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DEPARTMENT OF SPEECH PATHOLOGY AND AUDIOLOGY

THE EFFECTS OF AIRCRAFT NOISE ON THE AUDITORY LANGUAGE PROCESSING ABILITIES OF ENGLISH FIRST LANGUAGE PRIMARY SCHOOL LEARNERS

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A research dissertation submitted for the degree of Master of Audiology in the Department of Speech Pathology and Audiology, Faculty of Humanities, School of Human and Community Development.

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Declaration

I, Cara Hollander, hereby declare that this submission is my own original work and that the assistance that I have received is detailed in the acknowledgements of this report. To the best of my knowledge and belief, this submission contains no material which has been accepted for the award of any other degree or diploma at any other university or institute of higher learning, except where due acknowledgement or reference has been made in the text. I am responsible for the study and conclusions reached

_____ _____

Cara Hollander Date

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conclusions or recommendations expressed in this material are those of the authors and therefore the NRF does not accept any liability in regard thereto.

List of Abbreviations

AP	Auditory Processing
CAP	Central Auditory Processing
LP	Language Processing
CAPD	Central Auditory Processing Disorder
APD	Auditory Processing Disorder
CN	Cochlear Nucleus
MOCB	Medial Olivocochlear Bundle
TEOAE	Transient Evoked Otoacoustic Emissions
CAS	Contralateral Acoustic Stimulation
OAE	Otoacoustic Emission
CANS	Central Auditory Nervous System
MRI	Magnetic Resonance Imaging
ASHA	American Speech and Hearing Association
ALP	Auditory Language Processing
ALPD	Auditory Language Processing Disorder
IQ	Intelligence Quotient
LPD	Language Processing Disorder
LLI	Language Learning Impairment
JCIH	Joint Committee on Infant Hearing
HIV	Human Immunodeficiency Virus
AIDS	Acquired Immune Deficiency Syndrome
UNICEF	United Nations International Children's Emergency Fund
UNAIDS	Joint United Nations Programme on HIV/AIDS
PPS	Pitch Pattern Sequence Test
DPT	Duration Pattern Test
CES	Competing Environmental Sounds Test
MLD	Masking Level Difference
TAPS	Test of Auditory Perceptual Skills
PhAB	Phonological Assessment Battery
PA	Phonological Awareness
SNR	Signal to Noise Ratio
OSHA	Occupational Health and Safety Act
Hz.	Hertz
ASDS	Aircraft Sound Description System
SPL	Sound Pressure Level
fMRI	Functional Magnetic Resonance Imaging
MCL	Most Comfortable Level
FM	Frequency Modulated
NIHL	Noise Induced Hearing Loss
SNHL	Sensorineural Hearing Loss
ANSI	American National Standards Institute
SANS	South African National Standard
EFL	English First Language
RANCH-SA	Road Traffic and Aircraft Noise and Children's Cognition and Health-South Africa
LEQ	Average Sound Levels
ANOVA	Analysis Of Variance

ESOL	English Second or Other Language
ASA	Acoustical Society of America

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Abstract

The purpose of the research was to investigate the effects of aircraft noise on the auditory language processing abilities of English First Language (EFL) primary school learners. Schools located in close proximity to airports are exposed to extremely high levels of chronic, yet intermittent noise. These levels have been shown to cause cognitive, health and hearing problems. However, it is unsure whether this long term exposure to these noise levels may cause auditory language processing problems when hearing is normal, which could result in decreased academic performance. This study utilised a non-experimental, cross sectional and descriptive design, as well as a post-hoc design. Seventy children attending schools that are exposed to high levels of noise were matched according to socio-demographic characteristics to seventy children in quieter schools. All the schools were situated in Durban, South Africa, while the noisy schools were located 1.7 km and 1.9 km from the airport and the quieter schools were 4.6km and 3.5km from the airport. All participants are EFL, have attended the respective schools from grade 1, have hearing within normal limits, are in grade 6 or 7, are 12 years or younger, and have no pre-diagnosed learning, auditory or attention problems. Audiological screening and auditory language processing assessments (subtests of the TAPS, PhAB and the Dollaghan and Campbell task) were undertaken. This study utilised various types of statistical analyses, including descriptive methods, Pearson's chi-squared tests, Fisher's tests, three-way ANOVAs, Cramer's V tests and Cohen's D tests. The results from the schools that are exposed to noise have scored below average in all the auditory processing subtests. This study aimed to provide evidence that not only can hearing be affected by noise, but so too can the processing of sounds, even when hearing is normal. The results of this study are hoped to serve as a motivation for the provision of speech-language therapy and audiology posts within mainstream legislation with regard to schools due to the large amount of children with auditory language processing difficulties in both noisy and quieter schools, as well as for

noise treatment surrounding airports and appropriate to zoning of schools around airports to help and prevent this chronic noise interrupting the development of auditory language processing abilities and thus in turn affecting learning.

Keywords: Noise, Airports, Auditory Language Processing

CHAPTER 1

Background and Literature Review

Background

Auditory processing difficulties have shown to cause scholastic problems (Cacace & McFarland, 1998). Chronic noise exposure has been studied and yielded results that indicate that noise can have a negative effect on some auditory processing skills (Maxwell & Evans, 2000). However there has been very little research on the effect of long term aircraft noise exposure on the auditory processing skills of children, when hearing thresholds are within normal limits. Central auditory processing is the interpretation of the auditory signal from the peripheral auditory system until the auditory cortex. Language processing is the further analysis of this signal inside the auditory cortex, where meaning is attached to the signal (Richard, 2001). As processing encompasses the transfer of the signal from the peripheral auditory system, up and including the interpretation in the auditory cortex, the combination of central auditory processing and language processing can be termed auditory language processing. Airports are notoriously noisy environments and already in 1974, Crook and Langdon demonstrated that noise levels within schools near airports in London peaked at or above 70 dB (A) with at least one out of every four flights. Therefore, the primary aim of this research was to investigate the effects of long term aircraft noise exposure on the auditory language processing abilities of English First Language primary school learners. This will be discussed in greater detail in the following chapters.

Literature Review

Processing

Processing of an auditory signal has been described as “the ability to abstract meaning from an acoustic stimulus” (Masaro as cited in Richard 2001, p 12). This processing includes auditory processing and language processing. A pure processing disorder is not necessarily only the result of neurological problems, hearing problems, motor speech disorders or

emotional disabilities (Richard, 2001). However, the above-mentioned disorders can cause or contribute towards a processing disorder (Starr, Picton, Sininger, Hood, Berlin, 1996; Bellis, 2002). The consequences of these processing problems may be difficulties with reading, spelling or other learning problems. There are two models that can be used to describe processing, namely the bottom up and top down models (Richard, 2001).

The auditory processing of information is generally described in terms of the 'bottom up' model. This definition implies that the processing is mainly due to the organisation and interpretation of the signal which progresses along all the anatomical structures, including the external auditory meatus, middle ear, cochlea, auditory nerve and up to the auditory cortex. Accurate processing requires intact auditory signals to pass accurately through the peripheral auditory system.

Thus, the peripheral system is required to collect, organise and channel the acoustic stimuli from the environment through to the central auditory system to allow for the interpretation of this organised information (Bellis, 2002). Although there is much disagreement regarding the definition of auditory processing, Geffner and Ross-Swain (2007) state that the current thinking is that auditory processing encompasses the entire auditory system and its related processes. Thus, this model requires the tonotopic organisation in the cochlea, where the sounds are arranged along the basilar membrane according to its frequency, as well as further interpretation of the signal in the central auditory system. The tonotopic organisation in the cochlea occurs when the nuclei respond to the high frequencies at the basal section of the cochlea, while the low frequencies begin processing in the apex of the cochlea (Loeb, 1986).

This 'bottom-up' definition of auditory processing utilises all the auditory system mechanisms that are involved in sound localisation and lateralisation, auditory discrimination, pattern recognition and auditory integration. Thus, an auditory processing disorder, according to this model, can be a result of a malfunction in any area of the auditory pathways (Bellis, 2002), whether it be peripheral or central.

In contrast to this description, the 'top down' model is generally used to describe language processing. This model describes the processing of auditory stimuli to form part of a higher neuro-cognitive process. This representation employs the higher function to integrate auditory stimuli and to provide meaning to these signals (Bellis, 2002). According to this description, the processing of an acoustic stimulus is a complex process and can be described as the search for meaningful organisation of the auditory signal (Cooke, 1993). To distinguish from the 'top down' representation, the 'bottom-up' model makes use of the peripheral and central auditory pathways, while the 'top-down' model utilises the cortical structures to process and interpret sound (Richard, 2001).

Richard (2001) stated that processing involves movement of the auditory signal back and forth between the auditory features, as well as the language features of the signal. This movement occurs so that meaning is obtained from this sound. Put differently, processing takes place on a continuum, commencing at a level of pure auditory processing, then transitioning to a mix of both auditory and language processing, and ultimately ending in pure language processing.

Therefore, it seems probable that if a learner has any type of cognitive or language processing disorder, there may be some sort of deficit at the auditory processing level.

However, this should not imply that every child with a language disorder has an auditory processing problem or that there is a need for auditory interventions.

Alain, Arnott and Picton (2001) also explained that distinguishing auditory signals involves a widely distributed neural network that includes both bottom up and top down processing. Many auditory signals have linguistic elements and the learners are required to obtain these signals and provide meaning to this speech in order to learn. The concept of auditory processing in this project is grounded by the combination of these two models, i.e. sound is processed up, from the external auditory meatus to the cortex, while in conjunction, these signals are also being organised at the level of the cortical structures to provide meaningful information.

Central Auditory Processing

Auditory Processing (AP) includes both Central Auditory Processing (CAP) as well as Language Processing (LP). Central Auditory Processing is described to occur beyond the peripheral auditory system. However, in order for the full auditory signal to reach the central auditory system, an intact peripheral system is necessary. Thus, assessment of the peripheral system is essential in order for accurate diagnosis of a central auditory processing disorder (CAPD) (Richard, 2001). Although the peripheral system is essential for processing, it is generally not considered to be the source for auditory processing disorders, unless the subject is hearing impaired. However, Muchnik, Roth, Othman-Jebara, Putter-Latz, Shabtai and Hildesheimer (2004) explain that a common complaint of children with Auditory Processing Disorders (APD) is difficulty understanding speech in the presence of background noise, such as in a noisy classroom. This ability to process speech within background noise is essential for a learner as the learner frequently confronts this difficulty in the classroom. However, the

source of the difficulty of processing auditory signals, especially in noise, may arise from various sources.

The central auditory system comprises of many complex structures. CAP occurs beyond the peripheral auditory system and requires an intact peripheral auditory system to transmit the signal along the auditory pathway to the brain where it passes from the auditory nerve to the cochlear nucleus (CN), then continues to the superior olivary complex, through to the lateral lemniscus to the inferior colliculus. The signal continues through to the medial geniculate body of the thalamus and then reaches the auditory cortex (Katz, Stecker & Henderson, 1992; Phillips, 2007).

In addition to the above mentioned structures, the medial olivocochlear bundle (MOCB) has also been shown to assist with hearing in noise, and thus plays a part in processing. This has been observed in evidence from animal and human studies (Muchnik, et al., 2004). As the MOCB projects the nerves into the cochlea, the MOCB function was thus evaluated by the suppression effect of the transient evoked otoacoustic emissions (TEOAE) in response to contralateral acoustic stimulation (CAS). The otoacoustic emission (OAE) suppression effect is an objective technique to assess the functional integrity of the medial efferent system and is used to diagnose abnormalities within the MOCB (Girolamo, Napolitano, Alessandrini & Bruno, 2007). These suppression effects are larger as OAE levels decrease, indicating the activity level of the outer hair cells in the cochlea, generally indicating a hearing loss. Testing for OAE suppression may help to evaluate and diagnose difficulty to understand and discriminate speech in noise and thus this test can be used to evaluate hearing in noise. The efferent responses of OAE suppression originate in the superior olivary complex and are recorded in the outer ear (Lautenschlager, Tochetto & Costa, 2011). This suppression effect of TEOAEs was evaluated by comparing the TEOAE levels

with and without CAS. TEOAEs were significantly suppressed in response to the contralateral acoustic stimulation in the children with an AP deficit. There appears to be less hair cell function when children with APDs are exposed to contralateral stimulation, which can translate into children having difficulty hearing in noisy situations (Muchnik, et al., 2004). These noisy conditions are prevalent in the classroom, particularly in the South African public schools where the classes may have over thirty five children in one classroom. Thus, difficulty may arise in hearing and interpreting the teachers' instructions, while other children may be speaking or performing other activities. This suppression may appear that a child is struggling to hear, where in fact, there is an APD. Therefore, this seems to highlight the even deeper complexity and variability of sources of an auditory processing deficit. This confirms the necessity of evaluating the entire auditory system for the correct treatment of an APD of a learner.

The complexity of auditory processing is further observed when understanding the processing of high intensity signals. Auditory fibres of the brainstem are stimulated at a higher rate as the sound intensity increases. Large intensity increases cannot be encoded by individual nerve fibres and thus, at high intensities, many neurons help to achieve accurate coding. The latency of the brainstem neuronal responses depends on the type of stimulus being processed. Some neurons react quickly to a stimulus, while some have longer latency periods. Some neurons only respond upon the termination of the signal (Katz, Stecker & Henderson, 1992). As processing is complex in the central system, disturbances can occur at any level. The presence of environmental hindrances, such as noise, may possibly cause a disruption of accurate stimulation of nerve fibres in this already complex system.

As mentioned, the central auditory system is responsible for transferring auditory information from the brainstem to the cortex. Therefore, if compromised signals are

presented and accurately interpreted at the level of the brain or if the signals are accurately interpreted under stressed situations and still reach the auditory cortex, it may be assumed that the CAP abilities are normal. A CAPD is when the auditory stimulus becomes distorted or compromised before it reaches the language centre in the temporal lobe. Thus, the purpose of a central auditory processing assessment is to evaluate the brainstem and cortical function by stressing the auditory system or making the task more difficult, by eliminating or reducing redundancy (Richard, 2001). Redundancy can be described as superfluous repetition, or the overlapping of information, which, when presented may not be necessary to obtain the meaning of the message.

Redundancy is explained according to internal and external redundancy. External redundancy can be observed as the stimuli are usually represented bilaterally. The internal redundancy is provided by the crossover points to symbolize the acoustic message bilaterally several times during the neurological transfer to the cortex (Richard, 2001). CAP assessment involves reducing the redundancy in the signal which thus compromises what the central auditory nervous system (CANS) receives. However, the peripheral auditory system first needs to be assessed, and only thereafter can CAP evaluation begin (Richard, 2001).

The central auditory system allows a listener to endure a degree of inconsistency in an auditory signal, because of this built-in redundancy in the auditory pathway. A listener with normal CAP can listen to a signal, and fill in the missing segments using their prior language knowledge. Therefore, an individual with a CAPD might respond to signals appropriately, however, when the signal is degraded, the problem occurs (Richard, 2001).

Long latency auditory event evoked potentials have also shown to be a useful way of assessing this central pathway. Auditory evoked potentials are electrical responses of the

nervous system evoked by sound. Long latency responses occur at latency beyond 75 milliseconds. Each waveform should typically occur in a specified millisecond range (Gelfand, 2001). The P waveforms refer to positive voltage, or an upward deflection of the wave, while the N refers to negative voltage of the wave, or downward deflection (Hall & Meuller, 1997). The N1 wave typically occurs between 80 to 150 milliseconds, with the P2 wave appearing between 145 and 180 milliseconds, and P3 waveform emerges between 220 and 380 milliseconds (McPherson, Ballachanda, & Kaf, 2007). Jirsa and Clontz (1990) presented in their research that there was a significant latency increase for the N1, P2, and P3 components in the researched group with processing problems when compared to the group without processing deficits. Furthermore, the inter-peak latency interval P2-P3 was significantly longer in the clinical group. In terms of amplitude measures, only P3 amplitude differed significantly between groups with AP problems. These results suggest that the long latency potentials may be useful in the assessment of children with processing disorders. This study again points to the involvement of the central pathway in an APD, and the usefulness of this area of assessment.

Language Processing

Language processing, in comparison to CAP, begins once the auditory stimulus reaches the temporal lobe, specifically the left temporal lobe. Thus, LP occurs after CAP. The processing of language is the ability to attach meaning to an auditory signal using linguistic knowledge. The language centre for majority of the population is dominant in the left hemisphere (ASHA, 1997). Thus certain structures such as the Heschel's Gyrus, Angular Gyrus as well as Broca's area are larger in this hemisphere. This model also utilises the primary, secondary and tertiary zones of the brain to progressively attach meaning to the auditory signal (Richard, 2001). The processing of speech and language involves processing the signal as particles (each individual sound), relying on knowledge of the field by using

contextual cues in perception, as well as the stream by combining each particle into a wave of speech (Katz, Stecker & Henderson, 1992).

The primary zone receives the information into the primary area of the temporal lobe (Brodman area 41 and 42 or Heschel's Gyrus). Here the sound undergoes detailed processing and discrimination of its primary features. Impairment at this level may be described as a sensory impairment, not a higher-order processing impairment. The signal then moves onto the secondary zone where meaning is attached to the signal coming from the primary zone. The secondary zone entails Brodman area number 21 and 22. Brodman area 22 contains the Wernicke's area. This zone is responsible for the decoding, organisation, association with pre-existing information as well as the storage into memory for further use. Here, stimuli are integrated into meaningful experiences. The signal is further processed in the tertiary zone in the temporal lobe where the stimulus is integrated with old information as well as with other cortices. The structure here is the Angular Gyrus, which integrates stimuli with multiple other structures in the brain. This is also where the neurological system transfers from a passive receptive mode of processing to an expressive output (Richard, 2001). The following figure is a summary and a visual representation of the information based on the description by Richard (2001) (see Figure 1).

