reject Null Hypothesis if $p \leq 0.05$)

➢ Two Pair Dichotic Digit Test (TPDDT)

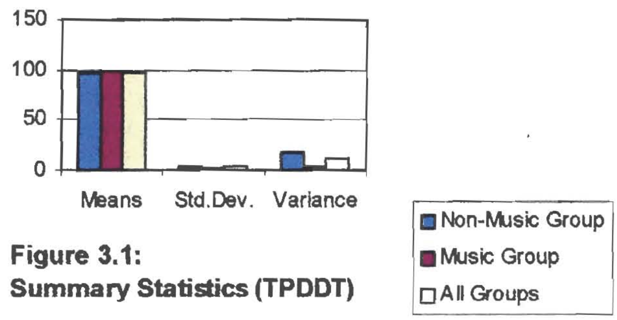

Figure 3.1:
Summary Statistics (TPDDT)

Statistical Analysis: The variance of the test scores in the control group was approximately four times larger than the variance of the experimental group scores (F = 3.79; p = 0.02). This indicates that the variance of the control group was significantly larger than that of the experimental group. The t-test for separate variances showed that there was no significant difference between the mean scores of the two groups (p = 0.11).

Interpretation: Overall, these results suggest that musical training may not contribute significantly to improved performance on tasks involving binaural separation of auditory-verbal stimuli and that, for this test, differences in performance were more likely to have been caused by intrinsic factors (i.e. natural competence). One possible explanation for these findings, may be the existence of distinct processing systems for complex auditory input, involving verbal or non-verbal stimuli. Thus improved processing of non-verbal stimuli (as a result of musical training) may not automatically lead to improved processing of verbal stimuli. It is also possible that musical training does not affect binaural separation of either non-verbal or verbal stimuli. Further non-verbal tests will be required to test these hypotheses.

Clinical Implications: It is suggested that music training or therapy may not be an appropriate intervention in the treatment of central auditory processing disorders involving binaural separation of auditory-verbal stimuli. Therapy techniques involving auditory-verbal input may be more useful in the remediation of binaural separation disorders evident for auditory-verbal stimuli. Further research should aim to develop such interventions.

Past studies: These findings may contradict Bellis' (1996) claim that music training is effective in remediating left-ear deficits on dichotic speech tasks.

➢ <u>CVC Binaural Fusion Test</u> (CVCBFT)

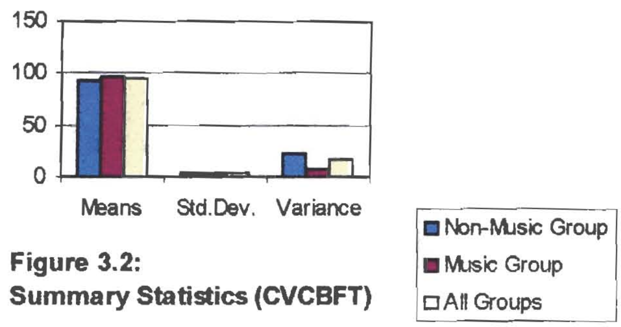

Figure 3.2:
Summary Statistics (CVCBFT)

Statistical Analysis: There was slight evidence for differences between the variances (F = 2.63; p = 0.08). The mean of the control group was significantly lower than that of the experimental group (p < 0.03), with mean scores of 93.57% and 96.91%respectively.

Interpretation: These results suggest that long-term musical training may significantly improve binaural fusion of verbal stimuli. It is therefore likely that binaural fusion, of auditory-verbal and non-verbal stimuli, involves similar and/or inter-linked processing systems. Thus improvements in the processing of non-verbal stimuli may lead to improvements in the processing of auditory-verbal stimuli. The converse statement may also hold true, with improvements in the processing of auditory-verbal stimuli leading to improved processing of complex non-verbal input.

Clinical Implications: It is suggested that music training or therapy may be an appropriate intervention in the treatment of central auditory processing disorders involving binaural fusion of either auditory-verbal or non-verbal stimuli. However, further studies will be required to assess the efficacy of such interventions. Studies may also assess the affect of auditory-verbal training, on the processing of complex non-verbal stimuli.

Past studies: These findings contradict Bellis (1996) who did not site music training as an effective intervention in central auditory processing deficits involving poor performance on binaural fusion.

➢ <u>Speech Masking Level Difference</u> (SMLDFIN)

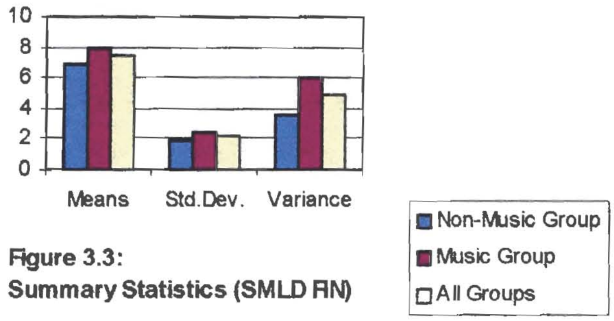

Figure 3.3:
Summary Statistics (SMLD FIN)

<u>Statistical Analysis:</u> The mean of the control group was 1.03 points lower than the experimental group but this difference was not statistically significant and there was no significant difference between the variances in each group.

<u>Interpretation</u>: These results suggest that musical training may not contribute significantly to improved performance on tasks involving binaural release from masking, where auditory-verbal stimuli is involved. Again, findings may have been due to the existence of distinct processing systems for complex auditory input, involving verbal or non-verbal stimuli. Thus improved processing of non-verbal stimuli (as a result of musical training) may not automatically lead to improved processing of verbal stimuli. It is also possible that musical training does not affect binaural release from masking, for either non-verbal or verbal stimuli. Assessment using tonal masking level differences will be required to test these hypotheses.

<u>Clinical Implications</u>: It is suggested that music training or therapy may not be an appropriate intervention in the treatment of central auditory processing disorders involving binaural release from masking, where auditory-verbal stimuli is involved. Therapy techniques involving auditory-verbal input may be more useful in the remediation of such disorders, and further research would be useful in developing and testing the efficacy of such interventions.

<u>Past studies:</u> These findings may be supported by Bellis (1996) who did not site music training as an effective intervention in central auditory processing deficits involving poor performance on binaural interaction tasks.

> ## Low Pass Filtered Speech (LPFSTT)

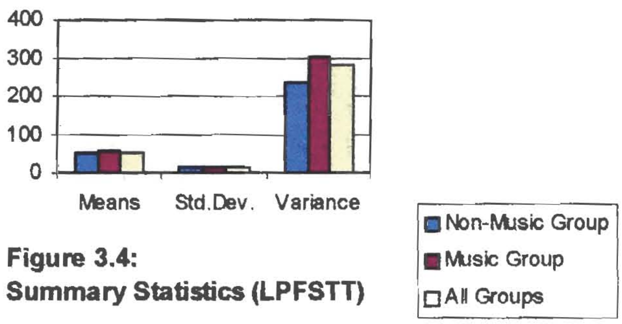

Figure 3.4:
Summary Statistics (LPFSTT)

Statistical Analysis: There was no significant difference between the variances in this test (F = 1.30; p = 0.63) and no significant differences between the means (p = 0.14).