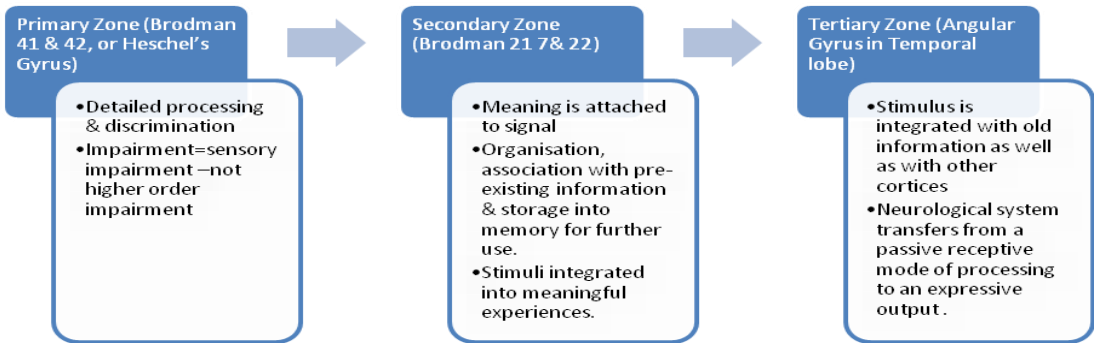


Figure 1. Flow diagram of primary, secondary and tertiary zones.

Research supports the notion that the LP structures undergo neuro-maturation from the primary through to the tertiary zone. Heschl's Gyrus is the primary zone for processing and develops first. Myelinisation of the other zones takes place at a later stage. The connections between the Angular Gyrus and Broca's area are the last to myelinate completely. This could explain the difficulty that children with processing problems might have with coordinating an expressive response quickly and accurately after receiving the auditory information. The accuracy of the output from the neural connections between receptive and expressive systems may be questionable in these children (Richard, 2001).

Reading is a skill which has an underlying linguistic basis, and thus activates the language areas of the cortex. In a study by Tallal (1980), reading-impaired and non-reading impaired children were given an experimental battery of nonverbal auditory perceptual tests which examined discrimination and temporal order perception. Stimulus tones were presented at various rates to these children. The results showed no significant differences between groups on the tests in which stimuli were presented at slow rates. However, when these same tones were presented more rapidly, the reading-impaired group made considerably more errors than the controls. The reading-impaired children's ability to use phonics skills (nonsense word reading) was also investigated. There was a high correlation between the numbers of errors made on the phonics reading test to the amount of errors made in response to the rapidly presented tones in the auditory perceptual tests. This shows that some reading impairments may be related to low-level AP dysfunction. This supports the model that auditory processing includes LP as well as CAP and that the two appear to be interrelated.

Auditory Language Processing

The British Society of Audiology (BSA) (2011) describes auditory processing to include both afferent and efferent pathways in the auditory system, as well as higher level

processing that provides 'top-down' modulation of such pathways. The American Academy of Audiology (AAA) (2010) refers to auditory processing as the perceptual processing of auditory information in the central nervous system and the neurobiologic activity that underlies that processing and gives rise to the electrophysiologic auditory potentials. This definition mostly describes central auditory processing, and thus AAA (2010) uses the term CAP. Bellis (2003) also describes auditory processing to be fundamentally auditory and thus relates it to 'bottom up' processing, and refers to CAP in contrast to AP or ALP. This research however is leaning toward the BSA definition in contrast to the AAA understanding. As described above, in order for a signal to be understood and for meaning to be attached, it needs to pass through the central auditory system (Katz, Stecker & Henderson, 1992; Phillips, 2007; Richard, 2001) where it undergoes processing. The signal then continues into the Heschl's gyrus, Brodman's areas 21 and 22 as well as to the Angular gyrus where the signal is further processed and meaning is attached and integrated (Richard, 2001). Therefore, it is evident that processing occurs up to and including the auditory cortex, and not only involving the central auditory system, and thus the understanding of the BSA of auditory processing was adopted in this dissertation.

This complex neural basis of the processing of acoustic stimuli, including both the bottom up and top down models, can be observed with magnetic resonance imaging (MRI). Poldrack, et al. (2001) investigated the neural basis of AP in comparison to phonological processing. As AP is seen to be a complex task, including a variety of skills, for example hearing, phonological awareness, auditory memory, and phonological memory and so on, the aim of this study was to examine how the brain responds to speech and to establish whether the same regions are also involved in phonological and language processes associated with reading. After subjects performed a sentence verification task with recorded speech, while being monitored with a functional MRI (fMRI), it was found that a subset of the left inferior

frontal regions involved in phonological processing in reading are also sensitive to acoustic features within the range of comprehensible speech.

Thus, it is evident that the processing of auditory and language signals overlaps greatly and cannot always be distinguished as separate entities, highlighting the value of the combination of CAP and LP in understanding speech processing. According to an American Speech and Hearing Association (ASHA) (2005) technical report, APDs can be described as difficulties in the processing of auditory information in a perceptual manner. This can be observed by decreased performance in one or more of the following tasks: auditory discrimination, temporal aspects of audition, auditory pattern recognition, auditory performance in competing acoustic signals, and auditory performance with degraded acoustic signals.

This displays the combination and overlap of language processing as well as central auditory processing, directing towards the idea of *auditory language processing* (ALP) (DeBonis & Moncrieff, 2008). As some of the areas responsible for auditory or language processing are also responsible for reading, we can see that a disorder in auditory language processing may be linked to a disorder in reading. By grade 3, there is a shift from learning to read to reading to learn (Owens, 2004). Therefore, the detection and understanding of an auditory language processing disorder (ALPD) can be regarded paramount, as well as the understanding of how environmental noise, such as continuous, yet intermittent aircraft noise can contribute to a possible ALPD.

As seen above, speech comprises of acoustic signals that reach the external ear. As soon as the sound enters the external auditory meatus, it passes through to the middle ear and then to the cochlea. It is here that the early stage of analysis begins. This acoustic

information is then transmitted from the eighth cranial nerve (vestibulocochlear nerve) to the ventral nucleus of the medial geniculate complex. As the acoustic signal is relayed to the brainstem, CAP begins. The message passes to a core of three primary or primary-like areas of the auditory cortex that are cochleotopically arranged and are highly responsive to pure tones (Cooke, 1993). This cochleotopic organisation implies that each hair cell has a most sensitive frequency. Auditory material is then distributed from the core areas to a surrounding belt of about seven areas that are less precisely cochleotopic and generally more responsive to complex stimuli, such as speech sounds, in comparison to tones. This cochleotopic representation illustrates how intricate and detailed the processing system is involving structures from the peripheral system up to and including the auditory cortex. Recent studies specify that the belt areas relay to the rostral and caudal divisions of a parabelt region at a third level of processing in the cortex lateral to the belt. These two regions have supplementary inputs from dorsal and magnocellular divisions of the medial geniculate complex and other parts of the thalamus. The belt and parabelt regions also seem to be concerned with integrative and associative functions involved in pattern perception and object recognition. The parabelt fields join with regions of the temporal, parietal, and frontal cortex that mediate additional auditory functions, including space perception and auditory memory (Kaas, Hackett & Tramo, 1999).

This processing from the time that the sound reaches the cortex can be named language processing (Richard, 2001). Hence, from this study by Kaas, Hackett and Tramo (1999), it is evident that the processing of speech includes CAP ability as well as LP ability. However, as mentioned above, LP occurs after CAP. Thus, if the later stage of processing such as the processing of language is within normal limits, one can assume that the earlier stage of CAP is normal. As information has to pass through the entire central auditory system as well as through the brain, it can be seen that the auditory processing of language makes use

of both models. It is important to note that the processing of some acoustic signals that does not include speech, such as music, does not use the LP system, but still relies on the central system. Processing in this case would take place on the right hemisphere (in most cases) (Tallal in Levinson & Sloan, 1980).

However, with regard to speech, the auditory system needs to integrate the component parts of the signal into structures that can be interpreted to meaning. As the signal can arise from different acoustic sources, the auditory system needs to determine which of the decomposed elements have arisen from which individual source (Cooke, 1993). Thus, AP does have a linguistic load as described earlier. Therefore, again, it is possible to assume that the processing of speech signals can possibly be referred to as *auditory language processing* (ALP) (see Figure 2).

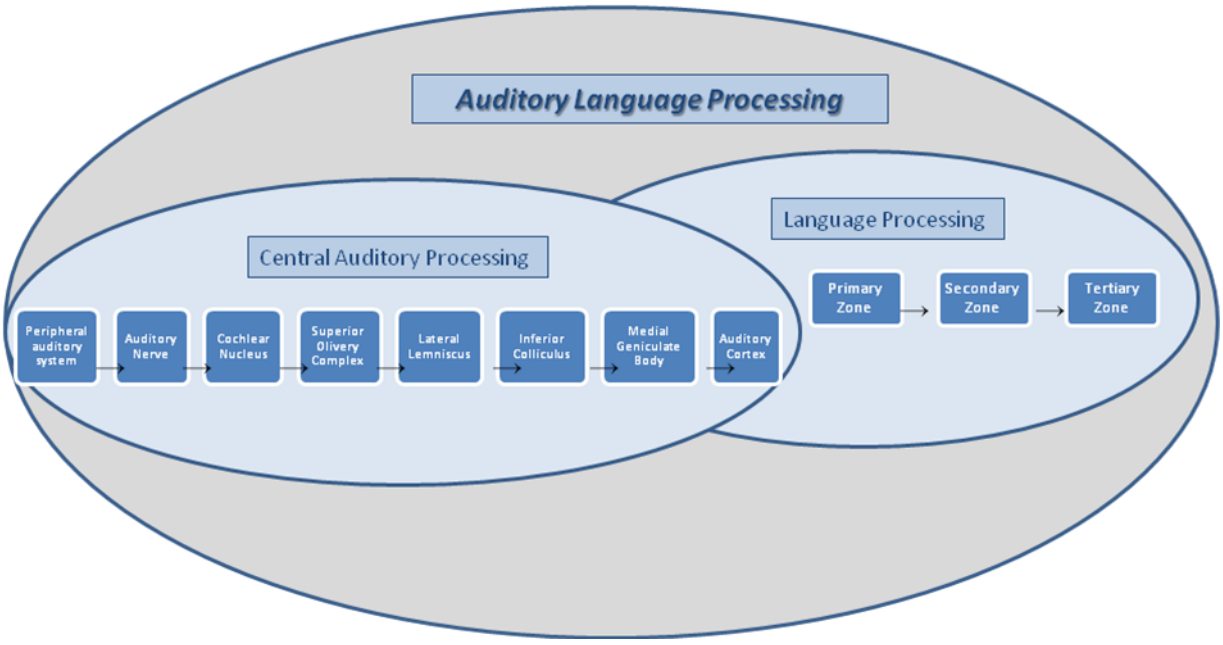


Figure 2. Auditory language processing

Signs and Symptoms of the Disorder

As ALP is the interpretation of acoustic signals, an ALPD is the lessened ability to understand and interpret this auditory information. There are various signs and symptoms of

this disorder, which demonstrate the decreased ability to comprehend these auditory signals. South Africa is a multilingual society and there are many ESL speakers. One must be vigilant to not confuse the language characteristics seen in ESL children to the symptoms of children with pure ALPDs in their first language, such as in English first language speakers. Therefore if an ALP test was standardised on EFL learners, it is essential to note that the reliability of the test will be compromised if it is performed on ESL speakers (Gardner, 1985). These signs and symptoms of an ALPD can vary drastically, depending on the degree of the disorder and the individual child affected (Geffner & Ross-Swain, 2007). The signs and symptoms of CAPDs and language disorders often overlap. Some may also be signs of other learning problems. Processing difficulties are often a part of other disorders, and can thus be part of a continuum of impairments. The behaviours associated with CAP problems are described separately to LP problems; however there is often considerable overlap (Richard, 2001). The difficulties that a child with an ALPD may have can be seen in various other disorders such as learning disorders and so on. Therefore, to differentially diagnose an ALPD from a learning disorder can be difficult. A child with a learning disorder will exhibit these difficulties in a general manner; in that they are likely to display a multitude of the difficulties that will be described below (Bellis, 2002). A child with a learning disorder will likely struggle with auditory and visual stimuli, yet a child with an ALPD will more likely struggle with purely auditory information. However, this can lead to further difficulties, such as with reading. An ALD disorder can therefore be very difficult to diagnose, and a variety of tests must be carried out to for an accurate diagnosis. It is important to be aware that although the symptoms of ALPDs and learning disorders can overlap quite significantly and that they often co-occur, they can also occur as discrete phenomena, and thus careful consideration when testing should be made. The population at risk for ALPDs often demonstrates typically developing intellectual potential and is approximately age-commensurate in language acquisition measurements. An ALPD, specifically occurring at the language processing level, is difficulty

accessing language ability already acquired and efficiently integrating those basic foundation language skills to formulate more complex thoughts and responses. A language processing disorder can often occur as a component or subtype of learning disorders and other language impairments (Richard, 2001).

Auditory language processing problems can manifest in several ways. In some instances, a person with an ALPD is aware of his/her difficulty with listening and understanding signals that is exacerbated by certain situations or environments. Such an environment may be a noisy area, such as a restaurant or classroom. However, with other people, the actual difficulties that arise from ALPDs are much more subtle, such as disturbances with learning, language, spelling, reading, socialising and problem solving skills (Bellis, 2002). This also depends on the severity of the disorder. Bellis in Musiek and Chermak (2007) estimated that half of all children identified with a learning disorder exhibit an ALP disorder. An ALPD is estimated to occur in 2–3% of children (Martin & Clark, 2003). With regard to ALP problems, children often have normal intelligence and hearing within normal limits. Although multiple behaviours and characteristics of an ALP disorder will be described further on in this document, it is unlikely that the affected children will match all the characteristics (Richard, 2001).

There are conditions that often co-occur with an ALPD, particularly attention deficit hyperactivity disorder. The diagnosing audiologist needs to be aware of these conditions as they may be contributing tremendously to the impact of the ALPD. Other known co-morbid problems can, but do not always, include reading impairment, difficulty with written language, nonverbal learning disorder and neurobiological disturbances such as anxiety problems, selective mutism and obsessive compulsive disorder. However, an ALPD may also cause difficulties such as with reading and written language. These overlapping disorders may

also consist of depression and bipolar disorder, Tourette's disorder, Asperger's disorder and sensory integration dysfunction (Geffner & Ross-Swain, 2007). It is important to be aware of these possible co-existing disorders in order to thwart misdiagnosis of the underlying ALP deficit and to not overlook the appropriate ALPD assistance.

When assessing a child for an ALPD, the areas that processing disorders can affect must be examined. These areas, such as reading difficulties, are often signs of the primary ALP disorder. Jerger and Musiek (2000) claimed that deficits in ALP likely cause difficulty in understanding speech with background noise, understanding degraded speech signals, and trouble with speech discrimination. They mentioned that although an ALPD may coexist with other disorders, they may not be causative of these disorders.

However, in contrast, Katz, et al. (2002) stated that an ALPD may be causative to speech and language deficits, dyslexia and attention deficit disorder. ASHA (2005), on the other hand, states that CAPDs are extremely complex, and thus it is difficult to completely demonstrate the causal link between the ALPD and other impairments. Bellis (2002) further described that language or learning problems are extremely complex, involving entire systems, from the ear to the highest level of thought and attention, relying on the integration from many sensory systems. Thus, although an ALPD may affect a child's ability to learn or spell, not all reading disorders are due to an ALPD. It is not always clear cut when differentiating between a learning and ALP disorder.

Based on the above described views, this dissertation recognises the complexity of an ALPD and acknowledges that language and reading disorders do not always encompass the central auditory and language processing systems. These disorders may go beyond the LP system as described earlier. Thus, although an ALPD may be linked to the root of a disorder,

it cannot be completely attributed to be causative of other disorders, such as attention deficit disorder mentioned above. However, because of the complexity of an ALPD, and the difference of opinions as to whether or not it may cause other deficits, it is important to understand and reduce causative factors for ALPDs, which will enable specific research regarding the prevalence of other deficits to be undertaken.

Children with a pure CAPD also usually exhibit normal pure tone audiometric results, as the peripheral system is often unaffected. However, these children may present as if they have a hearing loss, even though hearing acuity is within the normal limits (Bellis, 2002). Many teachers and parents complain that these children have difficulty following oral directions and show inconsistent responses to auditory stimuli. They also struggle specifically with multistep directions. Sometimes, it appears that the child is partially ignoring the speaker, and not paying attention. The fact that the responses are inconsistent, adds to the misconception that these children are misbehaved. Since the auditory information becomes a blur, they 'zone out' and teachers may describe these children with ALPDs as daydreaming or becoming distracted from the topic of interest in the classroom (Richard, 2001). These factors all significantly affect the child's performance in school and can cause other problems, such as social and emotional disturbances (Richard, 2001).

As listening can become extremely effortful for children with a ALPD, these children may have a short attention span and may tire easily during auditory tasks. Their short term and long term memory may be affected because they are channelling so much concentration and energy into filling in the missing gaps, and simply understanding the signal, that their attention available for memory is compromised. Many children with ALPDs struggle less with mathematics when using numbers only, but as soon as mathematics makes more use of language, i.e. in language based mathematics, the difficulty occurs (Bellis, 2002).

A child with an ALPD struggles to listen in noisy environments as the primary auditory signal is accompanied by various other auditory noises and stimuli, which makes the listening task extremely exhausting. They may struggle with sound localisation and lateralisation i.e. the ability to know where sound has occurred in space and the source of this sound (Geffner & Ross-Swain, 2007). They often display academic deficits, particularly in phonics, reading and/or spelling as well as mild speech-language impairments. These deficits as mentioned earlier may be co-occurring with the ALPD, or may be exacerbated by the ALPD. As auditory information is often distorted, the phonological processing is affected which in turn influences reading and spelling. It can be particularly frustrating when trying to listen, as they are often unable to achieve in class. This often results in disruptive behaviours, impulsiveness and other signs of frustration and often humiliation. It might also be tremendously frustrating and irritating for the teachers and parents when the child is constantly requesting for repetition and responding with 'huh?' These children however show greater success when there is a high degree of external organisation in the classroom to begin and complete tasks (Bellis, 2002). Chronic otitis media and frequent use of antibiotics can also be warning signs for slight differences in the central auditory system. In a study by Gunnarson and Finitzo (1991) findings suggested that early fluctuating conductive hearing loss may later disrupt auditory brain stem electrophysiology as shown in an auditory brainstem response (ABR).

Various other factors have been described in children with ALPDs which may relate to their auditory processing difficulties. Roeser and Downs (1988) described that children with ALPDs are often easily distracted by auditory stimulation. This can be highly distractible, as any other auditory input can cause the child to become unfocused on the target information from a parent, teacher or friend (Bellis, 2002). They struggle to block out irrelevant stimuli and thus respond to what they see, feel or hear, despite that this may be

unrelated and trivial. Due to possible co morbidity of other disorders, many children with an ALPD are often hyperactive (Richard, 2001) which can result in the underlying ALPD being difficult to isolate or diagnose.

Roeser and Downs (1988) further mention that these children often struggle with auditory localisation. This may include difficulty in judging the distance of the sound source and the inability to differentiate between soft and loud sounds. However there have been reports that children with ALPDs often become frightened or upset when they are exposed to very loud sounds. Although these described characteristics are the most common, there may also be other behaviours that a child may exhibit (Richard, 2001). These other behaviours may include awkward social skills to compensate for the lack of understanding the conversation and the trouble they have in taking part. Embarrassment can also occur when the child does not follow the conversation and when the other children laugh. If this happens consistently, the child may find it difficult to socialise or make friends (Bellis, 2002).

To be an effective communicator on the playground, a child needs to learn to proverbially "read between the lines". When communication becomes an effort, these skills do not develop, and these children often become loners. A parent may also continuously scold his/her child with an ALPD for not concentrating or doing what he/she is told. This can result in the child feeling unloved, unworthy and a burden on his/her family. These children may also refuse to participate in classroom discussions for fear of embarrassment or may answer inappropriately or off topic (Richard, 2001).

Teenagers with ALPDs have also shown to exhibit a higher incidence of sexual promiscuity and there is an increased prevalence of juvenile delinquents within this group (Bellis, 2002). The continuous frustration of not being understood, and trying to achieve, yet

not succeeding may lead to this behaviour and may have educational and vocational implications later on which again highlights the importance of correct identification and management in the early schooling years.

Children with an ALPD struggle particularly with verbal demands, in comparison to other nonverbal tasks. They may have a lower verbal intelligence quotient (IQ) than performance IQ. Hands-on exercises such as laboratory exercises may be an area these children excel in as these exercises provide other tactile and visual cues to compensate for the lack of auditory information that is being processed. Such a child will also likely perform better in mathematics, art and music (Bellis, 2002).

This difficulty with verbal tasks is further observed with speech and articulation. Articulation errors may persist longer in children with an ALPD, as they struggle to discriminate the sounds. These articulation errors are generally prevalent on words or sounds that are acoustically similar as accuracy of the fine discrimination is poor (Bellis, 2002).

The key aspect of a language processing disorder (LPD) is the difficulty to attach increasingly complex layers of meaning to auditory stimuli. Often, children with an ALPD may have normal intelligence and age appropriate language foundation skills (Richard, 2001). However, most learning difficulties include LP problems (Richard, 2001). An ALPD is a suspected factor contributing to language learning impairment (LLI). An ALPD often presents with difficulty perceiving, recalling, and/or organising auditory information and difficulties in these areas may result in a language learning impairment. This demonstrates the importance of correct identification, understanding and assessment of the disorder to prevent and manage other co-occurring disorders. This will allow for the treatment of the

target areas which may be contributing most to the difficulty and there can be less focus on the surface difficulties.

Dau (2009) stated that there are various models to describe ALP. He further mentioned that there are at least two main reasons why AP frameworks of impairment are developed, namely; to represent results from a variety of studies within a single framework, and to explain the functioning of the ALP system. The Buffalo Model of Central Auditory Processing Disorders describes four areas of processing difficulties that can be signs useful in the correct identification. These four categories include: tolerance-fading memory, decoding, integration, and organisation.

A child with a tolerance-fading memory may display impulsiveness and forgetfulness in response to auditory information, and thus will struggle with multistep directions. He/she may also present with noise sensitivity. A child with a decoding deficit will have difficulty analysing auditory information and may also struggle with temporal processing, while an integration deficit might be displayed by difficulty combining auditory and non-auditory information. Organisational problems are generally demonstrated in auditory sequencing tasks and may occur with decoding or tolerance-fading memory deficits (Masters, Stecker & Katz, 1998).

As Bellis (2002) suggests, children with ALPDs often have poor memorisation skills as tremendous energy is channelled into simply understanding and decoding the signal that very little energy is left to memorise the information. Although they have difficulties with memory, Bellis (2002) also mentions that children with an ALPD rely heavily on this compromised memorisation when learning new information or skills and thus they may struggle to attach meaning to the auditory signal. This memorisation may be developed as a

coping strategy of rote learning, where the child would try to attach the meaning, if at all, at a later stage. Thus, if they manage to memorise the information after the decoding, they often to not understand what has been remembered.

Children with LPDs also have problems with the retrieval of common words and use neutral, generic or less-specific labels (Richard, 2001). As they struggle with retrieval, they compensate with the use of more general terms. They may misuse words with a similar phonetic structure, such as with prepositions. As children with LPDs may struggle to express themselves, they appear to use descriptions and circumlocutions frequently. Their response latency is slower, as they need more time to process signals. They therefore use many types of fillers in their speech while the correct information is being retrieved. As children may become extremely anxious with the extended time that they need to retrieve information, they tend to simply respond that they "do not know" or "forgot the answer".

Verbal repetition or rehearsal is common as these children need to keep the signal in short term memory while they attach meaning to it. They struggle to store the information in an ordered manner, and therefore cannot retrieve it. Teachers often find that they have to re-teach the concept the following day. Children with LPDs may display incomplete sentences or thoughts, yet are able to recognise language errors but cannot fix them. Due to this constant battle to learn and process, children with LPDs repeatedly engage in disruptive behaviour (Richard, 2001).

Many of the above described behaviours are not unique to children with ALP disorders. They are common in children with peripheral hearing loss, attention deficit disorders, allergies, other language learning disorders and other problems (Roeser & Downs, 1988). From the above discussion, it is clear how significant ALP can be to children with a

learning disorder as well as to children with normal intelligence and/or hearing. Thus the importance of correct identification of the disorder as well as factors that may influence and cause the disorder is imperative, as well as for appropriate management.

Children Prone to Central Auditory Processing and Language Processing Disorders

There are several types of children who often struggle with listening in background noise and in the presence of reverberation. The cause of a processing disorder can be identified in some cases, such as neurologic problems, however in most cases the cause of an ALPD is unknown (Hurley & Fulton in Musiek & Chermak, 2007). There are several children who develop the disorder as toddlers, and it is unclear whether these children were born with the problem.

The Joint Committee on Infant Hearing (JCIH) (2007), which comprises of representatives from the fields of paediatrics, otolaryngology, speech pathology and audiology, deaf education and social welfare in America, developed a high risk register to help identify children with hearing loss. However, many of these risk factors have also been shown to be associated with a wide variety of developmental, cognitive or sensory dysfunctions. Risk factors can include any illness or condition that requires a child to be admitted to the neonatal intensive care unit for 48 hours or more, signs of syndromes, family history of childhood hearing loss, any visible head or facial abnormality, infection of the mother during pregnancy, infection of the baby after birth such as meningitis, severe jaundice, head trauma and repeated or chronic ear infections (Bellis, 2002). However, even if no risk factors are present, a child should still be monitored continuously to ensure typical development.

A common risk factor to develop ALPDs is chronic otitis media. Children with otitis media may experience a temporary and often fluctuating hearing loss. Children with acute otitis media may present with normal hearing or a mild to moderate conductive hearing loss, while children with serous otitis media often present with a conductive loss of 20 to 30 decibels (dB), depending on the extent on the effusion. The degree of the hearing loss depends on the duration and stage (Alper & Bluestone, 2004) of the illness. Otitis media can not only cause a mild, moderate or fluctuating hearing loss, but has been linked to the presence of processing difficulties (Davis, 1986). Children, who have displayed a recurrent history of otitis media within their first year of life, have shown to exhibit long-term subtle problems with regard to phonological awareness and working memory (Moody, Schwartz, Gravel & Ruben, 1999). Nelson and Soli (2000) reported that there are many children who have slight hearing loss from otitis media. This hearing loss goes undetected in routine hearing screenings, as these screenings do not assess hearing status below 25 dB HL. However, up to 13 to15% of school age children may have this slight hearing loss.

Northern and Downs (2002) describe how a very slight hearing loss in children, of hearing levels just worse than 15dB HL can result in difficulties with education, attention and processing. Children can be considered very vulnerable to develop an ALPD as a very slight loss can affect them, when a slight loss, of more than 25dB HL may not have an effect on adults. Although a hearing loss of slightly more than 25dB HL is acknowledged as a mild hearing loss, it may not affect adults' daily functioning to the extent that a mild hearing loss can affect children. Therefore, when diagnosing an ALP problem, one has to do more than a hearing screening, and a full diagnostic test battery needs to be completed of the peripheral hearing system, as a processing problem could simply be a result from a slight, undetected hearing loss, which although may be a small change in hearing, can have a significant effect on processing. This slight hearing loss can result in many educational consequences.

The hearing loss caused by otitis media can result in behavioural problems, increased stress and social issues and decreased self-esteem. Hoy and Hoy (2006) indicated that all these factors can cause further anxiety, which can lead to long term motivational and attention difficulties, and well as decreased information processing and performance. Thus, this demonstrates how early otitis media can cause ALP problems in the long term, even once the infection has resolved and no further hearing loss is evident. These children therefore require favourable listening environments, such as environments with decreased noise.

The effect of otitis media was also demonstrated in a study by Updike and Thornburg (1992). The research was conducted on 6 and 7 year old children who had suffered from chronic otitis media in their first 2 years of life. The results indicated decreases in performance in ALP tests and reading ability when compared to children who did not suffer from otitis media. This again shows the long term effects of this infection, and again, how much more so can noise affect these children with already established problems.

However, another study by Schilder, Snik, Straatman and van den Broek (1994) investigated the effects of chronic otitis media with effusion at 2 to 4 years of age. Both CAP tests and LP tests were performed. These included speech-in-noise, filtered speech, binaural fusion, dichotic speech, and auditory memory. The speech-in-noise test was the only test to be significantly affected from the otitis media. Therefore, the effect of background noise on an already compromised system from otitis media can result in even more difficulties with understanding speech. Zinkus, Gottlieb & Schapiro (1978) investigated whether infrequent mild and chronic severe otitis media in the first 3 years of a child's life affects developmental, psychological, and educational development of a child. The study revealed that the children with the chronic and severe history of otitis media were at risk for speech and language

problems, auditory language processing deficits, disturbances in auditory-visual integration, reading disorders, and poor spelling skills.

However, these risks were not indicated in the children that suffered from the milder otitis media. Thus, although many children will report suffering from ear infections as a child; unless it was severe, it may not be the cause of the identified delay. Swanepoel (2007) stated that middle ear effusion does not necessarily always result in developmental delay in the area in children's language, speech, phonology, attention, auditory processing and literacy. Therefore, when assessing a child for an ALP deficit, one must examine other environmental factors, such as noise which may, in conjunction with the otitis media, pose risks for ALPDs. Luotonen, Uhari, Lempina and Aino-Maija (1996) also mentioned that these ALP deficits may arise from children who have suffered from chronic otitis media as a child, even if the infection was treated appropriately and effectively.

Although there seems to be conflicting research regarding the long terms effects of chronic otitis media, there is still evidence that ALP skills may be affected by childhood infections such as otitis media. Awareness needs to be cultivated around the presence of, or the history of these ear infections when testing for AP disorders, and determining the cause of these difficulties. It is difficult to exclude this aspect when conducting research on the effect of environmental factors on ALP. Thus, by using two groups, both with equal chances of having suffered from otitis media as a child, the researcher can compensate for this chance and overcome this confounding variable.

Otitis media is a common childhood disease and alone has been shown to negatively affect ALP. It is thus important to investigate other factors, such as noise, that may exacerbate these already present ALP difficulties. The identification of an environmental

detriment, such as noise, can help in the assistance of managing this possibly already present ALP disorder. A child with an identified ALPD needs specialised environments to help him/her function in the classroom efficiently. However, the presence of more background noise, such as aircraft noise which comes over and above general classroom noise, can result in the child struggling even more than without aircraft noise.

Auditory Processing and HIV/AIDS in South Africa

Human immunodeficiency virus (HIV) and acquired immune deficiency syndrome (AIDS) can have an impact on hearing (Rarey, 2004). It is reported that there are approximately 5.3 million people infected by HIV/AIDS in South Africa (Lubbe, 2008). Swanepoel and Louw (2010) also described that in 2008, 6800 more people were becoming infected with HIV every day and more than 5700 persons died daily as a result of AIDS worldwide. In many countries, particularly in southern Africa, prevalence rates exceed 15%. The general effects of HIV/AIDS can be described into direct effects (primary) and indirect effects (secondary). Direct effects can include diseases like AIDS dementia, encephalitis, and cytomegalovirus and so on, while the indirect effects can comprise of opportunistic infections, neoplasms and HIV associated systemic disorders (Larsen 1998).

HIV/AIDS can have a direct and indirect effect on the auditory system as well. It is however difficult to completely separate the direct and indirect manifestations. Opportunistic effects are deemed indirect by some; while others feel that these auditory manifestations are a direct effect on the compromised immune system. Sensorineural hearing loss has been associated in a direct manner causing neural disturbances of the vestibulocochlear nerve; however, these neural disturbances can also be caused in an indirect manner by opportunistic illnesses such as cytomegalovirus (Friedman & Arnold, 1993, as cited in Khoza, 2009).

Hearing loss with HIV/AIDS patients have shown to range in types, from conductive to sensorineural as well as retrochochlear or central (Bankaitis, as cited in Khoza, 2009).

In 2005, in South Africa, it was estimated by the United Nations International Children's Emergency Fund (UNICEF) that there were approximately 240 000 cases of HIV/AIDS in the paediatric population (0-14 years) (United Nations International Children's Emergency Fund [UNICEF], 2005). The global report from the Joint United Nations Programme on HIV/AIDS stated that between 2001 and 2009, the statistics on the prevalence of HIV/AIDS had stabilised (Joint United Nations Programme on HIV/AIDS [UNAIDS], 2010). Thus, it is possible that the statistics from UNICEF (2005) are still relevant. Rarey (2004) stated that HIV/AIDS may be resulting in educational disturbances. HIV/AIDS is also a contributing factor to otologic disorders and middle ear pathologies resulting in conductive and sensorineural hearing loss (Rarey, 2004) and may also cause auditory neuropathy (Hain, 2008).

In a study conducted on HIV/AIDS patients' audiological status, comparing pure tone audiometry and ABR testing, 33% of patients presented with abnormal audiometry, while 56% presented with abnormal ABR results (Castro, Bango, de Ureta, Garcia-Lomas & Lopez, 2000). This shows that there is a large rate of neural or central problems, when hearing is considered normal on pure tone audiometry. The prevalence of neural or sensory problems is seen more in the paediatric population than in the adult population, as children are more susceptible to central nervous system involvement (Rabie, et al., 2007).

If the hearing impairment is in the central auditory system, this leads to the consideration of whether this central impairment causes a disturbance on the central processing aspect in the overall auditory language processing. Matas, Leite, Magliaro and

Goncalves (2006) stated that the neurologic involvement may result in ALPDs. Children with neural hearing loss often have poor temporal processing (JCIH, 2007); thus the central nervous system will impact on the LP system. This demonstrates how the testing of the LP system can help identify central processing deficits, even though the exact region of the deficit may not be identified.

Groce (2003) also indicated that people with disabilities, whether it be sensory or intellectual impairment were at a greater risk to develop AIDS. Thus children who may develop learning disabilities through impaired ALP skills may be at an increased risk to develop this disease. Children with learning disabilities may have a poor self-esteem, which could place them at a greater risk to engage in unsafe sexual activities (Leary, Schreindorfer & Haupt, 1995) and in turn lead to an increased risk to develop HIV/AIDS. HIV/AIDS already impacts quality of life, and thus it is important to intervene such as with auditory or auditory processing problems to enhance effective communication by teaching strategies to help children compensate for the root ALPD, and thus improve overall wellbeing and quality of life (Swanepoel & Louw, 2010).

It is also important to identify other areas, such as noise, that can cause ALPDs, and try to improve these aspects if possible, so as not to exacerbate an already possibly existing problem. Because of the increased risk of ALPDs in children with HIV/AIDS and the large number of children with HIV/AIDS in South Africa, one must be aware of this possible confounding effect of HIV/AIDS on many South African children's ALP abilities. As mentioned earlier, HIV/AIDS is prevalent in the paediatric population, and thus can cause hearing difficulties. Thus, when the learning environment is less than optimal, many children in South Africa suffering from HIV/AIDS are at an added disadvantage of potentially having ALP difficulties which are exacerbated by noise. Even though this dissertation is not setting

out to examine the effect of HIV/AIDS on ALP, it is recognised that this illness may, however, impact overall.