Interpretation: Music training did not significantly improve performance on this task. Regardless of exposure group, subjects may have scored particularly poorly due to the presentation of word lists in an unfamiliar and foreign accent (word lists were recorded by American researchers) coupled with distorting filter techniques. Due to the questionable validity of the test stimuli, it is unlikely that these particular results can be used to draw any significant conclusions regarding the relationship between musical training and auditory closure for verbal stimuli.

Clinical Implications: A primary recommendation may be the exclusion of this particular monaural low-redundancy speech task, from further research and clinical investigations involving South African populations.

➢ <u>45% Time compressed speech</u> (TCST45)

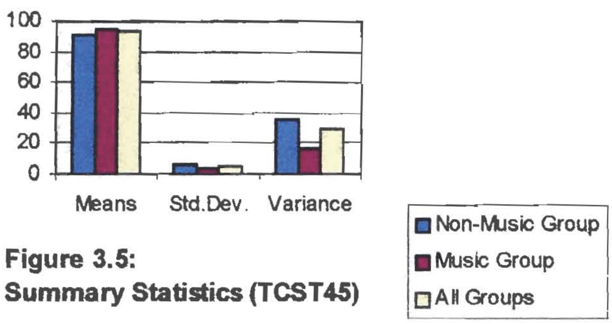

Figure 3.5:
Summary Statistics (TCST45)

Statistical Analysis: There was no significant difference between the variances (F = 2.16; p = 0.16). The mean of the control group was significantly lower (by 4 points) than that of the experimental group (p = 0,04). The mean scores were 91.17% and 95.17% respectively.

Interpretation: These results suggest that long-term musical training may, despite previous negative indications (see results for Low Pass Filtered Speech), significantly improve auditory closure of verbal stimuli. As with binaural fusion tasks, it is likely that auditory closure, of auditory-verbal and non-verbal stimuli, involves similar and/or inter-linked processing systems. Again, improvements in the processing of non-verbal stimuli may lead to improvements in the processing of auditory-verbal stimuli. The converse statement may also hold true, with improvements in the processing of closed-set auditory-verbal stimuli leading to improved processing of complex non-verbal input.

Clinical Implications: It is suggested that music training or therapy may be an appropriate intervention in the treatment of central auditory processing disorders involving auditory closure of either auditory-verbal or non-verbal stimuli. However, further studies will be required to assess the efficacy of such interventions. Studies may also assess the affect of auditory-verbal training, on processing involving closure for complex non-verbal stimuli.

Past studies: These findings may contradict previous statements by Bellis (1996), which do not site music training as an intervention in deficits of auditory closure.

- ➢ <u>Frequency pattern test – Correct Response</u> (FPTTOTC)
- ➢ <u>Frequency Pattern Test – Reversals</u> (FPTTOTR)

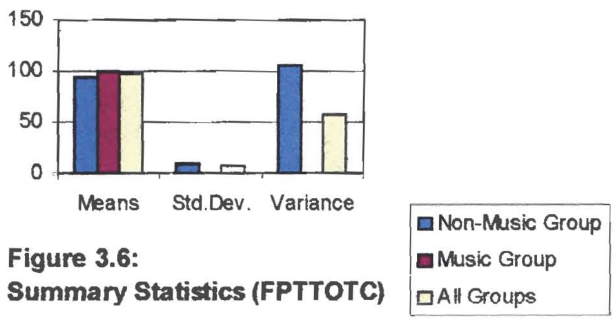

Figure 3.6:
Summary Statistics (FPTTOTC)

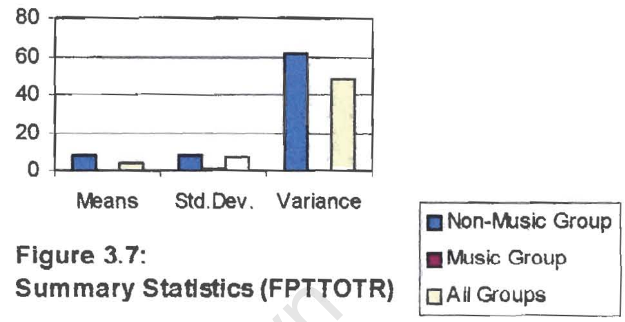

Figure 3.7:
Summary Statistics (FPTTOTR)

<u>Statistical Analysis</u>: As all the subjects in the experimental group scored full marks on this test, there was no valid test to compare the two groups. The mean score of the control group was lower (94.5%), with a 95% confidence interval from 90.6 to 99.6. The perfect score of 100 for the experimental group lay outside of this confidence interval which indicated that, for correct responses, the mean score of the experimental group was significantly higher than that of the control group. For reversals, the variance of the control group was significantly larger than that of the experimental group ($F = 232.43$; $p = 0.00$). The mean score, for reversals, in the control group was also significantly lower than that of the experimental group ($p = 0.00$).

<u>Interpretation</u>: Overall, these results suggest that long-term musical training may significantly improve interhemispheric integration, involving verbal labelling of non-verbal auditory stimuli.

<u>Clinical Implications</u>: It is suggested that music training or therapy may be an appropriate intervention in the treatment of central auditory processing disorders affecting the verbal labelling of non-verbal stimuli. However, further studies will be required to assess the efficacy of such interventions in disordered populations.

<u>Past studies:</u> These findings are supported by Bellis (1996), Chermak and Musiek (1997), and Musiek, Baran and Schochat's (1999) recommendations for the use of musical stimuli in development of interhemispheric integration and temporal processing abilities, as well as indications that integration of auditory-verbal information may be improved through 'integration' activities involving multiple modalities.

- Duration Pattern test – Correct Response (DPTTOTC)
- Duration Pattern test – Reversals (DPTTOTR)

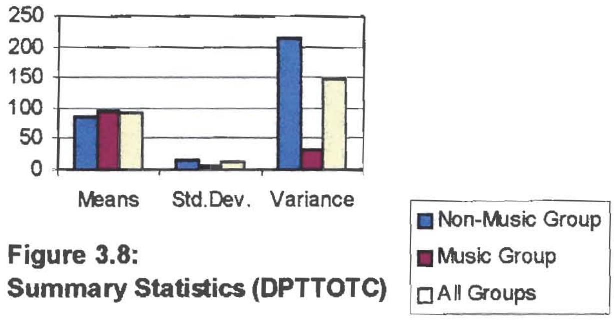

Figure 3.8:
Summary Statistics (DPTTOTC)

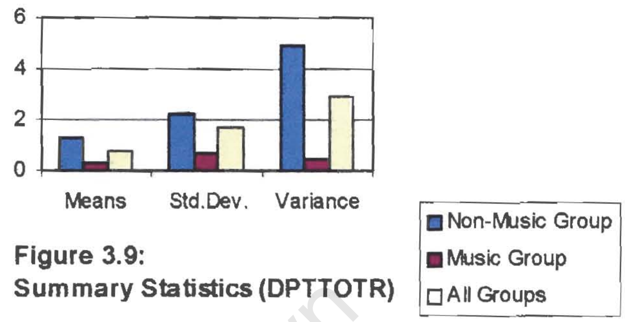

Figure 3.9:
Summary Statistics (DPTTOTR)

Statistical Analysis: The variance of the test scores in the control group was approximately seven times larger than the variance of the experimental group scores (F = 6.86; p = 0.00). This indicates that, for correct responses, the variance of the control group was significantly larger than that of the experimental group. The t-test for separate variances showed that the mean score in the control group was significantly lower (by 10.8 points) than that of the experimental group (p = 0.02). The mean scores were 86.0 and 96.8 respectively. For reversals, the variance of the control group was significantly larger than that of the experimental group (F = 10.0; p = 0.00). There was no significant difference between the mean score, for reversals, in the control group and the experimental group (p = 0.09).