Assessment

The purpose of the ALP assessment is to determine if the disorder is present, describe its parameters and indicate the functional effect of the deficit in order for remediation. ALPDs can coexist and mimic other disorders, such as attention deficit disorder. Therefore, an accurate diagnosis is essential as treatment differs for these disorders (Bellis, 2002). Auditory language processing can be assessed in a variety of ways, and a full diagnostic assessment for remediation should include many aspects, including a thorough history, non-standardised assessment measures such as questionnaires, behavioural and electrophysiological measures, focusing on the central system, and speech and language measures, targeting LP (Masters, Stecker & Katz, 1998). The assessment needs to examine the peripheral auditory system through a basic test battery or other appropriate audiometric measures that check the system up to the eighth cranial nerve. This is done through otoscopy, immittance audiometry and pure tone audiometry. Secondly, the CAP system must be assessed.

Assessment of the processing system is divided into audiological and non-audiological tests. Audiological tests cover the central nervous system; from beyond the peripheral auditory mechanism to the auditory cortex, while non audiological tests assess cortical abilities, including the temporal lobe, and structures involved in LP. Audiological instruments thus mainly assess the CAP system, while the non audiological measures assess the LP system.

With regard to the CAP assessment, we work on the premise that we hear one signal, but listen to it with two ears (the diotic condition where there is presentation of the same sound to both ears simultaneously). Audiometric tests attempt to alter this typical diotic condition to assess how the auditory system responds when the usual signal reception mode is changed. Therefore, this testing stresses the CAP system by compromising the signal.

Audiological assessment procedures can be classified into monotic, dichotic (presentation of two different sounds to both ears simultaneously), binaural and electrophysiological procedures (Richard, 2001). Some CAP tests, naming only a few, can include monotic tone tests such as the Pitch Pattern Sequence Test (PPS), duration pattern tests, such as Duration Pattern Test (DPT), dichotic digits tests, Competing Environmental Sounds Test (CES), Masking Level Difference tests (MLD) and Binaural Fusion Tests (Katz, Stecker & Henderson, 1992). Assessment also involves the testing of the perception of distorted speech and the perception of nonverbal auditory stimuli (tone patterns) (Bellis, 2002).

Thereafter, the higher language function must be assessed by using non audiological tests. In this higher language assessment, language, cognition and other related functions must be examined. Although ALPDs can be a contributing factor to a language learning disorder, it is merely one small component of overall language impairment (Bellis, 2002). When testing LP, there are a variety of standardised and non-standardized tests and assessment batteries to assess a diversity of LP skills. Such standardised tests can include the Test of Auditory Perceptual Skills (TAPS) and the Phonological Assessment Battery (PhAB), where a non-standardised test can include the Dollaghan and Campbell non-word repetition task. There are various other tests available as well. If a child scores age appropriately on these tests, assuming the test is appropriate for the population selected, and then one can

assume that the higher LP system and central system is intact. However, if results are not age appropriate, more specific testing in each area of the processing system must be carried out to determine the area of breakdown for appropriate treatment.

In an article by DeBonis and Moncrieff (2008), four types of APD tests are mentioned from ASHA (2005) and Bellis (2002). These cover both LP such as auditory discrimination tests and auditory pattern recognition tests, and CAP tests such as dichotic speech tests and monaural low redundancy speech tests.

As mentioned, ALP is a complex process involving a variety of skills for example hearing, phonological awareness, rhyme, alliteration, phoneme blending, segmentation or syllabification, synthesis, analysis, auditory sequencing, auditory memory, auditory discrimination and auditory closure (Owens, 2004). A rhyme is a repetition of identical or similar sounds in two or more different words and in order to recognize or produce rhyme, sensitivity to word parts smaller than the syllable is required (Ball, 1993).

While rhyming generally involves similarity at the end of a word, alliteration requires similarity at the beginning. Alliteration can be described as the ability to recognise or produce words with common initial sounds and requires sensitivity to word parts smaller than the syllable (Ball, 1993). Phonological awareness involves many aspects, including rhyme, alliteration and phoneme blending; all important in reading acquisition.

Phoneme blending is used when learning to read and to segment the sounds to create a word. It is one of the easier phonological awareness (PA) tasks and is the combination of two or more sounds to make words (Ball, 1993). In contrast to phoneme blending is segmentation or syllabification. This is the ability to break a word into constituent phonemes. Synthesis or

phoneme blending is the skill of forming a word by combining sounds (and form compound words, and sentences so one can perceive sounds as a whole), while analysis is the breaking of a word down by removing sounds. Individual words are combined to make sentences, from where meaning and communication is derived.

Analysis is the process which helps the auditory system to organize sound into perceptually meaningful elements. It is the ability to identify phonemes, syllables or morphemes embedded in words (Roeser & Downs, 1988). Analysis is essential to understand the individual components of a word or sentence, which can assist in learning to read and for overall literacy development. In order for a child to develop auditory sequencing, which measures a child's ability to perceive and recall sounds, words or sentences in their correct order, the child requires auditory memory. There are various types of auditory memory. In general, auditory memory refers to what a child can remember of what he/she has heard (Baddeley, 1997).

Auditory discrimination is the ability to differentiate between non-speech and speech sounds, as well as between words with one phoneme difference, using auditory cues only (Jaramillo, Ilvonen, Kujala, Alku, Tervaniemi & Alho, 2001). This will affect the child's ability to spell correctly and an older child may misinterpret information. The different types of discrimination were shown in a study by Jensen and Neff (1993). They showed intensity discrimination displayed the least improvement with age and was adult-like by 5 years of age for most children. In contrast, frequency and duration discrimination showed highly significant improvement with age, but remained poorer than adults' discrimination for many 6-year-olds. Lastly, auditory closure is the capacity to complete a word/phrase/sentence when only a portion of that word has been heard (Whitehead, 1992). It relies on an intact language and vocabulary system. Redundancy, as mentioned earlier, also assists with auditory closure.

When basic ALP skills are hindered, such as decreased ability to discriminate sounds, the child may not understand and process the information, and subsequently learning and the development of further cognitive skills may be stunted. Decreased performance in areas such as memory, discrimination and phonological awareness, can affect performance in all areas of school academically, as well as socially, as the child may feel isolated when he/she cannot process what is being said in the classroom and on the playground. This can cause frustration and disruptive behaviours, which can result in more social isolation, and in turn, possible impulsiveness, delinquent activity and so on. Therefore, learning in a noisy environment can hinder the development of ALP skills, and result in academic difficulties. This in turn can cause the social, psychological and emotional consequences later on, as described above.

All these mentioned auditory skills enable a child to learn, perceive and interpret sounds by giving them meaning. It allows them to understand and process individual sounds to comprise words, and then to constitute sentences, which assists in literacy development, learning, overall communication and socialisation. One cannot communicate if he/she is unable to combine different sounds to comprise a word and a sentence, which in turn results in conversation. This correct understanding of speech will assist in a child's cognitive maturation, aiding the development of literacy and learning skills (Chermak & Musiek, 1992). In a noisy classroom, not all that is said is heard by the children. A child that is not able to rely on his/her language system to fill in the gaps and process the meaning of what was said will have difficulty following instructions and understanding what is being relayed (Bamiou, Campbell & Sirimanna, 2006).

Although there are various areas that need to be assessed for a full ALP assessment, a few ALP skills and testing methods will be discussed. The selected areas include verbal working memory, auditory discrimination, phonological awareness and phonological memory

as they are specifically important basic skills for learning in the classroom. A full ALP assessment tests a variety of skills, and thus various areas of the brain are being examined.

In order to differentiate between a pure ALPD and cognitive or attention skills, one can examine the amount of ALP skills affected. With a pure ALPD, the therapist would expect some isolated ALP skills to be below average, yet with attention or cognitive problems, all the ALP skills would be below average (Bellis, 2002). This differentiation, therefore, allows the therapist to separate a pure ALPD from a cognitive or attention based disorder. As this research specifically focused on the effect of noise on processing of auditory information in schools, the above ALP skills were assumed to be extremely relevant. As mentioned, these ALP areas are also important for reading, which is imperative in the schooling environment, as well as for general learning as it influences cognitive development which may also influence social and emotional development. Thus, it is important to be able to differentiate whether the ALP skills are below average, or whether there is a cognitive based problem affecting the ALP skills.

When basic learning skills are hindered, such as decreased ability to memorise sounds, the child cannot understand and process the information and subsequently learning and the development of further cognitive skills may be delayed. The auditory number memory test comprises two modalities: digits forward and digits backward. It has been established that age, education, and culture are important variables that affect performance on this test. In a study by Ostrosky-Sol and Lozano (2006) it was found that a strong predicting factor for success on a test, such as with the number memory test, was the level of education. The task is generally administered as a series of increasingly longer sequences, where the task is discontinued after a specified number of sequence errors. Typically, the tested individual needs to recall the entire sequence correctly in order to be scored as correct (Torgesen in

Lyon, Krasnegor & Maryland, 1996). Regarding culture, differences were found among the studies on digit span for both the forward and backward conditions.

It can be argued that learning to read and write affects the development or usage of the abilities measured by the Digit Span task, and those cultural variables such as language and method of education might also contribute to the differences in scores in different countries. Thus, before this test is used as a diagnostic assessment tool, specifically for this research project and its potential findings, it is important that it be piloted on children of the same culture and language to assess the reliability. The assessment of auditory sentence memory is used to assess another component of working memory, specifically the linguistic elements. This task requires the participant or learner to listen to sentences of various lengths and subsequently repeat them verbatim. This task also tests phonological memory. The performance of this test is greatly affected by the span duration of the words to be remembered. Therefore, when using a standardised procedure, it is essential to follow the administering guidelines (Torgesen in Lyon, Krasnegor & Maryland, 1996).

Individual differences in reading comprehension may reflect differences in working memory capacity. A poor reader's processes may be inefficient, so that they decrease the amount of additional information that can be maintained in working memory. The assessment of sentence memory allows one to remember meaningful information in comparison with the traditional digit span and word span measures which do not correlate with comprehension (Daneman & Carpenter, 1980).

Auditory discrimination forms part of the process of receiving, analysing and utilising auditory stimuli. A disruption in this process can have a deleterious effect on a child’s development and learning. Poor readers have been shown to have poor auditory

discrimination (Deutsch, n.d.). If a learner cannot hear the individual sounds correctly, the word /dɒg/ (dog), may sound very different, e.g. /gɒg/ (gog). It is then very difficult for a child to choose which letters he/she should use to spell a particular word. Similarly, same sounds are also sometimes represented differently in orthography, for example the auditory /dʒ/ sound can be represented orthographically by 'j' or 'dg', such as in 'judge' or /dʒʌdʒ/. Thus an intact discrimination skill is essential with such a complex spelling system, which not only relies on discrimination, but also on higher level processing, memory and integration of other senses (Bellis, 2002).

Because reading is a very complex skill, ALP may not be the root of a reading problem, but more so, the underlying problem may be at a higher cognitive level. Reading is not a standalone skill, as it is phonics and auditory based, while also relying on various other cognitive measures. However, a discrimination problem can further translate into a reading difficulty. Reading text requires auditory and visual components in deciphering the text. This complex ability to read may call on auditory skills such as auditory discrimination which, in a learner with an ALPD, may make reading difficult. Intact discrimination skills are necessary, as they help to compensate for difficulties that everyone experiences, such as in everyday situations, people often mumble and slur their words. A child with no ALPD will still be able to discriminate the sound differences; however, a child with an ALPD at the level of discrimination will struggle to differentiate sounds. Furthermore, if the phonemes sound the same, they may likely be used that way when spelling, or even speaking (Bellis, 2002).

This further illustrates how an ALP problem not only affects the input and understanding, but is also directly linked to the expressive abilities. Thus, an assessment tool, such as the discrimination test in the Test of Auditory Perceptual Skills (TAPS), is useful to gain a deeper understanding of how the child is processing the individual sound differences.

Discrimination is considered a relatively basic skill in comparison to more complex LP skills. It generally precedes the other skills such as segmentation. If a child struggles with discrimination, it is likely that they will struggle with synthesis and other complex skills.

Phonological awareness is essentially the understanding of how speech sounds are used in words. PA includes rhyme and alliteration tasks, and is strongly linked to learning and literacy development (Lonigan, Burgess, Anthony & Barker, 1998) as it has been found that the sensitivity to rhyme leads to awareness of phonemes, which in turn affects reading. It also indicates that rhyme makes a direct contribution to reading which is independent of the link between reading and phoneme awareness. The study by Lonigan, et al. (1998) indicated that phonological awareness, which includes both rhyme and alliteration, contributes to reading development. In turn, reading development affects learning. However, the learner still requires other skills as well as the phonological awareness, such as working memory. The child needs to be able to manipulate sounds, *and* store them in his/her memory until reception and full processing is achieved. Therefore, all these skills form part of AP, more specifically ALP.

More recently, however, it has been shown that the development of rhyming skills is a good predictor of the reading ability that individuals already have. One reason for this relationship may be that children who have put words into rhyming categories may be quick to realize that these words also tend to share the same spelling patterns, and may then use such similarities in spelling to make predictions (analogies) about how new written words will sound. The present study tests one aspect of this hypothesis, which is that children who make more analogies in reading are also better at rhyming than children who do not. Thus the understanding of rhyming is imperative for school going children and is a skill that is important to assess (Goswami, 1990).

With regard to alliteration, the identification of the initial sound develops post rhyme development (Hepenstall, 2004). Thus, if there is no breakdown in rhyme, yet in alliteration, one can assume that the breakdown of LP is at a higher and more complex level.

Phonological memory is also important for learning, especially for vocabulary acquisition. A study by Gathercole and Baddeley (1990) suggested that immediate phonological memory processes are directly involved in the learning of new vocabulary. The Dollaghan and Campbell Non-Word Repetition Task has been found to be an extremely good predictor of processing as it is not biased with regard to income and educational levels (Dollaghan & Campbell, 1998).

Nationally, as well as internationally, there are no screening protocols for children at risk for ALPDs in schools (Jerger & Musiek, 2000). ASHA (2005) also states that there is no universally accepted method for screening for an APD, however ASHA (2005) mentioned that screening involves a systematic observation of a child's listening behaviours and performance on auditory function tests in order to identify at risk children.

A processing disorder of such can have seriously negative consequences on a child's life if undiagnosed and untreated (Bamiou, Musiek & Luxon, 2001). It can cause academic failure, behaviour problems due to the frustration of constant failure as well social and emotional problems (Richard, 2001). Cook, Mausbach, Burd, Gasco, Slotnick, Patterson, Johnson & Reynolds (1993) also found that many children who are diagnosed with an ALP deficit may also have attention deficit disorder. This leads us to consider how multifaceted the disorder may actually be, and the importance of identification and treatment of the disorder before it affects multiple areas in the child's functioning. This study thus examined

the ALP abilities in children. It is important for clinicians to understand the disorder and be aware of potential causes and implications in order to allow for accurate management.

Noise

Noise can have negative side effects. Scales and Snieder (1998) described noise as a coherent, interfering but uninteresting signal. It is an unwanted disturbance, as it interferes with speech and music understanding and perception (Roeser & Downs, 1988). Noise varies randomly and aperiodically in intensity and frequency and it often masks another sound (Loeb, 1986). It is however the necessary by-product of the operation of transportation vehicles. Cars produce noise from the engine, tyres and gearbox. Trains produce noise from rail wheel contact, suspension, motors and from aerodynamic sources. Aircrafts generate noise from their engines and from the aerodynamic flow of air over the wings (Ashford, Stanton & Moore, 1984). Air transportation has increased since the early 1960s and is currently a necessity for many with an urban lifestyle (Pillay, Archary & Panday, 2011).

Additionally, there are different types of noise: white noise which contains all audible frequencies, violet noise which has more high frequencies and pink noise which is biased towards low frequencies. Noise with only certain frequencies is considered band limited noise. If the range is wide, it is wide-band noise, yet if it the range is narrow, the term narrow-band noise is utilised (Loeb, 1986). Therefore, it is evident that different types of noise are present in everyday lives, and cannot necessarily be decreased. Thus, the effect of this noise must be determined, so as to motivate for the zoning of recreational and educational institutions and environments away from this noise, and to compensate for the existing noise by noise control methods, including insulation and correct acoustical design. It is not only important o recognise the effects of noise for further zoning purposes and better insulation

methods, but it is necessary to identify these already existing ALPDs possibly caused by noise in order for correct treatment and therapy.

In order to motivate the zoning of buildings away from noisy environments, acoustically optimised designed classrooms, as well as for the provision of acoustic dampening materials for already existing schools, the effects of the noise must be determined. By understanding that environmental noise, in this case aircraft noise can have negative consequences on ALP and education; one can provide these data as evidence to governing bodies. This evidence aims to motivate the educational governing bodies for new legislation with regard to zoning and architectural design of classrooms, and consideration for methods to improve the signal to noise ratio (SNR) within learning environments.

The consequence of the effect of noise on ALP, however, cannot be measured directly and thus needs to be determined from the sensations and perceptions of an individual. The experience of the listener must therefore be inferred from his or her behaviour. Thus, it is important to obtain information regarding perceptions of loudness and pitch, as well as to obtain more objective measures such as from standardised tests to indicate the effects of noise, such as with ALP.

When examining loudness, it is important to note that as the intensity increases, so too does the loudness of the signal. However, loudness does not necessarily increase at the same rate as intensity. Loudness sensation propagates faster in the lower frequencies than in the higher frequencies (Hurley & Fulton in Musiek & Chermak, 2007). Shapiro (1980) described loudness as the perceptual correlation of intensity. Noise can be measured physically with the decibel scale by the use of a sound level meter, while the subjective measure or experience is

measured with loudness, often measured in phons (Hurley & Fulton in Musiek & Chermak, 2007).