Interpretation: Overall, these results confirm findings for the frequency pattern test, and suggest that long-term musical training may significantly improve interhemispheric integration, involving verbal labelling of non-verbal auditory stimuli.

Clinical Implications: Findings strengthen previous recommendations for the use of musical stimuli in development of interhemispheric integration abilities. It is also suggested that music training or therapy may be an appropriate intervention in the treatment of specific central auditory processing disorders affecting the verbal labelling of non-verbal stimuli. As with the frequency pattern test, it is recommended that further research be undertaken, to assess the efficacy of 'musically orientated' interventions in disordered populations.

Past studies: These findings are supported by Bellis (1996), Chermak and Musiek (1997), and Musiek, Baran and Schochat's (1999) recommendations for the use of musical stimuli in development of interhemispheric integration and temporal processing abilities, as well as indications that integration of auditory-verbal information may be improved through 'integration' activities involving multiple modalities.

3.2.2 Comparison of Scores between Left and Right Ear Presentations

The difference between performance, for left and right ear presentations, was investigated using paired t-tests. The results of this statistical analysis are presented in table 3.3.

Table 3.3: Comparison of Left and Right Ear Scores (using T-tests for dependant samples)

T-test for Dependent Samples (scores.sta)	**Mean**	**Std. Dv**	N	**Diff.**	**Std. Dv Diff.**	t	**df**	**P**
Control group only								
FPTLC	94.40	10.78	15	-1.33	2.468853	-2.09	14.00	0.06
FPTRC	95.73	9.85						
All students								
DPTLC	90.13	14.12	30	-1.47	9.31	-0.86	29	0.40
DPTRC	91.60	15.02						
TPDDL	97.17	4.72	30	-0.50	3.68	-0.74	29	0.46
TPDDR	97.67	3.53						
LPFSTL	52.83	17.60	30	-1.67	13.35	-0.68	29	0.50
LPFSTR	54.50	18.49						
Marked differences are significant at $p \leq .05000$								

* Std. Dv = standard deviation; N = sample size; Diff = difference between sample means; Std. Dv Diff = standard deviation of the difference scores; t = t statistic; df = degrees of freedom; p = significance level (reject Null Hypothesis if $p \leq 0.05$)

Statistical Analysis: Results for the 45% Time Compressed speech test were not included, as overall mean scores were equal for the left and right ear. For the Frequency Pattern Test, all the music students scored 100 on both left and right ears so there was not valid comparison of left and right ear scores. Comparisons for this test were made on the non-music students only. All other comparisons were made on both groups combined.

Interpretation: There was no evidence of a significant difference between scores for left and right ears on any of the tests. However in all cases the mean score for the left ear was slightly lower than that of the right ear. As the left ear was examined first in all subjects this may indicate a slight learning effect which occurs during testing.

Clinical Implications: Although the difference in performance, between ears, was not statistically significant in this study, it may be a topic for further investigation and possible 'practise effects' should be taken into consideration during interpretation of future test results (for research or clinical purposes).

3.2.3 Effect of Years of Musical Training and Age to Commence Training, on Test Scores

The effects of 'years of training' and 'age to commence training', on test performance, were investigated (separately) using correlations. The results of this statistical analysis are presented in table 3.4.

Table 3.4: Correlation between Musical Training, Age to Commence Training and Test Performance

Correlations (scores.sta)	FPTTOTC	TPDDT	DPTTOTC	LPFSTT	CVCBFT	TCST45	SMLDFIN
TOTAL TRAINING	0.24	0.34	0.32	0.19	0.4078	0.35	0.25
	N=30	N=30	N=30	N=30	N=30	N=30	N=30
	p=.211	p=.064	p=.080	p=.322	p=.025	p=.058	p=.174
RECENT TRAINING	0.34	0.31	0.44	0.23	0.3764	0.38	0.27
(years of training in the past	N=30	N=30	N=30	N=30	N=30	N=30	N=30
10 years)	p=.066	p=.093	p=.015	p=.215	p=.040	p=.039	p=.142
AGE TO COMMENCE	0.04	-0.09	-0.05	-0.03	-0.3961	-0.12	-0.07
TRAINING	N=23	N=23	N=23	N=23	N=23	N=23	N=23
	p=.864	p=.688	p=.806	p=.876	p=.061	p=.590	p=.748
* Marked correlations are significant at $p \leq .05000$							

Figure 3.10 shows performance, on each test (vertical axis), plotted against total years of music training (horizontal axis).

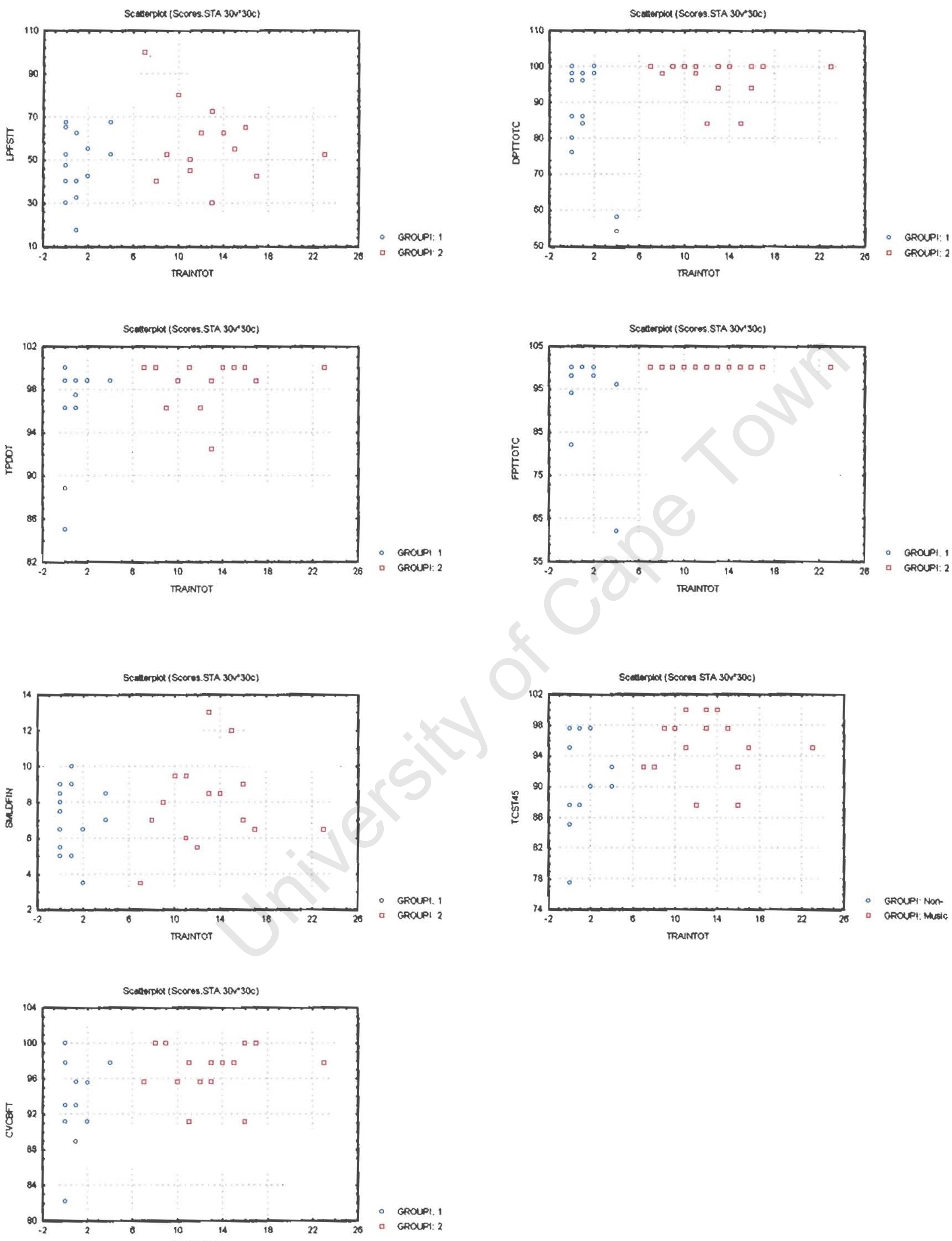

Figure 3.10: Effect of Total Years of Training on Test Performance

Interpretation: Overall, the correlations between the test scores and total years of musical training (see figure 3.10 and table 3.5) were small. They were significantly different from zero at the 6% level for the two pair dichotic digit test and the 45% time compressed speech. However, in each of these tests one member of the *group without musical training* (subject 16) had a very low score compared to the rest of the subjects. This single case could have induced a spurious correlation between the test score and total years of musical training. The correlation between the CVC binaural fusion test and total years of musical training was also statistically significant ($p = 0.025$), but again the correlation seems to have been induced by a single low score in the *group without musical training* (subject 30). Plots indicate that the test scores are more variable in this group and that this is the cause of the apparent very weak correlations observed. The same patterns were observed when the data was plotted against years of recent training (see figure 3.11). The significant correlations observed with the frequency pattern test, the duration pattern test and the 45% compressed speech seem to have been induced by one or two low scores in the control group.

Clinical Implications: Overall results suggest that musical training is related to improved performance on certain central auditory processing tasks (binaural fusion, auditory closure, interhemispheric integration). Current findings may thus suggest that performance, on these central auditory processing tasks, reaches a plateau after a specified period of musical training – where further training does not result in improved performance on tasks. Further research may thus be required; to aid prediction of this 'plateau' in clients with central auditory processing difficulties. A knowledge of the possible duration of effective therapeutic interventions (involving musical training) is likely to aid development of management plans and efficient distribution of therapeutic resources.

Past studies: These findings are further supported by Pantev, Oostenveld, Engelien, Ross, Roberts, and Hoke (1998, 813), who concluded that it is 'unlikely that duration of training alone is the critical variable' in cortical reorganisation as a response to musical stimuli.

Figure 3.11 shows performance, on each test (vertical axis), plotted against years of music training, in the past 10 years (horizontal axis).