When measuring the physical intensity that a person can hear, the dynamic range is often determined. The dynamic range of intensity begins with absolute threshold (what we can barely detect) to terminal threshold (what we can barely tolerate) (Loeb, 1986). As mentioned above, perceptions regarding loudness *and* pitch should be determined. Thus, not only is sound described according to loudness, but also encompasses pitch, which is measured on a scale from low to high.

The physical or objective measure is quantified using the frequency scale, which is defined as the rate of vibration of a sound source expressed in cycles per second (Horonjeff, 1975). The basic unit of pitch is the mel, while the unit of frequency is hertz (Hz). However, when measuring the effect of pitch, or pitch perception, one must note that pitch perception increases at a slower rate than the increase in frequency (Hurley & Fulton in Musiek & Chermak, 2007). These measures of loudness and pitch help in determining the subjective perception of noise, and from there, the effects of this noise, for example, can be studied by the use of ALP tests.

Electrophysiological studies indicate that pitch is processed near the anterolateral border of the primary auditory cortex and is thus part of the central processing system (Hall & Plack in Kollmeier, 2007). Masking refers to the decrease in audibility of one sound due to the presence of another sound. Noise in the environment can thus mask speech signals making speech difficult to comprehend (Casali & Robinson, 2001). Noise is prominent in the environment, such as in industry, transport systems and from neighbours. Different intensities or types of noise may cause different types and amounts of damage or effects on

behaviour and performance, whether it may be auditorily, cognitively or with regard to other areas of health.

As mentioned, as intensity increases, so too does loudness perception. The duration of the stimulus, loudness adaption and bandwidth also affects the loudness perception. Loudness perception is affected by temporal integration, similar to the acoustic reflex threshold. Temporal integration correlates to the duration of a stimulus. This is important, as generally, when an aircraft flies overhead, the duration of the noise lasts a few seconds, and then all is quiet again. Thus, the loudness perception may not be particularly significant, however, this constant, intermittent interruption, that may not be affecting children's loudness perception, may be affecting their ALP abilities.

Loudness adaption is the perceived decrease in the loudness of a long, steady tone at a fixed intensity. This loudness adaptation is likely to affect the subjective effect of noise levels, as a person living near the noisy area for an extended period may show less irritability than a person who is in the noisy environment intermittently. Even though children at schools with aircraft noise are not exposed to a long steady sound, the chronic intermittent sound may also result in loudness adaptation, and thus, the noise may not affect irritability, but may still be affecting ALP (Hurley & Fulton in Musiek & Chermak, 2007). Because of loudness adaptation, children in primary school as well as the educators in schools located in close vicinity to airports may not be aware of the effects of this constant interruption from noise, and thus the need to decrease this noise. It is therefore important to investigate the effect of noise on ALP measures, in order to educate learners and educators on the effect of this noise pollution, and the importance of measures to compensate or decrease these high noise levels.

Apart from temporal integration, another psychoacoustic variation when considering sound and noise is temporal resolution. This is when the auditory system is required to discriminate small timing differences when processing speech. Temporal resolution can be affected by hearing disorders, aging and possibly CAPDs (Hurley & Fulton in Musiek & Chermak, 2007). Chronic exposure to aircraft noise may cause hearing loss and ALPDs. Thus, when considering the effects of these aircrafts flying over schools, it is important to be aware that possibly CAP disorders, resulting from the noise, can disrupt temporal resolution, which can further affect LP of speech and higher integration.

As human ears are sensitive to sounds from 20 Hz to 20 000 Hz (Loeb, 1986), both low frequency and high frequency noise fall within the range of hearing, and thus may affect a person's functioning. This range includes the low frequency noise which is a common background noise, such as the noise often produced from road vehicles, aircrafts, machinery, artillery and mining explosions and ventilation units. Intense low frequency noise has shown to cause respiratory impairment and aural pain (Berglund, Hassmen & Job, 1996). However, low frequency background noise such as aircraft noise has shown to also cause other disturbances such as in cognitive function (Cohen, Evan, Krantz & Stokols, 1980). Loudness judgments and annoyance reactions are greater than for higher frequency noise of the same sound pressure level. The complete effects of low frequency noise, such as aircraft noise, must be investigated, as it is very prevalent and fits into an individual's hearing range, which can affect the clarity of speech, and possibly processing (Berglund, Hassmen & Job, 1996).

When looking at noise levels, specifically loudness levels, a study by Babisch, Beule, Schust, Kersten & Ising (2005) in Germany indicated that average traffic noise is approximately 60 dB (A) in the day and approximately 50 dB (A) during the night at a distance of 25 metres from the streets. As many schools are located near busy roads, these

noise levels are the reality for many learning environments. It is thus important to understand the effects of these noise levels in schools as it could be impacting on the educational and other learning environments.

Rosenberg, et al. (1999) stated in their study that for the best learning to occur in the classroom, the teacher's voice must be extremely intelligible to all children. Speech recognition in noise and reverberation achieves adult-like performance between 13 and 15 years of age. Thus, primary school learners have not achieved this adult-like level of complex speech processing necessary to listen effectively in a noisy classroom environment. They also do not have language rich learning experiences to help them fill in the gaps as adults do, as well as decreased level of redundancy when compared to adults. They thus rely heavily on external redundancy when signals are represented bilaterally, as well as internal redundancy when the crossover points symbolise the acoustic message bilaterally several times during neurological transfer to the cortex (Richard, 2001).

Adult listeners are able to ‘fill in the missing gaps’ by relying on context, however, children have not achieved this level of processing, and rely on the redundancy, such as both on the context as well as the entire verbal message being heard accurately. Adult listeners require a SNR of at least +6 dB for maximum communication to occur. Subsequently, it has been estimated that children need quieter listening environments of at least a +10 dB SNR to achieve speech recognition at a level comparable to adults (Roeser & Downs, 2004). From the above study, it appears as though it is possible that the exceedingly high levels that may be present in schools are interfering in learning. In a study by Koehnke and Besing (1996), room acoustics, as well as noise was shown to influence speech intelligibility tremendously. A room with high levels of reverberation was demonstrated to affect the intelligibility gain of speech four times greater than in an anechoic environment. Therefore, a classroom

environment can greatly affect speech intelligibility, and consequently learning. This speech intelligibility can be hampered by constant aircraft noise, when a school is situated near an airport and reverberation levels are exacerbated.

The Occupational Health and Safety Act (OHSA) of 1993 states that noise of 85 dB (A) can cause a significant hearing loss in adults, and by law, workers who are regularly exposed to these levels of noise require hearing protection devices and regular monitoring (Stach, 1998). Acceptable noise levels are also discussed by the ASHA (1996). They state that 30 dB (A) is an acceptable acoustical standard for unoccupied classrooms. Therefore, it appears as though, from aforementioned studies, such as the study by Babisch, Beule, Schust, Kersten and Ising (2005), that the traffic noise and aircraft noise exceeds the 30 dB (A) mark in the classrooms as it was discussed earlier that aircraft noise can reach up to 60 dB (A) in the day and 50 dB (A) at night.

At an international airport in Durban, South Africa, the number of aeroplanes landing and taking off within a 24 hour period were shown to be 60 and 65 aeroplanes respectively. The engine noise levels from aircrafts do differ, however, these levels may reach 140 dB (A). It was noted by Pillay, Archary and Panday (2011) that aircrafts either land or depart on average, every 20 minutes. Although this noise is not continuous, it is chronic and intermittent, which was shown to cause hearing difficulties (Pillay, Archary & Panday, 2011) and possibly further ALP problems.

When a developer is selecting land near an airport for construction, or land for airport construction, a system known as Aircraft Sound Description System (ASDS) is utilised. This model describes any point near the airport according to the noise levels, in terms of total amount of minutes that the noise exceeds 85 dB (A). Although different aeroplane engines

differ in noise emitted upon take-off and landing, average values of 15 seconds for take-off and 10 seconds for landings can be used to calculate total time of exposure. Thus, if a plot of land is exposed to noise at or above 85dB (A) for 30 minutes per day, the planner must consider whether the land is suitable for residence. The situation index must be calculated by determining the total exposure time above 85 dB (A) and the area exposed in acres (Horonjeff, 1975).

However, this situation index has limitations, and should not be used as a defining factor. As mentioned, an area with a situation index of 85 dB (A) for 30 minutes per day should not be considered for residence as it may cause noise induced hearing loss. Although research has shown that high noise levels can damage hearing, there is limited research to the extent of chronic *intermittent* noise exposure. Thus, one cannot use this index to depict a good or bad situation; it simply allows one to understand the noise levels in the surrounding areas.

It is clear that norms should be established, and thus this dissertation on the effect of aircraft noise on ALP is beneficial to help define the effects of chronic, yet intermittent noise levels, on human functioning, such as with ALP. There is limited knowledge on how noise levels may affect individual performance, even though the levels may not be loud enough to damage one's hearing. Therefore, this model of the situation index to calculate the minutes of exposure over 85 dB (A) does not take in lower decibel levels which, although may not cause hearing loss, may cause other disturbances whether it be cognitive, health or with ALP which will be described below.

Outer cochlear hair cell functioning has been measured with the use of Otoacoustic Emission testing (Hall, 2000). OAEs are extremely sensitive to noise and cannot be

conducted if the noise level is too high. In a study on the acceptable noise level for TEOAE screening, it was found that the ambient noise level must not exceed 50 dB (A) to obtain accurate results and have no negative effect on the screening process (Rhoades, McPherson, Smyth, Kei & Baglioni, 1998). Thus, as 50 dB (A) is an appropriate standard for TEOAE screening, it can be inferred that this 50 dB (A) is an appropriate level for pure tone screening and ALP assessment. As the aircraft noise and traffic noise mentioned exceeds this level of 50 dB (A), it is important to pause hearing screening and ALP testing while the aircraft passes over, so as not to affect the reliability of testing.

From the noise standards and measures mentioned above, it can be observed that classrooms located by airports or near streets are not the ideal listening and learning environments. Often, speech cannot be heard due to the noisy environment and thus cannot be processed. However, it is not clear whether this constant noise is able to cause not only a disruption in learning, but also ALP difficulties.

Noise measurements

The effects of aircraft noise on surrounding communities may cause a serious problem in individual productivity and overall health and wellbeing. Noise measurement is essential in order for developers to build in surrounding areas of airports and to minimise detrimental effects of this noise. Noise is generally measured with a sound level meter which measures sound in decibels (Horonjeff, 1975). Subjective noise evaluation is completed in terms of duration of the noise, the number of times the noise is repeated and the time of day at which the noise occurs (Ashford, et al., 1984).

When measuring the noise levels, the audiologist or site planner needs to choose from three weighting networks or filters available (Roeser & Downs, 1988). The weighing filters

are intended to simulate the equal loudness curves by attenuating low and high frequency stimuli (Smurzynski in Chermak & Musiek, 2007). They are dB (A), dB (B) and dB (C). This provides a general indication of the frequency distribution of the noise. A dB (C) measurement gives an indication of the overall sound pressure level of the noise, while dB (A) and dB (B) filter out the more low-frequency energy. The dB (A) scale is however mostly used as the weighting curve corresponds to the frequency response of the human ear (Roeser & Downs, 1988) as it attenuates low frequencies. The dB (B) weighting filter is not widely used (Smurzynski in Chermak & Musiek, 2007).

The sound level meter indicates the total amount of sound present at a certain location and is described as the sound pressure level (SPL) (Horonjeff, 1975). Hence, this essentially measures the force or bombardment of air particles in an area or space (Bluestone, Stool, Alper, Arjmand, Dohar, & Yellon, 2003). When measuring noise levels, one must note that listening in background noise of other voices may be the most difficult type of competition, as the frequency of the intended message is competing with a similar frequency range (Roeser & Downs, 1988). A sound level meter consists of a pressure sensitive microphone amplifier, weighting filter, temporal averaging circuit, and a display providing the result in dB SPL. Most sounds that need to be measured, such as background noise, fluctuate over time (Smurzynski in Chermak & Musiek, 2007).

The SNR is the difference in decibels between the incoming speech levels and the competing background noise. A SNR of at least +10 dB is necessary for children, while a SNR of at least +20 dB is needed for hearing impaired children to function effectively in the classroom (Roeser & Downs, 1988). Although the sound level meter measures the overall sound pressure level, it does not provide information on the subjective reaction and effects of this noise. The sound level meter measures the physical noise, but the individual's

performance and behaviour needs to be measured through other procedures, one of which being ALP tests.

Understanding the effects of certain noise levels on the population helps a site planner to zone community institutions such as schools in areas where the levels do not affect human functioning. Noise measurement is essential to plan the construction of airports and residential surrounding areas, but also helps with the development of quieter aircraft engines, so to enable the utilisation of available land (Horonjeff, 1975).

Noise causing cognitive, psychological and health problems

Stress is described as an applied force or system of forces that causes strain or deformity in a body (Levi in Cooper, 2005). Noise, to some extent, can be viewed as an environmental stressor as it has been found to cause a number of negative effects. In a study by Miller (1974), noise measured according to the dB (A) weighting scale, was shown to cause auditory, psychological, sociological and general physiological effects. Aircraft and road traffic noise can impact on a cognitive task.

The effects of aircraft and road traffic noise on children's cognition and health in the Netherlands, Spain and the United Kingdom were investigated, as exposure to environmental stressors have been shown to impair children's health and their cognitive development (Stansfeld, et al., 2005). Thus, this study by Stansfeld, et al. (2005) involved a cross sectional study of 2844 children attending schools in noisy environments. A linear association was found between exposure to chronic aircraft noise and impairment of reading comprehension and recognition memory. Hence, the findings indicated that a chronic environmental stressor (aircraft noise) could impair cognitive development in children, specifically reading comprehension. Consequently, schools exposed to these high levels of aircraft noise are not

considered healthy educational environments, as the noise together with environmental stressors appear to be impacting on the children's learning and academic development. However, it was not stated if the noise is also impacting on other areas, such as ALP skills.

Aircraft noise was also studied in four of the noisiest schools located in the air corridor of the Los Angeles airport. This study investigated the effects of noise on blood pressure as well as the motivation in which children completed the tasks. It was shown that there were approximately 300 over-flights daily, with one flight every 2.5 minutes. Peak sound readings in these schools were 95 dB (A). This level, as stated above, can cause a permanent hearing loss. This study, however, showed that the children in the noisy schools, compared to the matched quieter schools were more likely to give up before the time to complete a task ended, were more likely to fail on a cognitive task, and more likely to have higher blood pressure (Cohen, et al., 1980). This study shows how aircraft noise can affect motivation, however, does not look at skills such as ALP.

The effect of long term noise exposure was demonstrated in a study on rats. These rats were exposed to noise as they were developing. These developing rats exposed to the noisy surroundings showed delayed emergence of adult-like topographic representational order and refinement of response selectivity in the primary auditory cortex long beyond typical developmental standards. Additionally, when these noise-reared adult rats were subsequently exposed to auditory stimuli, they showed poorer ability to those non-noise reared rats with regard to cortical organisation of these stimuli. Various results of rat studies are shown to mimic human development. Thus, although this study looked at rats, it is possible that so too, noise reared human adults may have the same or similar effects of long term noise exposure (Chang & Merzenich, 2003).

The effect of noise on cognitive abilities was further seen by Hambrick-Dixon (1986) who conducted a study on the effects of noise on children of 5 years of age in a day care centre in a low socio-economic area in London. This noise was measured to be at 80 dB (A). The results showed that these levels affected their psychomotor functioning, serial memory of words and pictures, incidental memory, visual recall of paired associates, perceptual learning and coding performance. However, psychomotor functioning was affected more than the other tasks. This thus shows that different functions may be affected differently with noise exposure. By observing the effect of noise on certain cognitive processes, we cannot be certain that the noise affects other areas of cognition, such as memory. It is thus beneficial to investigate the result of this noise on other processing abilities, such as auditory memory and discrimination as well as phonological processes necessary for learning in the classroom.

Although aircraft noise may reach approximately 100 dB (A) as mentioned above, higher intensity noise (135-140 dB (A)) has shown to affect vestibular function. This can include nystagmus, vertigo, nausea, and displacement of the visual field and loss of equilibrium (Loeb, 1986). Parker, Tubbs and Littlefield as cited in Loeb (1986) mentioned that vestibular receptors may be affected even though acoustic ones may remain unaffected. This shows that although hearing may not be affected, other areas of the auditory system may still be affected.

Whilst noise was shown to affect cognition in the aforementioned studies, van Kempen, et al. (2006) analysed the effects of noise exposure on children's blood pressure and heart rate in Europe. The results of 1283 primary school age children were examined. The outcome showed that aircraft noise exposure at school did not have a statistically significant effect on blood pressure and heart rate. Aircraft noise exposure at home was related to a statistically significant increase in blood pressure. This noise exposure during the night at

home was also positively and significantly associated with an increase in blood pressure. Negative associations were found between road traffic noise exposure and blood pressure, which cannot be explained. Hence, it is evident that aircraft noise can cause physical health effects as well as cognitive disturbances.

Although the noise did not have an effect on the children's blood pressure at school, we cannot rule out that this noise will not have an effect on the cognitive, auditory and language processes at school. Hence, it is important to investigate further any other possible effects of noise. Although noise did not affect blood pressure at school in the study by van Kempen, et al. (2006), it was shown previously by Cohen, et al. (1980) to affect blood pressure and motivation. As the noise affects health and motivation, other effects of noise, such as ALP skills, must be investigated. Noise sensitivity, which mostly affects the younger population, can cause increased stress, somatic and psychological problems. Therefore, it is particularly important to examine the effect of noise on the younger population, such as school-age children (Heononen-Guzejev, et al., 2011).