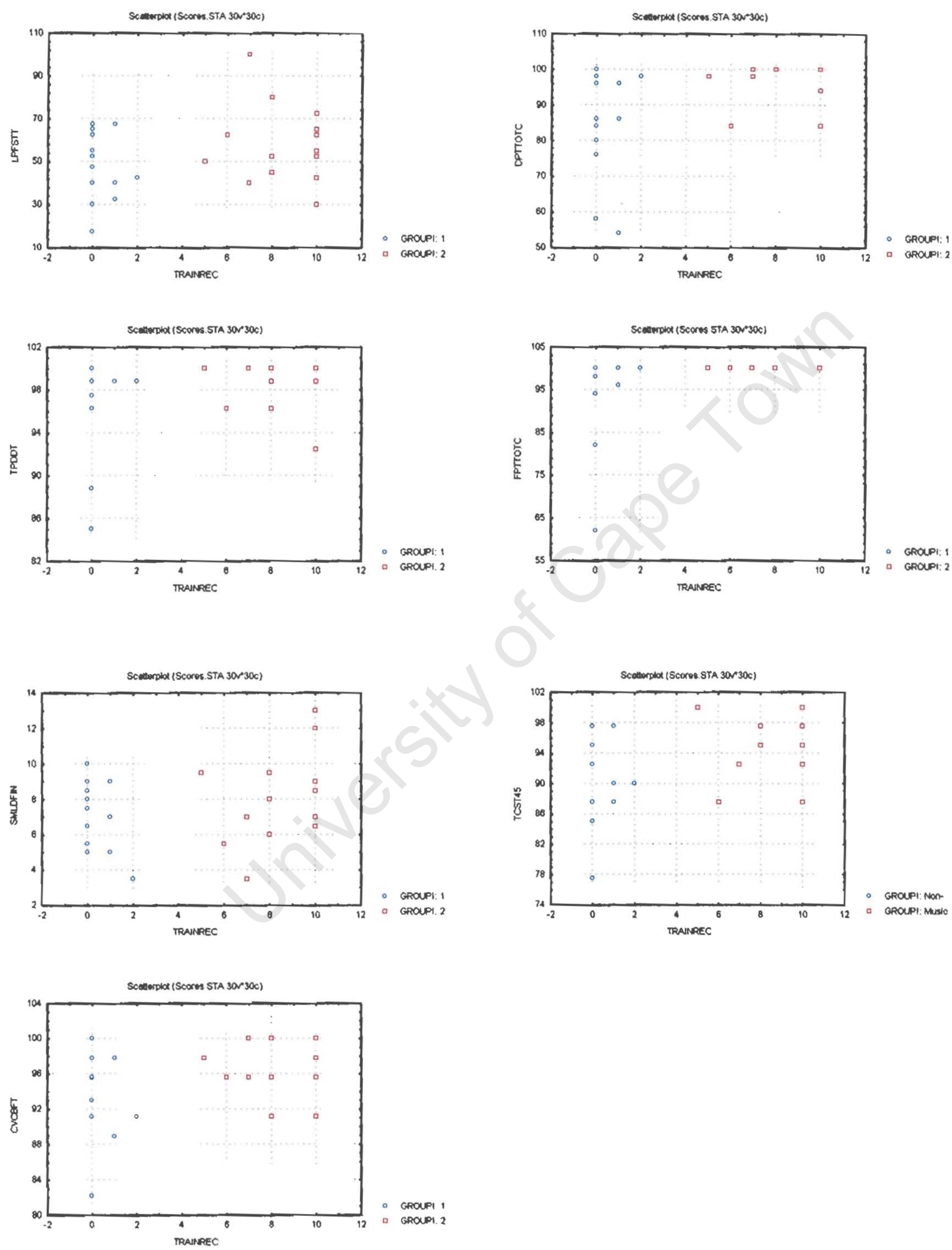

Figure 3.11: Effect of Recent Training on Test Performance

Figure 3.12 shows performance, on each test (vertical axis), plotted against 'age to commence music training' (horizontal axis).

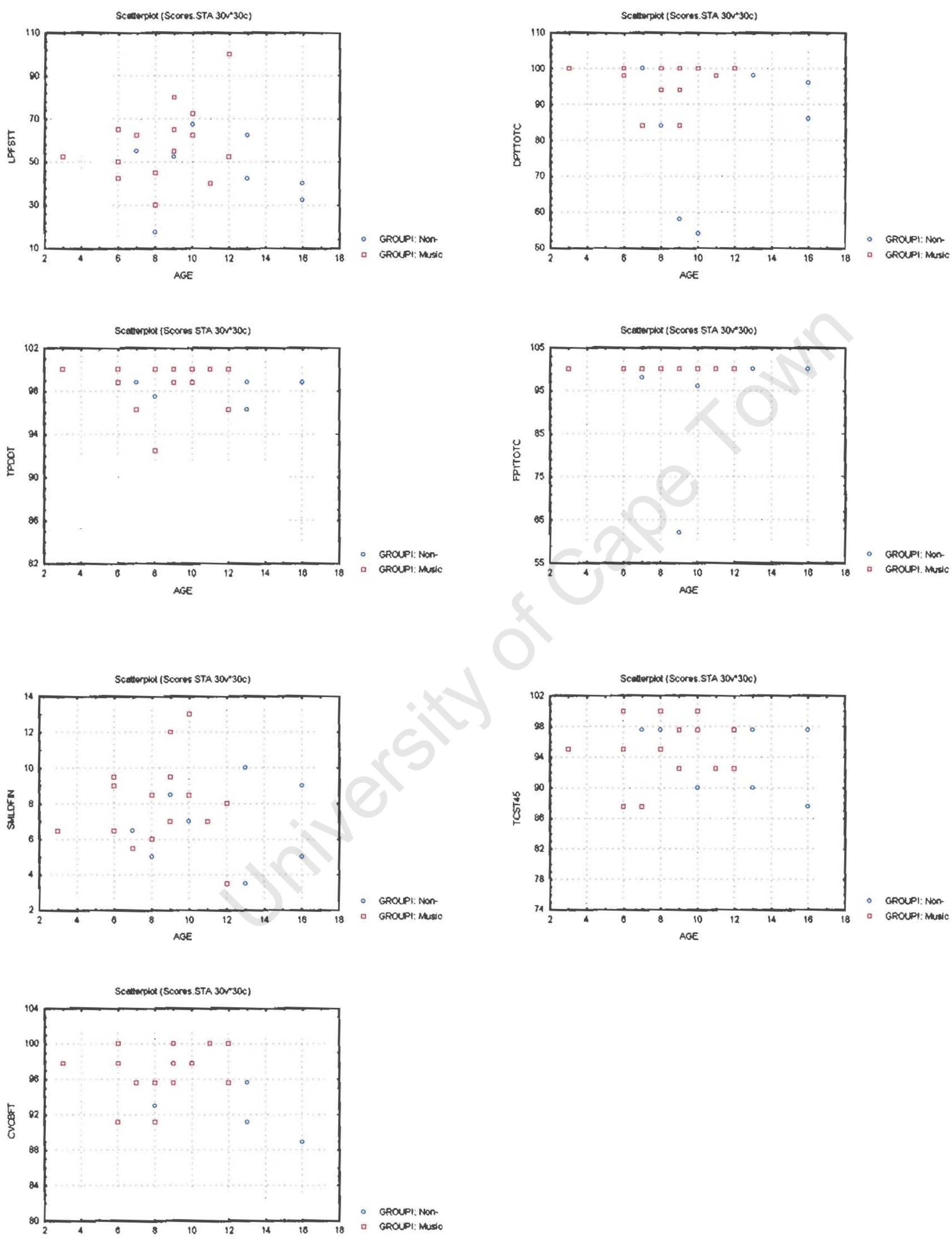

Figure 3.12: Effect of 'Age to Commence Music Training' on Test Performance

Interpretation: There were no significant correlations between the tests scores and 'age to commence music training', except for the CVC binaural fusion test. Here the correlation was -0.396 which was significant at the 6% level. This would indicate weak evidence for the test score to depend on age. However the correlation with age would only account for 16% of the variation in the test scores. This test showed a correlation of the same order with years of total training and years of recent training, but the discussion of outlying values (above) should be borne in mind when interpreting this association.
Clinical Implications: If valid, the above results suggest that music training may be effective - in producing improved performance on specific central auditory processing tasks (binaural fusion, auditory closure, interhemispheric integration) - when interventions occur between 3 and 16 years of age. This wide age-range may allow a greater number of clients to benefit from music training interventions.
Past studies: These findings are in contrast to certain previous studies, which suggest that earlier (rather than later) experience with musical stimuli may have a greater effect on development of auditory processing skills and cortical reorganisation (Pantev, Oostenveld, Engelien, Ross, Roberts, and Hoke, 1998). However, findings are supported by Katz and Wild (1994, 498), who found that auditory therapy was 'highly beneficial to older children and young adults as well.'

3.2.4 Effect of Gender on Test Scores

Two-way multivariate analysis of variance (Morrison, 1976) was used investigate the possible effects of gender on overall test results. The results of this statistical analysis are presented in table 3.5.

Table 3.5: Effect of Gender on Test Scores

Stat. General Manova	**Wilks' Lambda**	**Rao's R**	**df 1**	**df 2**	**p-level**
GROUP	0.48	3.09	7	20	0.02
GENDER	0.77	0.85	7	20	0.56
GROUPxGENDER	0.63	1.68	7	20	0.17
Summary of all Effects; design: (scores.sta)					

* df = degrees of freedom; p = significance level (reject Null Hypothesis if $p \leq 0.05$)

Statistical Analysis: Multivariate analysis of variance on the total scores from the seven tests showed that there were significant differences between the mean scores of the music and the control groups on some of the tests ($p= 0.02$), but that 1) these differences did not depend upon gender and 2) the interaction term was not significant ($p=0.56$ and $p=0.17$ respectively).

Interpretation: The variable of gender may be ruled out as a possible confounder, in the study results discussed in preceding sections.

Clinical Implications: It may not be necessary to consider gender effects during the interpretation of central auditory processing test results. Furthermore, the link between music training and improved performance on binaural fusion, auditory closure and interhemispheric integration tasks, may be generalised to both male and female subjects. The clinical implications discussed in section 3.2.1 to 3.2.3 may, therefore, be applied to male and female clients.

Previous studies: Past studies have found that central auditory processing disorders are more prevalent in males than females, and that differences in prevalence may be explained by structural differences in the corpus callosum of males compared to females (DeFries et al., 1990; Geschwind & Behan, 1982; DeLacoste-Utamsingh & Holloway, 1982; Witelson, 1989; in Katz & Wilde, 1994). Based on these studies, Katz and Wilde (1994) concluded that females may be able to integrate auditory information, from the two hemispheres, more effectively that males. However, current findings suggest that, in normal populations, there may be no significant difference in performance (on selected central auditory processing tasks) for females compared to males. Furthermore, past findings, related to prevalence of central auditory processing disorders, should not affect basic *interpretation* of findings on central auditory processing tasks (for either normal or disordered populations).

4. GENERAL DISCUSSION AND CONCLUSIONS

The primary outcomes of this study may be summarised as follows:

Compared to individuals who did not regularly sing or play a musical instrument (control group), individuals who regularly sang or played a musical instrument (experimental group) showed significantly better performance, on tasks involving binaural fusion of verbal stimuli, auditory closure of verbal stimuli, and interhemispheric integration involving verbal labelling of non-verbal auditory stimuli. Furthermore, these differences could not be attributed to the years of training, age at start of training or the gender of the subject. Significant differences in performance were not evident for tasks involving binaural separation and binaural release from masking, where auditory-verbal stimuli was involved.

A number of theoretical arguments may be made in support of the primary outcomes of this study:

Although a number of variables were controlled for, this study does not prove conclusively that significant differences in performance (between experimental and control groups) were due to musical training rather than to an innate perceptual predisposition. However, a number of interlinking theoretical arguments may support the efficacy of musical training. Firstly, significant differences in performance were evident in only a limited number of the given auditory tasks, rather than across the entire test battery. If test results were entirely due to an innate perceptual advantage in the experimental group, one might conclude that the same perceptual advantage which provided the experimental group with musical talent, allowed them to perform better on specific verbal and non-verbal auditory tasks. Furthermore, it would suggest that the processing of musical stimuli and the processing of auditory stimuli used in these tests (binaural fusion of verbal stimuli, auditory closure of verbal stimuli, and interhemispheric integration involving verbal labelling of non-verbal auditory stimuli), may be interlinked; thereby allowing perceptual advantage in one area to affect performance in another. If certain perceptual processes underlying musical and other auditory tasks are interlinked, one could conclude that changes affecting processing in one area may affect processing in other areas too. Thus, if any change or improvement were to occur in musical processing, similar improvements may automatically be witnessed inn processing of verbal stimuli. Finally, the proven existence of cortical plasticity supports the theory of alterations, in perceptual processing, in response to changes in perceptual input. As a logical result, music training may lead to improvements in musical perception and hence improvements in other specific auditory-verbal and non-verbal tasks (with shared underlying perceptual processes). Further studies may seek to identify whether certain individuals show limited cortical plasticity in response to musical stimuli.

A further issue to be raised is whether significant performance advantages, on the given auditory tasks, translate into significant effects in real life situations. Bellis (1996) states that interhemispheric interaction may occur at a supramodal level, with training in one modality or task, affecting performance in other modalities and tasks. Test results show significantly better performance, in the experimental group, on interhemispheric integration tasks involving verbal labelling of non-verbal stimuli. Based on Bellis (1996), it may be theorised that these performance advantages may be noticeable in a number of other tasks, both clinical and those related to real life situations (i.e. following verbal instructions). Further research may seek to confirm this theory and to quantify the exact nature of performance advantages in daily life. Further research may also be required to determine how the performance advantage on clinical tasks involving binaural fusion and auditory closure of verbal stimuli, may be translated into perceptual advantages in daily life situations. However, such research would require strict controls for the linguistic, semantic, and environmental cues that might contribute to improved performance independent of the individual's processing ability.

The area of CAPD remains largely a 'mystery' (Bellis, 1996, 277), with '...unlimited opportunities for clinicians wishing to contribute to the general bank of knowledge by engaging in research activities. Further study is needed in virtually all CAP-related areas, from identification to management and everything in between...' (Bellis, 1996, 275). This research need will only be met through the development and testing of new theories and hypotheses, and it is likely that new data will continue to raise more questions than it provides answers for. It is in this spirit that the researcher endeavoured to shed light on several clinically and theoretically related issues, while highlighting future research possibilities.

5. FINAL CONCLUSIONS

In conclusion, this study set out to provide objective evidence of the potential role of musical training, in the development of a variety of central auditory processes fundamental to the perception of speech and language. A more specific focus of the research was to determine whether adult listeners with a range of musical training, perform better on a battery of central auditory processing tasks, compared to non-musicians. Broadly, the researcher sought to determine whether exposure to listening tasks involving musical stimuli, was associated with improved performance on a variety of verbal and non-verbal auditory processing tasks.

To the best of the researcher's knowledge, the study was unique for the following reasons:

The study sought to identify and/or confirm the potential role of music training, in the development and enhancement of a variety of central auditory processes. Previously, music training (including singing and dancing) had only been recommended as an intervention in one of the four central auditory processing subtypes – integration deficit – identified by poor performance on temporal processing tasks requiring verbal report, and dichotic listening tasks (Bellis, 1996). Research outcomes confirm this recommendation and indicate that music training may also be applied to perceptual deficits present in other subtypes of central auditory processing deficit (output-organisation deficit and auditory decoding deficit). The study also sought to determine the relationship between music training and performance on a battery of behavioural test of central auditory processing. Furthermore, it sought to determine whether the processing of verbal stimuli requires processes, or models of processing, similar to those required for the perception of music.

Finally, the study sought to determine the effect of long-term music training (and lack thereof) on **individuals whose intellectual ability and central auditory processing abilities fell within the range of normal**. The study thus aimed to eliminate the confounding effects of past and present perceptual interventions, as well as the influence of disorders involving executive dysfunction, on central auditory processing test results.

Unlike Hillenbrand, Canter and Smith (1990), this study made use of test subjects with exposure to a wide range of musical training –**none had received intensive formal training** commencing before age 12 and continuing up until the time of testing. The length and intensity of the training period used during this research may thus be practically applicable to future research seeking to develop music therapy programmes (to be used in the treatment of central auditory processing disorders).