In comparison to the above study, traffic noise was shown to be a risk factor for health problems, such as myocardial infarction. This study by Babisch, et al. (2005) was, however, not conducted on school-age children. Studies on the relationship between transportation noise and ischemic heart disease suggest a higher risk of myocardial infarction in subjects exposed to high levels of traffic noise. This study was carried out on adults between 20 and 69 years of age, who were exposed to traffic noise of 65 to 67 dB (A). Results supported the hypothesis that chronic exposure to high levels of traffic noise increased the risk for cardiovascular diseases. This demonstrates another area which is affected by chronic noise exposure.

Another area affected by noise was studied by Ljungberg and Neely (2007). This study investigated the effect of noise and whole body vibration on saliva cortisol levels. The participants were also required to subjectively rate difficulty and stress while performing a cognitive task. Although the participants reported higher stress when exposed to noise while completing cognitive tasks, performance was not significantly affected. These results possibly indicate that children consume more energy when completing a task while exposed to noise. Although this noise exposure may not have an immediate effect on the tasks, we do not know if after months or years of exposure, it will have a negative effect on specific tasks. Therefore, when investigating the effects of noise of ALP skills at schools, it is necessary to evaluate learners who have been exposed to the noise for some time, such as learners in grade 6 and 7.

The effects of environmental white noise of 85 dB (A) on simple helping behaviours were investigated. The study showed that individuals exposed to this noise were less likely to help others (Mathews & Canon, 1975). This could be because noise can affect mood and drive level. This is also particularly important in the educational setting, as teachers may also be affected by this noise. Teachers are required to aid students continuously; however, if their mood and drive level is affected, this could negatively affect their teaching manner and effectiveness.

Yet, in another study by Stallen (1999), noise annoyance was shown to not only be affected by the acoustical factors of the noise, such as the typical noise metrics, but also by individuals' traits, such as their personal ability to deal with annoyance. This study showed that annoyance was also determined according to a person's individual recourses and personal ability to deal with annoyance. Though, despite that the level of noise may not be the key determinant of annoyance, it can contribute to annoyance, in particular with individuals who

struggle to deal with interfering factors. Specifically though, children's annoyance is likely to be affected as their speech understanding in noise it is not as mature as adults.

Noise may also indirectly be affecting ALP. As aircrafts fly throughout the day and night, the children living near the airports or in the vicinity of the school could be struggling to sleep from this constant noise. Loeb (1986) considered that during the hours that sleep typically occurs, as the noise levels increase, so does an individual's annoyance level. Schomer as cited in Loeb (1986) further mentioned that environmental noises are more bothersome due to less background noise present at night, yet in the day, this other background noise may mask this constant noise (Loeb, 1986). If a child struggles to sleep at night due to this noise exposure, he/she will not be fully alert the next day at school to concentrate on auditory information. Thus, it is possible that chronic noise exposure can have an indirect effect on ALP skills.

Aircraft noise has shown not only to cause health, motivation and cognitive problems, but there has also been a positive link to psychological symptoms. There appears to be mixed evidence with regard to aircraft noise exposure and hospital admission due to psychiatric illness. Some evidence exists of an association between aircraft noise exposure and use of psychotropic medications, yet other research showed no difference with the aircraft noise. However, people who have a pre-existing psychological condition, or are predisposed to psychological illness may be affected more by the constant noise. Aircraft noise can also produce effects on electroencephalogram sleep patterns and cause wakefulness and difficulty in sleeping (Morrell, Taylor & Lyle, 1997). This sleep disturbance may even produce an indirect effect on processing ability; if a child is unable to sleep, he/she is tired and has limited concentration, which in turn can affect learning and acquisition of ALP skills.

Stansfeld and Matheson (2003) also described how exposure to transport noise has also been shown to disturb sleep, as in the study by Morrell, et al. (1997). However, this study illustrated this effect in the laboratory, but not infield studies where adaptation occurs. Stansfeld and Matheson (2003) further described how noise can hinder complex task performance, can modify social behaviour and can cause annoyance. This exposure can result in psychological symptoms but is not clinically defined with a psychiatric disorder.

In addition to behaviour and psychological symptoms, chronic aircraft noise exposure has been associated with cognitive and health problems, such impaired reading comprehension and long-term memory, as well as raised blood pressure. It is unclear what other areas this noise may be affecting, such as ALP. Different noise standards have thus been suggested so as not to interfere with work, learning, hearing evaluations and so on (Stansfeld & Matheson, 2003). However, it is difficult to control noise in some situations, such as in schools located by airports.

In another study by Cohen (1973), two groups of workers were compared, where one group was exposed to low levels of noise and the other to high noise levels at work. The age of the participants differed, from below 26 years to 65 years of age. The study found that although both groups were exposed to noise, the group exposed to the higher noise levels demonstrated more accidents, more medical diagnosed disorders (e.g. respiratory disorders) and a higher rate of non-attendance. More accidents occurred with the younger workers. This can be attributed to less experience or that they have had less time acclimatise to this noise. Whatever the case, the noise levels were detrimental to a variety of health areas as well as overall productivity. This indicates that younger people may be affected more by noise. If younger adults are affected more by noise than their older counterparts, this leads the research

to assess how much more so children can be affected. A study to investigate the effect of long term effects on ALP in children exposed to noise is therefore specifically important.

It is thus apparent that noisy environments may be detrimental to a variety of factors, such as blood pressure, heart function, drive level and cognitive function. This leads us to think about how many more areas noise may be affecting, especially amongst children.

Noise and Auditory Language Processing

The measurement of the physiological relationship between noise and ALP has been investigated through rat studies as mentioned above, where noise-exposed rats presented later emergence of adult-like topographic representational order and refinement of response selectivity in the primary auditory cortex, than their non-noise exposed counterparts. However, the effect of noise on ALP skills, which can include the response selectivity of the primary auditory cortex, has not been demonstrated in human studies in clinical and everyday settings.

Herrmann, Oertel, Wang, Maess & Friederici (2000) revealed this physiological relationship by investigating the interference of noise on neural responses when listening to spoken sentences. The participants were required to listen to sentences and judge their syntactic correctness. Sentences were presented with a silent background and then with noise. Noise had differential effects on early auditory and syntactic processes. While noise affected early (temporal regions) auditory processes only in the right hemisphere, noise had a general (temporal and frontal regions) effect on syntactical processes. The syntactical responses were significantly suppressed when noise was present. The noise suppression effect, however, was not lateralized. Noise, therefore, showed some effect on ALP. This study yielded a theoretical and physiological understanding of the effects of noise on ALP; however, as it was

not performed in a natural setting, such as in a school, it could not describe practical implications relevant to everyday practice.

Peiffer, Rosen & Fitch (2002) analysed the physiological effect of noise on the microgyrus that affects ALP on rats. Rats with induced microgyric lesions have proven to exhibit significant deficits in rapid ALP. In this study, microgyric lesions were induced from stimulation such as chronic white noise (80 dB) within standard housing, 3 hours per day of 78 dB (A) filtered light classical music within social housing, or standard acoustic environment (control) within standard housing. Thus, noise was shown to cause microgyric lesions which subsequently affected ALP. Although this study was done on rats, it is possible to extrapolate a similar effect on human brains.

The effect of chronic noise exposure was investigated on pre-school children, and their pre-reading skill development. Some pre-reading skills include ALP skills, such as rhyme. This study did not investigate the effect of aircraft noise, yet just simply environmental noise. Children were tested in Year 1 of school, before sound attenuation work in the classrooms, and in Year 2, after the installation of sound absorbent panels. In the quieter condition, children were rated higher by their teachers on the language scale than in the noisy situation.

In addition, children in the quieter classrooms were less susceptible than those in the noisy classrooms to induced helplessness. This study investigated the effects of general environmental noise, not the nature of chronic, yet intermittent noise exposure from aircrafts. Although aircraft noise may reach high decibel levels, the noise is more intermittent when compared to general environmental noise.

It is important to further investigate the effect of intermittent aircraft noise exposure, as possibly, schools in the future should not be zoned near airports. This study on environmental noise exposure shows that some ALP skills may be affected after only one year of this noise exposure. These children were 4 and 5 years old. This leads the researcher to contemplate the greater amount of damage that chronic noise exposure can result in with children of the ages of 11 and 12 years, in environments with more than just general environmental noise (Maxwell & Evans, 2000).

It was therefore essential that more practical elements of the effect of noise on the processing of auditory information were investigated. These ALP areas that can yield practical elements are areas such as auditory working memory, phonological memory and awareness and auditory discrimination. Such areas are used in everyday learning, specifically at school.

Gender and Auditory Language Processing

Auditory language processing abilities appear to be different between genders. The majority of children with CAP disorders are male (75%). Male and female differences within the brain development are evident from the literature reviewed. Male hormones during embryonic development can affect the structural, physiological and biochemical organisation of the brain. Myelinisation may be slower in males and males also can exhibit a vulnerability to an ALPD (Richard, 2001). This ALPD thus appears to stem from the CAP system in comparison to the LP system.

Speck, Ernst, Braun, Koch, Miller & Chang (2000) studied gender differences in brain activation during working memory tasks, while using functional magnetic resonance imaging. Nine males and eight females were studied with four different verbal working memory tasks

of varying difficulty using whole brain fMRI. The task performance data demonstrated higher accuracy and slightly slower reaction times for the female participants. These gender-specific differences in functional organization of the brain may be due to gender-differences in problem solving strategies or the neurodevelopment and anatomical structures.

A further study demonstrated the differences in gender performance with regard to the auditory processing of vowels (Obleser, Eulitz, Lahiri & Albert, 2001). The vowels that were studied were [a], [e] and [i], using the fMRI technique (example: fat, far, bet, beet, bit and wise). Female participants exhibited stronger responses than their male participants over the left hemisphere. This observation was highly reliable across repeated experimental sessions. In this study, it appears that females' ALP skills are better than their male counterparts with regard to the processing of vowels.

Rogers, Harkrider, Burchfield & Nabelek (2003) investigated the level of acceptance of background noise while participants were required to listen to speech at their most comfortable level (MCL). The accepted noise levels were thus calculated according to the individual MCL and maximum background noise levels. This research was conducted to differentiate the between genders, age and hearing status. Results revealed that both males and females could cope with equal amounts of background noise relative to their individual MCL. No difference was found between age and hearing status.

Various studies have suggested a trend in male and female performances with processing tasks due to differences in neuro-maturation (Richard, 2001). These differences are often observed with ALP tasks (Richard, 2001). It is important to understand these gender differences to facilitate different sex learners to achieve their full potential. These studies have suggested that females tend to score better in the ALP tasks than their male counterparts,

which have resulted in many stereotypes that lean towards females ALP skills being superior to male learners. These stereotypes may lead educators to excuse problems displayed by male learners simply due to their gender.

However, it is important for teachers to not justify these possible difficulties, but rather be prepared for them, and provide suitable strategies to enable both genders to perform at their true potentials. Thus, this may suggest that educators may need to provide multi-dimensional means to access information, both auditory and visual, to offer equal learning opportunities for both males and females. However, there is scarce literature on the difference in ALP skills between genders when there is an interfering variable, such as noise.

Evans, Hammer, Meis, Ising and Kofler (2001) investigated the stress of environmental noise on school children. The study specifically focused on traffic and aircraft noise. The study examined multi-methodological indices of stress among children living under 50 dB (A) or above 60 dB (A) in Austria. All children had hearing within normal limits. The children from noisier neighbourhoods had elevated heart rate reactivity to a discrete stressor (reading test) in the laboratory and rated themselves higher in perceived stress symptoms on a standardized index. Furthermore girls, but not boys, seemed to demonstrate diminished motivation and more reported stress in a standardized behavioural protocol.

According to Rogers, et al. (2003), males are generally able to accept a higher intensity of background noise and still be able to understand the signal or message but females seem to show more distractibility when the auditory task requires more cognitive effort, as with background noise, which may suggest that females prefer lower levels of background noise. The results from the research suggest that although females may have

more developed ALP skills than males, they may actually exhibit poorer ALP skills when exposed to background aircraft noise. Therefore, if educators become aware of these differences in noisy situations, they can tailor strategies taught within the classrooms to maximise learning for both genders, such as possibly providing increased visual stimuli to females in these situations. The consideration of these differences can allow for optimal results for all learners, regardless of gender.

From the above studies, females' ALP skills appear to be stronger than males. However, females, when exposed to environmental noise, showed greater stress to noise, and had decreased motivation. It is unclear whether this stress impacts on their learning abilities, as well as ALP skills. As the practical element of ALP skills in noise has not been studied, it is also unclear, that if this is affected, will it be affected equally amongst genders? This can influence the knowledge of educators and therefore the strategies implemented within the classroom to influence an ideal method of education for both genders.

Learning and Cognition Linked to Auditory Language Processing

Auditory perception and phonological abilities have been proposed to play a critical role in skilled reading as well as in reading disabilities. A study by Watson and Miller (1993) showed that auditory perception and processing of speech was strongly related to short-and long-term auditory memory and phoneme segmentation. These phonological variables in turn were strongly related to reading. Nonverbal temporal processing was not significantly related to any of the phonological variables in the structural equations. It was concluded that speech perception, which was measured with speech repetition, syllable sequence discrimination, and degraded speech tasks, may contribute significantly to individual differences in the phonological abilities necessary for skilled reading. Reading is very closely linked to cognition and learning (Ferrer, McArdle, Shaywitz, Holahan, Marchione & Shaywitz, 2007).

Baddeley (1992) again shows the links between ALP, specifically working memory affecting learning. Working memory may be defined as the system for the temporary maintenance and manipulation of information, necessary for the performance of such complex cognitive activities as comprehension, learning, and reasoning. Working memory can be divided into three subcomponents. First is the central executive which is assumed to control attention. Subsequently the visuo-spatial sketch pad manipulates visual images, and lastly the phonological loop stores and rehearses speech-based information which is important for the acquisition of both first language and second language vocabulary (Baddeley, 1992a). The various subcomponents of working memory, such as the constituents of the phonological loop relate to other aspects of memory and cognition. The central executive which regulates the operation of the two subsystems, namely the phonological loop and visual sketchpad performs a multitude of executive functions. The term executive function refers to a set of cognitive abilities that control and regulate other abilities and behaviours. The link between working memory, which is a component of LP is clearly linked and overlaps areas of cognition (Gathercole, 2001).

Thus, it is evident that there is a positive relationship between ALP and learning. In the study mentioned previously by Stansfeld, et al. (2005), cognition was shown to be affected by noise. As there may be a link between cognition and ALP, it is also important to investigate the effect of noise on ALP.

Classroom Acoustics

When a school enrols a student with a physical disability, it is expected that the school makes modifications to facilitate learning for the child with special needs e.g. if a child requires a wheelchair, structural changes such as a wheelchair ramp should be implemented. If a student has poor listening, this could be an indicator of ALPD, then so too, adaptations

should be made. However, in America, Palmer (1997) described how poor listening conditions were present in schools on a daily basis.

However, until recently there were no standards for classroom acoustics internationally, and implementations to facilitate these ALP difficulties were not accounted for. Fifty dB is an acceptable level for OAE testing, a measure extremely sensitive to noise which suggests that it is a standard level which could be applied to pure tone testing too. This noise level could possibly also be ideal for an occupied, learning environment. This lack of standards though is distressing as children may spend up to 45% of their school day engaged in listening activities (Palmer, 1997). There are currently no regulations with regard to classroom acoustics in South Africa.

Sound or excess noise occurs as air molecules are in constant random motion which creates static air pressure. This air pressure is proportionate to the density of the molecules. Under some conditions, changes in air pressure may be perceived as sounds. The human auditory system needs to detect the changes, whether they are local or diffuse, big or small, and slow or fast. These detections need to be processed and sent to the brain for meaning.

When designing classrooms and facilitative learning environments, the major goal in the acoustical design is to facilitate energy and direct sound, and minimise reflections in order to enhance communication (Smurzynski in Chermak & Musiek, 2007). This is implemented by taking reverberation, background noise, construction materials, amount of children in the class and many other factors into account.

In order to make changes within the classroom environment to maximise listening, the classroom acoustical elements, such as background noise, reverberation time, the SNR and

the distance from the speaker to the listener needs to be understood (Crandell & Smaldino, 2000). Any external, internal or room noise is regarded as background noise.

External noise can be traffic noise and aircraft noise while internal noise arises from within the school building, but not from the classroom, such as noise from the hallways. Room noise can be regarded as any noise arising from within the classroom such as the scraping of chairs against the floor. Background noise needs to be considered carefully as it can mask the teacher's voice (Berg, Blair, & Benson, 1996). Reverberation occurs when the listener receives multiple and delayed copies of the sound as it is reflected off the room surfaces. These reflections often cause distortion (Sayles, Schouten, Ingham & Winter in Kollmeier, et al., 2007). This reverberation is always present to some extent in closed rooms; however, depending on the amount of reverberation, the teacher's voice may be masked out. Reverberation increases as the volume of the room increases and the amount of sound absorption decreases. This also contributes towards background noise (Nabelek & Nabelek, 1985).

The SNR is one of the most relevant factors to consider when determining the effectiveness of spoken communication. It is the comparison of the signal level to the level of the background noise (Crandell & Smaldino, 2000). As mentioned earlier a child needs at least a +10 dB SNR, while an adult only requires about +6dB to hear speech effectively. Lastly, the distance from the speaker to listener influences the perception of speech. Loudness of a direct sound decreases in proportion to the distance. In the ideal situation, a learner should be seated in close proximity to the teacher; however, this is not always possible, specifically in South Africa, where the number of learners in the classes is large (Palmer, 1997).