Major limitations of the study were as follows:

One downfall of this study may have been the selection criteria for the experimental group. Some members of the musically-trained group had not been exposed to training within the past 5 years, prior to being tested, despite meeting the criteria for inclusion in the experimental group. Past studies have found that certain trained auditory processing skills may regress after training ceases. Furthermore, this regression may occur as little as 6 months following training (Katz & Wilde, 1994). Thus a lack of correlation between musical training and performance on tests of binaural separation and binaural release from masking (where auditory-verbal stimuli was involved) may have been due to skills regression in the musically-trained group. Future studies should ensure that members of the experimental group continue to receive regular musical training up until the time of testing.

Due to the retrospective nature of the study the researcher was unable to account or control for exposure to non-structured listening activities (i.e. listening to the radio). Due to normal memory limitations, subjects would have been unable to supply information regarding the nature and frequency of exposure to such activities over their life span. However, due to the high rate of exposure to such activities over the broad spectrum of our modern society, (including individuals with CAPDs), it may be suggested that if such activities do enhance CAP, their effects are unlikely to be significant. This may be evidenced by the persistence of CAPDs in cultures with regular exposure to unstructured listening activities.

Regardless of exposure group, subjects may have scored poorly on the monaural low-redundancy speech task due to the presentation of word lists in an unfamiliar and foreign accent (word lists were recorded by American researchers) coupled with distorting filter techniques. Due to the questionable validity of the test stimuli, it is unlikely that these particular results can be used to draw any significant conclusions regarding the relationship between musical training and auditory closure for verbal stimuli.

Finally, when interpreting outcomes in the experimental group, it may not be possible to differentiate between those outcomes due to musical training itself, and outcomes due to innate perceptual ability (which may have led the individual to receive musical training). Future research will be required to control for such variables.

The following major clinical and future research implications have emerged from this research:

Musical training may not contribute significantly to improved performance on tasks involving binaural separation and binaural release from masking, where auditory-verbal stimuli is involved. Findings may have been due to the existence of distinct processing systems for complex auditory input, involving verbal versus non-verbal stimuli. It may also be possible that musical training does not affect performance for the above tasks when auditory input involves either verbal or non-verbal stimuli. It was therefore suggested that music training or therapy may not be an appropriate intervention in the treatment of central auditory processing disorders involving binaural release from masking, and binaural separation where auditory-verbal stimuli is used.

Musical training may significantly improve binaural fusion of verbal stimuli, auditory closure of verbal stimuli, and interhemispheric integration involving verbal labelling of non-verbal auditory stimuli. The processes of binaural fusion, auditory closure and interhemispheric integration (of auditory-verbal and non-verbal stimuli), may therefore involve similar and/or inter-linked processing systems. Music training or therapy may thus be an appropriate intervention in the treatment of central auditory processing disorders involving the above processes (i.e. integration deficit, output-organisation deficit and auditory decoding deficit).

'The plasticity of the human auditory system is inherent' (Kraus, McGee, & Koch, 1998, 12). Significant difference between specific test results for the experimental and control group may confirm the brain's ability to adapt in response to auditory training involving musical stimuli.

Research findings suggest the **exclusion of the Low Pass Filtered Speech task** (LPFSTT) (from the RSA CAPD Taskforce Disc 1 – 2001) from further research and clinical investigations involving South African populations. This speech task may have reduced reliability and validity in South African populations due to 1) the presentation of word lists in an unfamiliar and foreign accent (word lists were recorded by American researchers), as well as 2) the use of distorting filter techniques.

Differences between scores for left and right ears (on each test) were not found to be statistically significant, however **possible 'practise effects'** should be taken into consideration during interpretation of future test results (for research or clinical purposes).

Performance (on tests of binaural fusion, auditory closure, interhemispheric integration) **may reach a plateau** after a specified period of musical training – where further training does not result in improved performance on tasks. Further research may be required; to aid prediction of this 'plateau' in clients with central auditory processing difficulties. A knowledge of the possible duration of effective therapeutic interventions (involving musical training) is likely to aid development of management plans and efficient distribution of therapeutic resources.

'Age to commence music training' did not significantly affect test results, suggesting that music training may be effective - in producing improved performance on specific central auditory processing tasks (binaural fusion, auditory closure, and interhemispheric integration) - when interventions occur anywhere between 3 and 16 years of age. This wide age-range may allow a greater number of clients to benefit from music training interventions.

Subject **gender did not significantly affect performance** on selected central auditory processing tests, allowing the potential application of research findings and recommendations to both males and females.

Future studies should ensure that members of the exposed group continue to receive regular musical training, up until the time of testing, to control for the possible regression of auditory processing skills.

Further research is recommended to confirm the validity of the above findings and outcomes, by assessing the effect of musical training on populations with known central auditory processing disorders. Furthermore, research should determine the relationship between test performance in the clinical environment and perceptual functioning in daily life.

Future research involving 'normal' adult populations, may seek to separate the effect of innate perceptual ability from the effect of musical training. Such studies should make used of young adult subjects in order to eliminate the effects of normal maturation or degeneration of the central auditory system. Furthermore, studies may record test results prior and subsequent to a standardised musical training programme. Subjects should thus have no history of musical training prior to participation.

Multiple clinical and future research implications have thus emerged from this research, confirming the potential role of music training, in the development and enhancement of various central auditory processes, providing a therapeutic compromise between interest, enjoyment and motivation, and the need for structured presentation of auditory stimuli.

5. APPENDICES

APPENDIX A – Information Pamphlet

8 Sandown Grange
Ventnor Road
Claremont, 7700
Tel: 021-762 4736

To whom it may concern

Re: Central Auditory Processing Research

In partial fulfilment of my MSc Logopaedics, I am required to complete a research dissertation. I wish to undertake research in the field of central auditory processing. A brief summary of the proposed research is outlined (below), including the assessment procedures to be used.

Purpose of Research

Many individuals, across a wide spectrum of cultures, experience listening, learning and language difficulties as a result of Central Auditory Processing Disorder (CAPD). This complex and little known condition affects the brain's electrical response to various sounds and may result in a range of behavioural difficulties (involving the organising, monitoring, and understanding of sound signals). It has been suggested that music training may be useful in the development and remediation of particular central auditory processes. However, little research is available to confirm the relationship of music training to these processes. The purpose of this study is to assess performance of normal functioning adults, with musical training, on a variety of central auditory processing tasks, compared to adults without musical training.

Assessment Procedure

Assessment of central auditory processing requires the use of sophisticated test material, which has been developed in the United States. These tests involve listening to and identifying various recorded sounds, presented via headphones, in a soundproof audiometric booth. All sounds will be presented at safe listening-levels and no procedures will be painful or damaging. The entire assessment procedure will not last for longer than 1 hour.

Research Sample

All participants will be required to meet the following selection criteria:

- Normal hearing.
- English as a mother-tongue language.
- No history of learning disability, Attention Deficit Disorder, head injury, or known central auditory processing deficits.
- Not currently on any long-term medications which may have central nervous system effects.
- Normal intellectual abilities - having received mainstream schooling and some form of tertiary education.
- Adult (either male or female) between the ages of 18 and 40 years.

Research Procedures

All assessment results, birth dates, gender, and details of musical training will be tabulated in the final dissertation. Names and contact details will remain confidential. **Attached please find a subject consent form.**

Thank you for your contributions to my study.

Yours Sincerely

Monique Lund (Speech-pathologist/Audiologist)

APPENDIX B – Consent Form

- I, the undersigned, consent to participation in the above study - to be undertaken by Monique Lund (qualified speech-pathologist/Audiologist and MSc Logopaedics student from the University of Cape Town), and supervised by Dr Dale Ogilvy (lecturer employed by the University of Cape Town).
- I consent to participation in this study, only on the grounds that all personal information (names and telephone numbers) will remain confidential.
- I understand that all procedures are safe and that testing will take no more than 1 hour to complete.
- I understand that all testing will be completed, in a sound-proof audiometric booth, at the Department of Communication Sciences and Disorders, Groote Schuur Hospital.
- I understand that I may withdraw from the study at any time.
- Please call me at________________(landline) or _________________(Cell), to arrange a suitable time for testing.

Name: ______________________________________

Signature: ______________________________________

Date of birth ______________________________________

Musical Training ____

____

____

APPENDIX B – Subject Outcomes

GROUP	SUBJECT	FPT LC	FPT LR	FPT RC	FPT RR	FPT TOTC	FPT TOTR	TPDD L	TPDD R	TPDD T	DPT LC	DPT LR	DPT RC	DPT RR	DPT TOTC	DPT TOTR
Music	1	100	0	100	0	100	0	95	97,5	96,3	84	0	84	0	84	0
Music	2	100	0	100	0	100	0	100	100	100	84	0	84	4	84	2
Music	3	100	0	100	0	100	0	100	100	100	100	0	100	0	100	0
Music	4	100	0	100	0	100	0	100	100	100	100	0	100	0	100	0
Music	5	100	0	100	0	100	0	97,5	100	98,8	100	0	100	0	100	0
Music	6	100	0	100	0	100	0	100	100	100	100	0	100	0	100	0
Music	7	100	0	100	0	100	0	100	100	100	100	0	96	0	98	0
Music	8	100	0	100	0	100	0	95	97,5	96,3	100	0	100	0	100	0
Music	9	100	0	100	4	100	2	100	100	100	100	0	100	0	100	0
Music	10	100	0	100	0	100	0	90	95	92,5	92	0	96	0	94	0
Music	11	100	0	100	0	100	0	97,5	100	98,8	100	0	100	0	100	0
Music	12	100	0	100	0	100	0	100	100	100	100	0	100	0	100	0
Music	13	100	0	100	0	100	0	100	100	100	96	4	92	0	94	2
Music	14	100	0	100	0	100	0	97,5	100	98,8	100	0	100	0	100	0
Music	15	100	0	100	0	100	0	100	100	100	92	0	100	0	98	0
Non-	16	96	20	100	16	98	18	77,5	92,5	85	72	0	88	0	80	0
Non-	17	96	20	96	12	96	16	92,5	90	98,8	52	0	28	4	54	2
Non-	18	96	8	100	0	98	4	97,5	100	98,8	100	0	100	0	100	0
Non-	19	100	0	100	0	100	0	100	97,5	98,8	88	4	84	4	86	4
Non-	20	100	0	100	0	100	0	100	97,5	98,8	92	0	100	0	96	0
Non-	21	100	8	100	0	100	4	100	95	97,5	80	4	88	12	84	8
Non-	22	100	8	100	0	100	4	97,5	95	96,3	96	0	100	0	98	0
Non-	23	96	8	100	8	98	8	100	100	100	96	0	96	4	96	2
Non-	24	60	8	64	20	62	14	97,5	100	98,8	52	0	64	0	58	0
Non-	25	100	4	100	0	100	2	95	97,5	96,3	88	0	72	0	80	0
Non-	26	96	16	100	20	98	18	90	85	88,8	60	4	92	0	76	2
Non-	27	96	16	92	16	94	16	97,5	95	96,25	84	0	88	0	86	0
Non-	28	100	0	100	0	100	0	97,5	100	98,8	96	0	100	0	98	0
Non-	29	100	4	100	0	100	2	100	97,5	98,8	100	4	96	0	98	2
Non-	30	80	12	84	32	82	22	100	97,5	98,8	100	0	100	0	100	0

Table 3.1: (Cont.)

GROUP	SUBJECT	LPFSTL	LPFSTR	LPFSTT	CVCBFT	TCSL45	TCSR45	TCST45	SMLD SONO	SMLD SNNO	SMLD FIN
Music	1	70	55	62,5	95,6	90	85	87,5	43	37,5	5,5
Music	2	60	50	55	97,8	100	95	97,5	43	31	12,0
Music	3	70	60	65	91,1	95	80	87,5	50,5	41,5	9,0
Music	4	55	50	52,5	97,8	95	95	95	47,5	41	6,5
Music	5	55	30	42,5	100	95	95	95	46	39,5	6,5
Music	6	40	50	45	91,1	95	95	95	36	30	6,0
Music	7	30	50	40	100	85	100	92,5	42	35	7,0
Music	8	40	65	52,5	100	100	95	97,5	43	35	8,0
Music	9	50	75	62,5	97,8	100	100	100	42	33,5	8,5
Music	10	25	35	30	95,6	100	100	100	42,5	34	8,5
Music	11	80	80	80	95,6	100	95	97,5	39	29,5	9,5
Music	12	100	100	100	95,6	90	95	92,5	44,5	41	3,5
Music	13	65	65	65	100	95	90	92,5	43	36	7,0
Music	14	60	85	72,5	97,8	100	95	97,5	42,5	29,5	13,0
Music	15	55	45	50	97,8	100	100	100	43	33,5	9,5
Non-	16	40	40	40	93	16	18	34	43,5	34,5	9,0
Non-	17	70	65	67,5	97,8	18	18	36	38	31	7,0
Non-	18	55	55	55	95,5	19	20	39	43	36,5	6,5
Non-	19	45	35	40	88,9	20	19	39	45,5	40,5	5,0
Non-	20	25	40	32,5	88,9	16	19	35	50	41	9,0
Non-	21	25	10	17,5	93	20	19	39	43,5	38,5	5,0
Non-	22	55	70	62,5	95,6	20	19	39	54	44	10,0
Non-	23	50	55	52,5	91,1	17	18	35	44,5	36	8,5
Non-	24	45	55	52,5	97,8	17	20	37	44,5	36	8,5
Non-	25	65	65	65	97,8	20	19	39	42	34	8,0
Non-	26	60	75	67,5	100	20	18	38	37,5	30	7,5
Non-	27	50	45	47,5	93	18	17	35	45	40	5,0
Non-	28	40	45	42,5	91,1	18	18	36	38,5	35	3,5
Non-	29	75	55	65	97,8	17	18	35	34	27,5	6,5
Non-	30	30	30	30	82,2	14	17	31	40	34,5	5,5

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