In a classroom, not only can the reverberation affect the listener's perception of the teacher's voice, but this reverberation can cause teachers to emit higher vocal emissions, and thus, this places educators at a higher risk to develop voice disorders (Astolfi, et al., 2011). These voice disorders can, in turn, cause a poor quality of the voice when teaching, and thus can affect the 'ease of listening' for learners. In noisy environments where the signal is already compromised, the weakened signal from the teacher may mean that the children do not get optimal information transfer.

A child with an ALPD or a hearing problem needs preferential seating, and should ideally to be provided with a frequency modulated (FM) system or infrared system. Infrared systems are often the chosen option for a group of learners in a classroom. It transmits sound in the form of invisible infrared light waves. This technology is immune to electromagnetic interference (Waldowski, 2002).

However, the more common FM system can be useful as it assists in projecting the teacher's voice at a level where students can hear comfortably without straining, it improves the SNR in the range of +5 to +10 dB by producing a nearly uniform loudness level in the classroom that is unaffected by the teacher's location. It reduces the effects of reverberation and distance from the teacher so those students in the back of the classroom can hear, and it facilitates acoustic access to information for all students in the classroom (Hamaguchi, McCullough, Novak, Ross-Swain, Wilkerson & Roberts, 2002).

The main premise for improving classroom acoustics though, is that the better a child can hear, the easier it will be for a child to process information. Also, children are viewed as vulnerable populations, and thus more susceptible to be affected by noise (van Kamp &

Davies, 2011). Thus, vulnerable populations, such as children, are at risk to develop certain disorders, such as ALPDs.

Therefore the exposure to noise, specifically for children, can be more detrimental than to adults (Aday, 1994). As described, background noise, such as aircraft noise can decrease the SNR, making it more difficult to hear. This constant noise seems to disrupt concentration, and thus processing problems may be the long term result.

However, by improving the acoustics, one can increase the SNR, thereby decreasing the disruptions in concentration and so on, and hopefully assist in the prevention of processing problems. Nevertheless, once processing problems are already present, improving the classroom acoustics, by small changes within the classroom to help and reduce reverberation, as well as with the FM system, can help these children manage and cope with this already existing difficulty.

With regard to FM systems, children are often resistant to wear these devices due to cosmetic reasons. Therefore, hearing aids have been suggested, as they are smaller, and learners may be more willing to wear them. The success of these hearing aids depends very much on the type of hearing aids, and different features, which often contributes to the cost. The aspects that these hearing aids should include to possibly assist with ALPDs are wide dynamic range compression, open ear fittings, mild gain with maximum power output adjustment, directional microphones and noise reduction algorithms (Kuk, 2011). However, especially in developing countries such as South Africa, this is not always a reality, due to the cost. Therefore, although it is optimal, it is not always possible to provide learners with assistive listening devices as well as adjusting the frameworks of learning. In such cases,

where costs are an issue, one can adjust the different areas of learning to provide a more optimal listening environment.

As the school and classroom environment is critical for the learning and development of children, there is a framework of areas that needs to be considered to maximise learning. This framework divides the complex environments and interactions within schools into different areas which can be the focus of a design-led approach to change. Learning is the centre of this framework which needs to be maximised to attain each learner's true potential. It is the outcome both of changes to the school's environment as well as modifications to the communication within the school and its services. As learning is in the centre, it is likely that changes to one area will impact and influence changes in another area (Higgins, Hall, Wall, Woolner & McCaughey, 2005).

Research on the effects of aircraft noise on ALP is thus important as it can assist to motivate for the transformation within the support system of a school (i.e. better acoustical design), and consequently it will in turn assist with learning (Higgins, et al., 2005). By identifying the factors that interfere with the development of ALP and learning, such as noise, changes to this environment can be made and can enhance this acquisition of knowledge in a true productive manner.

Typical school buildings and classroom layouts vary between countries in ways that are often related to material resources. Some schools, specifically in rural South Africa are not buildings, but space under a tree. In other schools, as in peri-urban areas in South Africa, learning takes place in prefabs with very thin walls, and some schools do consist of brick classrooms, yet with poor acoustics such as thin windows and doors, and limited posters and carpets to absorb the sounds. This does not help to achieve an acceptable SNR for the

children to learn. This is not to say that this does not happen outside of South Africa, but generally in the developed world classrooms and schools are carpeted, the quality of the doors are thicker, and the brick walls are often plastered due to more resources being available. Schools have been described in South Africa as having large, deteriorated and unwieldy classrooms with limited resources (Ndungane, 2010). Although the layouts and environments are important, it is necessary to make reservations and accommodations depending on budget and resources (Higgins, et al., 2005), which is a common issue in South Africa.

As it would be difficult to rebuild existing schools, specifically in South Africa due to limited financial budget, it is thus important to develop new ways to structure the future schools that have not yet been built. Research on the effects of environmental factors, such as noise on children's learning is important as it can help to motivate for better structural planning of future schools. Thus research on the effect of noise, such as aircraft noise on a child's ALP skills can help to motivate for the improvement of acoustical design of future classrooms. Without the advance of research to motivate for improvement of schools layout, it is seems unlikely that much will change with these future structures.

However, one cannot merely plan for future schools as it is also essential to make accommodations for already existing schools. By reducing the internal noise level, one can help to compensate for the already existing external noise, such as from aircrafts. However, by reducing both internal and external noise levels, it may be possible to achieve the ideal SNR within the classroom. It is important to consider the fundamental aspects of the physical environment, including the internal noise sources, such as heating devices, lighting apparatuses and acoustics, which can increase these internal noise levels, as well as the overall design of the school, which will encompass these aspects (Higgins, et al., 2005).

Therefore, it is important to identify impacting environmental aspects such as noise on ALP and education, and to motivate for the appropriate changes in zoning. However, it is also important and ethical to deal with these existing problems that have been identified from this research, by advising for changes in the environment including lighting and so on, as well as to provide methods for teachers to assist in the management of the ALPDs and the referrals to other therapists.

Bamiou, Campbell & Sirimanna (2006) state that intervention strategies of an ALPD can be divided into five main categories which can include environmental modifications such as structural changes within the building, signal enhancement strategies including assistive listening devices, teacher/speaker based adaptations, formal and informal auditory training, and compensatory strategies. Teacher adaptations and strategies can include preferential seating, use of multimodality cues, repetition and rephrasing of information, checking frequently for understanding and pre-teaching information where possible (Bellis, 2002).

The signal enhancement strategies do not only entail strategies as mentioned above, but include several options available to improve the listening and noise levels within an already occupied classroom. This can include the installation of sound absorbing room and ceiling tiles and replacing old doors and windows (which may also improve the energy efficiency). The use of carpeting can reduce reverberation of middle and high frequency sounds, generally beginning at 1000 Hz. Acoustical ceiling tiles can provide a more uniform effect by reducing reverberation in a variety of sound frequencies, typically with higher levels of diminution occurring at 500 Hz to 4000 Hz (Berg as cited in Brace, 2006). The exact effect of blinds is still unknown. Average ceiling height in classrooms is also recommended to be at 9.57 feet (Rosenberg, et al., 1999). FM and infrared systems can also be included as methods to assist in the increase of the SNR.

The installation of sound absorbing tiles, doors and windows can be quite costly yet there are alternative methods that can be used to increase the SNR. Walls can be covered with posters, decreasing the reverberation, carpets and curtains can be used. Egg-shell boxes have also been useful in dampening sounds, much like the sound absorbing tiles. This can be placed on the walls. Sound systems are also an option. It is less costly than the ceiling tiles as mentioned above, however, may not be as cost effective as the 'home made' option of curtains, carpets and egg-shell boxes.

Long and Flexer (as cited in Brace, 2006) conducted a two-year study of a school district in Oconto Falls, America, which improved the sound acoustics and SNR in all 37 of their regular elementary education classrooms. In the two years of this study, the referrals for special education evaluation decreased from 7.72% to 4.6%. Thus, although change in acoustics may be costly to implement, it can reduce the need for further referrals, and thus reduce costs in that manner.

Higgins, et al. (2005) also mentioned that other researchers have drawn attention to inadequate acoustical layout, and proposed various solutions such as increased carpeting, implementation of sound amplification systems, and ceiling hangings to lessen the reverberation. Ahrentzen and Evans (as cited in Higgins, et al., 2005) found that higher classroom ceilings decrease the perception of crowding, for both learners and teachers. However, Earthman (as cited in Higgins, et al., 2005) mentioned that these high ceilings may increase acoustical problems as a result of reverberation. The reduction of internal noise can assist to reduce the SNR, although it would be ideal to reduce both internal and external noise levels.

From the literature above, as well as other existing literature, it is evident that there is a considerable effect of noise on health, cognition and psychological well-being. As a result, reviews of the consequences of aspects of the physical environment tend to conclude that acoustics and noise are important factors in a school environment (Higgins, et al., 2005).

Acoustical problems and inadequate design result in reverberation. In an environment when there is already plenty of existing environmental noise, such as aircraft noise, correct acoustics are essential. Without this, the external noise together with the classroom noise and then combined with competing speech signals, all reverberate constantly, creating even more noise and decreased clarity (Higgins, et al., 2005).

CHAPTER 2

Rationale

Rationale

The studies mentioned show that environmental noise exposure can cause health related problems, such as myocardial infarction, as well as cognitive disturbances (Hygge, Evans, & Bullinger, 2002). In addition, this noise has been shown to hinder some ALP abilities. In turn, these decreased ALP skills can lead to poor cognitive development. As discussed, the correct acoustics can help minimise `these noise levels, and therefore decrease the damaging effects of noise. For that reason, in combination to studying the effects of aircraft and traffic noise on ALP skills, this research also aims to motivate for appropriate compensations of this noise, as in acoustics.

Feuerstein (2002) described that noise can produce a permanent threshold shift. The cochlear hair cells can swell following noise exposure, causing some rupturing, resulting in permanent loss. Hair cells may also be distorted and stereocilia may become fused, or the stereocilia may no longer transmit energy effectively to the hair cells post noise exposure. Progressive damage may lead to degeneration of auditory nerve fibres and to changes within the central nervous system.

In a longitudinal study, 2325 children's hearing was tested at age 7, 10 and 13 with screening audiometry. Results showed that the increasing incidence of hearing loss, specifically for boys as they grew older was probably due to noisy leisure time activities (Axelsson, Anlansson & Costa, 1987). There has been a considerable amount of research on noise induced hearing loss (NIHL), which is becoming more prevalent in the younger generation, as seen in the above mentioned study. Children are thus increasingly being exposed to noise, partly due to leisure activities, as well as in combination to environmental noise, such as from aircrafts. It has been perceived that other environmental factors, such as

lead exposure, can also negatively influence ALP (Dietrich, Succop, Berger & Keith, 1992). However, there has not been as much emphasis to the extent to which noise affects ALP, when hearing is normal, particularly within the South African context.

The studies on noise and ALP have, however, been demonstrated in a more anatomical manner, i.e. at what level anatomical site of the central auditory system does noise cause abnormal activity (Gaab, Gabrieli & Glover, 2006). These anatomical studies have great value, yet they do not always translate into practical implications in the classroom. These practical elements are relevant as many schools are located in noisy suburbs.

The Cape Town International Airport has four schools located within a 2 kilometre radius from the airport, the M10 and M12 highways as well as from the railway line. Near the previous Durban International Airport, there are six schools within 2 kilometres from the airport and 1.1 kilometres from the M4 highway. These schools are also surrounded by and are within 500 metres from the railway line. In close proximity to the O.R. Tambo International Airport in Johannesburg, there are three schools within 2 kilometres from the airport. The noise sources mentioned exclude other main roads and traffic noise sources. It is thus important to understand the effects of the noise on the learners.

For instance, when an aircraft passes overhead, the noise can interrupt a school lesson and consequently disrupt concentration and processing. Then within a few seconds all is quiet again (Stockbridge & Lee, 1973). Therefore, noise effects often appear to be transitory. However, in cases where there are aircrafts frequently flying overhead, cognitive defects were not found to be momentary (Cohen, et al., 1980).

In conjunction to the schools being exposed to aircraft noise, many learners are not taught in their first language as South Africa is a multilingual country, as discussed earlier in the literature review section. In a country where there are multiple existing educational considerations, such as bilingualism in schools, children are not always educated in their home language, and in addition, many schools are exposed to noise. This language barrier can be extremely difficult for the child, and can already place him/her at an educational disadvantage, as he/she may not understand the teacher. It is thus imperative to try to alleviate other such potential barriers, such as environmental factors, for example noise.

Theoretically, environment induced disorders can be prevented by adjusting factors or links in the pathogenic chain (Levi in Cooper, 2005). Noise in the classroom can cause a reduction in hearing and decreased intelligibility and understanding of speech by the learners (Shield & Dockrell, 2003). Excessive background noise and reverberation has been demonstrated to affect the achievement and educational performance of children with sensorineural hearing loss (SNHL), children with normal hearing sensitivity who have other auditory learning difficulties, as well as elementary school children with no verbal or hearing disabilities.

In a study done in Ohio, USA, 32 different unoccupied elementary classrooms in eight public school buildings were investigated. The results were compared with the limits recommended in the American National Standards Institutes' (ANSI) standard for acoustical characteristics of unoccupied classrooms in the United States (ANSI S12.60-2002). Results indicated that most classrooms were not in compliance with ANSI noise and reverberation standards. Although classroom acoustics and noise levels affect the learning environment, many schools do not adhere to these standards. Therefore, it is important to illustrate the

extent that noise affects learning, and possibly ALP in order to motivate for the modification of our classrooms (Knecht, Nelson, Whitelaw & Feth, 2002).

According to Smith, Cowie and Blades (2003), children attend to information that is stored in memory through the processes of rehearsal, organisation, and elaboration. This information is often presented auditorily by the teacher. Therefore, noise can have a great effect on the degree to which information is processed, retained, and recalled (Cohen, Evans, Stokols & Krantz, 1986), and can ultimately impair early childhood development and education, as well as have life-long effects on achievement of academic potential and good health.

A study by Klatte, Wegner and Hellbrück (2005) exposed that noise causes verbal information to either not be fully understood or to be completely misunderstood. Furthermore, listening becomes more as the learners must use more cognitive capacity to decode speech. This noise can negatively affect the learners' development of the auditory and cognitive functions relevant to listening (Nelson, 2003).

Thus, it is evident that children learn a great amount in the classroom. The classroom acoustics and listening environment should therefore nurture this listening, learning and processing. It is difficult to find literature on policies in South Africa that outline the necessary architectural design for classrooms, and the measures to enhance the acoustic environment. The South African National Standard (SANS) Policy in South Africa recommends the noise level to not exceed 40 dB (A) in classrooms (SANS, 2008). However, if aircrafts are continuously flying overhead, these regulations are not being met. If learners are not able to clearly hear the educator, it is likely that they are unable to process the correct speech and acoustic signals. Thus, the crucial classroom function of providing an enriching

environment that enables the transfer of information and knowledge from the educator to the learners is adversely affected.

This noisy classroom environment not only disturbs listening and learning, but can also have a negative impact on a child's ability to socialise and interact. Pre-adolescence is the stage where children establish close intimate friendships that becomes exceedingly important in adolescence. In order for these social relations to occur, the processing of speech is imperative (Bushmester, 1990). Since a child's ability to process and understand speech in a noisy environment does not reach an adult level until the teenage years (Nelson, 2003), it is crucial to investigate the effects of noise on the learners' auditory ALP and how the possible negative effects can be alleviated. The main focus is on preadolescent children as opposed to adults, specifically school age learners in grade 6 and grade 7.

Noise may have an effect on preschool learners; however, school age learners are of particular interest, as they are immersed in learning daily and an ALPD result in a significant disadvantage for them. As children advance in school, the listening requirements become more demanding, and listening skills and note taking are required. Problems with ALP can affect listening and note taking, a skill specifically important for grade 6 and 7 learners, as they soon transition into high school where these skills are essential.

In a study by Gaillard, Jertz-Pannier, Mott, Barnett, LeBihan & Theodore (2000), it was established that children had on average, 60% greater extent of activation in the language area of the brain (Broca's area) than adults. Children also displayed significantly more right hemisphere and inferior frontal gyrus activation than adults. The greater activation found in children, including the right inferior frontal gyrus, may indicate developmental plasticity for organization of neural networks, which underlie language capability. Children's brains are

still growing and developing in the school age years. It is therefore even more crucial to investigate the effects of noise on learning and processing, not only in an anatomical domain, but in a more functional and clinical manner, in order to provide them with the ideal environment to maximise their potential.

This research expounded on the effects of long term aircraft noise exposure on the ALP abilities of English First Language (EFL) primary school learners and aimed to assist in the identification of these problems. The research also proposed ways of assisting the rehabilitation of children, if they were identified with an ALP problem, in order to assist in the prevention of further problems. In this way, overall health will be promoted, be it auditory, social and/or emotional.

The promotion of health is what nations should aspire to, rather than solely focusing on the treatment of symptoms, problems and diseases. Causative variables can be identified and accommodated by suggesting preventative implementations (Levi in Cooper, 2005). In the promotion of health and education, teachers need to be educated on multiple educational disorders, however, this research targeted specifically of ALPDs. They need to be informed on early identification and methods to aid in the rehabilitation of ALPDs and environmental layouts need to be modified to decrease the possibility of the development of disorders and to minimize the consequences of already identified disorders.

Therefore, this study investigated the effect of this noise on the ALP of learners in noisy school environments when hearing was within normal limits. Loeb (1986) stated that overall human efficiency is decreased when exposed to noise, when studied in a laboratory. This has not been shown in an everyday setting. One of the reasons for decreased effectiveness may be an ALPD. Thus, the implications of the study will hopefully lead to the

motivation for the development of more appropriate laws with regard to the zoning of schools, as well as to the development of better acoustically designed classrooms to enhance the listening of learners.

These environmental modifications will facilitate everyday learning in an everyday setting. Classrooms need to facilitate the clear acquisition of speech while preventing unwanted reverberating sound that interferes in this speech. By adjusting some measures of design in the classroom, it can provide for a more acoustically conditioning classroom (Edwards, 2002). Apart from the design and acoustical changes necessary, a trans-disciplinary approach to help learners with diverse language and educational difficulties, including ALPDs, is also necessary to assist learners in the classroom. "SLTs need to inform the Department of Education, schools and educators about their roles in order to secure posts in education, which should be included in policies and negotiated with school administrations" (DiMeo, et al., as cited in O'Connor & Geiger, 2010). Therefore, posts for speech therapists and audiologists in mainstream schools should be recognised and implemented.

This research also aimed to increase the awareness of ALPDs and thus the management of these children through referrals to speech therapists and audiologists, as well as the implementation of classroom based strategies by the educators. In South Africa, a country with developmental challenges, where successful education is seen as a hope for future development, addressing factors which can compound learning difficulties, such as ALP difficulties brought on by environmental noise, may provide opportunities for successful learning.

CHAPTER 3

Methodology

Methodology

Research Question

Do the auditory language processing abilities of English First Language (EFL) learners who attend aircraft-noise-exposed schools differ from learners who attend non-aircraft-noise-exposed schools?

Aim

The aim of this study was to investigate the auditory language processing abilities of English First Language (EFL) learners who attend aircraft-noise-exposed schools and learners who attend non-aircraft-noise-exposed schools.

Sub-Aims

The following sub aims were incorporated into this study:

- To investigate verbal working memory, auditory discrimination, phonological memory and phonological awareness in grade 6 and grade 7 learners.
- To examine auditory language processing abilities in male and female learners in noisy and quieter schools.

Context of the study

This study formed part of a larger project, RANCH-SA (Road Traffic and Aircraft Noise and Children's Cognition and Health-South Africa), conducted in the Departments of Psychology, Education (Geography discipline) and Speech Pathology and Audiology at the University of the Witwatersrand. This audiology study was conducted at two schools exposed to aircraft noise which were matched to two control schools in Durban that were not exposed to aircraft noise. The schools were equivalent with regard to socioeconomic status, race and

language. This audiology study on the effects of aircraft noise on auditory language skills utilised the ALP data from the above project that had been collected at the two schools exposed to aircraft noise at the time of the proposal. More data was subsequently collected from the two schools in quieter areas, in order to make a comparison of ALP performance and were also used in the larger RANCH-SA study.

Research Design

Mann (2003) stated that the hallmark of a good study is the way in which it is conducted. It is important for the researcher to plan the design in the best way that will elicit the desired information (Doehring, 1988). Therefore, the current study utilised a non-experimental, cross sectional and descriptive design, as well as a post-hoc design. This study was non-experimental as there was no experimental manipulation of variables, such as the aircraft noise and children being tested. The descriptive research allowed for the observation of group differences, trends within and between groups, and relationships within the different factors of research (Gravetter & Forzano, 2011). This allowed for the investigation of the relationship between auditory language processing and aircraft noise.

Cross-sectional research is a method of sampling often used in epidemiological studies that allow the researcher to observe and analyze a population at one point in time (Bland, 2000). This cross-sectional study therefore permitted the researcher to measure the nature of the changes by drawing samples from learners of different age groups. Cross-sectional studies describe research carried out at one point in time or over a short period (Levin, 2006). These methods are generally conducted to estimate the prevalence of the outcome of the study and are often used for health care planning.

Levin (2006) described how cross-sectional studies can be used to determine associations between risk factors and the outcome of interest. Mann (2003) also stated that these studies are useful to study the aetiology of a certain condition, yet it does not allow for the determination of cause and effect alone. Thus, in these cases the comparison of groups is necessary. These cross sectional studies help to determine prevalence of an occurrence or condition, and all the measurements of the individual are made at one point in time. An advantage of this method is that the subjects or participants are not deliberately exposed to a potentially dangerous causative factor and this may help to lessen ethical dilemmas (Mann, 2003). However, a cross sectional study can be limited by the fact that they are carried out at one time point and therefore give no indication of the sequence of events (Levin, 2006). In this study, it was not determined whether chronic aircraft noise exposure over fewer years may also cause auditory language processing difficulties, but, instead, focused on exposure for at least six years to gain an insight into learners' performance at a particular point in time after prolonged exposure. However, this does not impact on the reliability of the study; it simply does not provide a specific period needed for aircraft noise exposure to result in auditory language processing difficulties.

Epidemiological studies have become a familiar tool for investigating long term health effects of the occupational environment, such as of noise. A retrospective study is an epidemiological study where a group of people have been identified to have all experienced a certain event or environmental influences (such as noise). Retrospective studies are a powerful method used to identify long term health effects of specific exposures (Swaen & Meijers, 1988). As studies utilizing this retrospective type of design make use of data already collected for other purposes, this study utilized the already collected data of ALP skills conducted at the noisy schools under the larger RANCH-SA project. This design can help prevent bias as the data was already collected for the other study. One advantage of such a

study design is the lack of bias because the outcome of current interest was not the original reason that the data was collected (Mann, 2003).

Ethical considerations

In every research involving the investigation of human participants, ethical approval is required in order to ensure the psychological and physical safety of each person. The need to conduct research ethically is vital to every research project and is essential in order to obtain credibility of the collected data (O'Leary, 2004). Permission to conduct this study as well as the pilot study was obtained by the Department of Psychology at the University of the Witwatersrand under the auspices of the RANCH-SA study. Permission was also obtained from the University of the Witwatersrand (protocol number 2008ECE94) as an addition to the RANCH-SA application. In addition, permission to conduct the study in the identified schools was obtained from the KwaZulu-Natal Department of Education. Permission to conduct the study in the individual schools was subsequently sought from the school principals.

Information sheets and consent forms were sent to both the parents of the grade 6 and grade 7 learners and to the learners themselves. Parents signed the consent forms to indicate that they understood the purpose of the study and the voluntary basis of participation of their children. The purpose of the study was verbally explained to the individual learners as well as what was required from them.

It is important to obtain written permission or consent from the parents, with the assent of the children when they are capable of making their own decisions and understand the research in question (Wendler, 2006). It is therefore essential that a health care provider offers clear details to children in a language that they can understand (Broome, 1999). The

parents and children were given the option of not participating or withdrawing from the study at any time without any repercussions or penalty. They were also given the opportunity to ask further questions or express any concerns. Participants' confidentiality was insured by coding the data once it was captured. The data was kept in a secure place and only the researcher's supervisors and the researcher has access to the data.

Participants were told during recruitment in both the information sheet and the consent form that there were no direct benefits to individuals for participating in the research. The researcher provided contact details of herself in the cover letter, should participants have felt that they required additional information.

Participants who were identified with ALP problems or hearing difficulties were referred to the nearest speech-language therapist and audiologist for further assessment and treatment. Public and private sector options were provided. A referral letter was provided to the parents once the tests had been scored within a week after testing. Referrals were provided for the hearing loss identified, as well as/or the ALP difficulties. The results of the hearing screening were also immediately explained to the learner although the results of the ALP assessments were not provided to the learners with immediate feedback as the assessments needed to be scored. The referral letters provided the researcher's personal details should the parents have had any further questions regarding the research or their child's assessment results.

Due to the fact that many government facilities are not permitted to treat 'school age language' problems, the teachers at the schools were also provided with strategies to help the identified children compensate and cope with their difficulties. School age language problems, in South Africa, are viewed as an educational problem, and not a health problem,

and thus are not treated by the health department. This brings forth a dilemma as 'main stream' public sector schools do not employ speech therapists or audiologists. S. Bolton, the Head of the Speech Therapy and Audiology Department at Chris Hani Baragwaneth Hospital stated that free health care is available for children below 6 years of age, however, there are limited recourses available, and thus, healthcare is prioritised to this age group. Due to limited resources, children older than 6 years of age who present with school age language problems cannot be treated in government hospitals (personal communication, May 16, 2011).

Participants

Learners from two groups of schools were utilised in this study. These two groups consisted of two schools exposed to high intensities of aircraft noise, while the other group consisted of two schools exposed to considerably less noise, not located in close vicinity to the airport. The noisy schools, School A and School B, were located 1.7 km and 1.9 km respectively from the airport. These two schools were under or very close to the flight path and were over-flown by landing and departing aircrafts.

The quieter schools, School C and School D were 4.6km and 3.5km from the airport. Equivalence was sought between these quieter schools and those schools exposed to aircraft noise on the basis of socio-demographic characteristics. Classroom acoustics were also considered during the matching process. Reverberation levels were not directly measured; however, various observations were made. Reverberation would be affected mostly by the room size, construction materials and furniture inside the rooms.

The classrooms at all of the schools were of almost identical dimensions, which meant that the volumes experienced in the classrooms were very similar. All of the classrooms had very similar furniture – a teacher's desk and chair, and standard learners' desks and chairs of

the type found in state schools in South Africa. All classrooms were similarly constructed from brick and mortar, had a hard floor (i.e. no carpeting which would affect acoustics), gypsum board ceilings, a chalkboard in the front of the class, one 600mm door and windows on the side walls. Given the similarity of reverberation characteristics of the classrooms, it was assumed that reverberation was extremely similar and therefore would not affect the results. All of the classrooms did not have optimal absorption of the sound, which created high levels of reverberation and poor sound quality in the presence of the external aircraft noise.

These equivalent groups were sought to assist in helping with the isolation of the effects of the independent variable (Doehring, 1988), namely noise. The participants were in grade 6 and grade 7. In total, there were 129 children whose results were analysed for this study. Sixty-one children participated from the noisy schools, while 68 children participated from the quieter schools. The number of children of each respective grade and gender can be observed in Table 1.

Table 1

Participant profile – grades and gender

	Noisy Schools (total n=61)	Quieter Schools (total n = 68)
Grade 6	n=27	n=32
Grade 7	n=34	n=36
Males	n=31	n=34
Females	n=30	n=34
Males in Grade 6	n=16	n=16
Females in Grade 6	n=11	n=16
Males in Grade 7	n=15	n=18
Females in Grade 7	n=19	n=18

This study drew on a non-probability purposive sampling technique, whereby the researcher selected the participants based on identified variables under investigation. There were various criteria for the participation in the study including:

- Attendance at the school from grade 1.
- Hearing within normal limits when screened by an audiologist. According to Doehring (1988), hearing levels can be defined by standard audiological tests. Thus, the criteria included thresholds at or better than 20 dB SPL at 500 Hz, 1kHz, 2kHz and 4kHz.
- In addition, only the learners from grade 6 through to grade 7 were eligible to participate in this study. This group was selected for a variety of reasons. First, as the data was available and being used in the RANCH-SA study, these were the grades

currently being used in the study. Second, the study aimed to investigate the long term effects of aircraft noise exposure on ALP abilities. Thus, these are the last two grades in primary school, allowing for the children to have been exposed to the aircraft noise for many years.

- Only English First Language learners were utilised in this study due to the fact that these formal tests are standardised on first language English speaking children and to preclude any reliability and validity issues from second language English speakers who are prevalent in these four selected schools. In order to determine whether the child was an EFL speaker, the researcher asked each learner what language they speak at home, what language their parents speak, if they remembered speaking to or being spoken to in another language besides for English at home. If English was the answer to the above questions, the learner was assumed an EFL speaker. As the learners were in grade 6 and 7, they were considered old enough to provide reliable answers to the above questions. Although all of the grade 6 and 7 learners were assessed, for ethical reasons, only the EFL learners' results were analysed for the study. It is essential to provide assessment measures to all the children within the selected grades, as well as to provide them with appropriate referrals, in order to maintain accepted ethical standards.
- Learners with known learning difficulties, auditory and attention problems were excluded from this study. Some ALPDs can occur as a toddler. This could impact on language and learning, and may cause a learning disorder. Even though the ALP tests may yield a result diagnosing the problem, one cannot be sure when this occurred, and cannot attribute it to the noise at school (Bellis, 2002). The teachers were thus informed of this requirement and their subjective judgements were used to help identify previously diagnosed children with learning, AP, and hearing difficulties, as well as children who had been failing and struggling in school in previous years. This

was to alleviate the over diagnosis of ALP difficulties, where the problem may actually have been a pre-existing hearing or attention problem, independent of the aircraft noise. This requirement was to ensure validity and to not skew the results. The instruments, thus, specified these criteria to enhance the reliability and validity of the measurement.

- Children above 12 years of age could not participate as the instrument was only normed on children up to 12 years of age. The data collection at both the noisy and quiet schools was completed within the first term of the academic year to ensure that the children were at similar academic levels.

As mentioned in the literature, HIV/AIDS can cause neural disturbances which in turn may affect ALP. Although HIV/AIDS can possibly affect ALP test results, for the purposes of this particular study, it would be considered unethical to request participants to disclose their HIV/AIDS status, and exclude them from the study based on their status. Therefore, it was not an exclusionary criterion. However, because two groups were utilised in this study, with equal chance of having HIV/AIDS, it should not have affected the conclusion of this research of the effect of aircraft noise of ALPDs. Due to the large number of children infected with the disease throughout South Africa, it is important to identify the effect that HIV/AIDS has on auditory language processing skills, and thus is an important area for future research but, because this study was not looking at the effects of HIV/AIDS in themselves and because of the high numbers of children with HIV/AIDS in school, children with HIV/AIDS were not excluded to represent the general school going population where HIV/AIDS may be a feature.

Although the requirements for participation were stringent, the group design can still have disadvantages. Doehring (1988) explained that group designs have many advantages

and disadvantages and cognisance of these advantages and disadvantages were taken in this study. Some advantages of collecting data from a group setting, for example a school, include: the ability to isolate and control the effects of independent variables, such as noise levels, gender and grade and the ability to obtain detailed information about interactions and causal relationships.

However, there may be limitations of the information of each group member that can be obtained, such as a detailed case history probing areas that may cause ALP difficulties. It was not practical to conduct detailed case history interviews with the children's parents/caregivers, as many of the caregivers work, and some children did not live the their parents who would know the child's history. However, this group design seemed to be the most appropriate for this research study, despite these disadvantages.

Instruments and Materials

As discussed, verbal working memory, auditory discrimination, phonological awareness and phonological memory are important skills for learning. These areas were thus selected to be the focus of this research.

Auditory processing instruments. The study utilised:

- Subtests of the Test of Auditory Processing Skills (TAPS) (Verbal Working Memory and Auditory Discrimination) (Gardner, 1985).
- Subtests of the Phonological Assessment Battery (PhAB) (Phonological Awareness) (Frederickson, Frith & Reason, 1998).
- The Dollaghan and Campbell Non-word Repetition Task (Phonological Memory) (Dollaghan & Campbell, 1998).

Test of auditory perceptual skills (TAPS). The TAPS is an assessment tool developed to measure a child's functioning in various areas of auditory perception. This diagnostic measure may be administered by psychologists, speech and language pathologists, learning specialists, diagnosticians and other professionals. Even though the main function of this tool is to examine a child's auditory perception, it can only be used to learn about the child's ability to understand directions, articulation and thought processes. The TAPS purports to prevent any bias from ethnicity, gender, education or language. The test was designed to be suitable and appropriate for children in the United States and in other English speaking countries. Even though it was developed for other countries other than the United States, it has not been formally standardised for the South African population. A pilot study was thus essential. The TAPS is applicable for children from 4 to 12 years of age (Gardner, 1985). As the TAPS is standardised, the test provides the examiner with standard scores (scaled scores and auditory quotients), percentile ranks and language ages for each subtest (Gardner, 1985).

From the time of the development of the initial TAPS test, there have been two more editions of the test, namely the TAPS-R and the TAPS 3. There are slight differences in the subtests. With regard to auditory number memory (reversed), all the tests progress in difficulty from two numbers to three numbers and so on. The numbers however used in the TAPS, compared to the TAPS–R and TAPS 3 are different. With regard to auditory discrimination, the TAPS and TAPS–R make use of the same word discrimination subtest. The TAPS-3 however has fewer test items (32 in comparison to the 50 in TAPS and TAPS-R), and although many of the words are the same, some of the words do differ from the original TAPS.

With regard to the sentence memory test, all three tests are slightly different. The original TAPS begins with a two part sentence, with five words. The parts of the sentences

and amount of words increase as the test increases in difficulty. When examining the TAPS-R, the initial test item has four words, and as the test continues, the sentences increase with the amount of words. The TAPS 3 however differs in that it increases in difficulty with sentence parts, and not necessarily words. Although it is ideal to use the most recent TAPS 3, the original TAPS was the instrument used because it was the test utilised in the data collection obtained by the RANCH-SA study in the earlier stages of the study. However, because there only appears to be slight differences in the versions, the TAPS appeared to still be a valid measure.

In addition, the study aimed to compare the results of the noisy and quiet schools and therefore, the comparison needed to be on the same measure; the TAPS. Because the main aim was to observe and compare the differences of scores between the schools, the use of the original test should not have impacted the validity of the study. The subtests that were used in this study from the TAPS included:

Auditory number memory- reversed. Digits reversed - this subtest required the child to be attentive and perform different mental functions involving working memory. The child was required to listen to the digits listed in a sequence, subsequently store these digits in memory, then reorganise the digits from a forward series to a reversed order, and then repeat the data in the new required auditory sequence. This subtest specifically analysed a child's ability to concentrate and perform an activity requiring mental control. Each digit was presented with a 1 second pause between numbers, as outlined in the manual. The ceiling score was obtained when the child repeated, omitted or substituted one of the numbers. This subtest was scored by providing each number in a set where there was no error with a score of one. The total number of correct digits was summated. This raw score was calculated into an age equivalent score from the TAPS manual (Gardner, 1985).

Auditory sentence memory. This subtest targeted the skill of immediate recall for auditory material in a sequence. This subtest assisted in indicating whether the child omits words, substitutes words, distorts words, and/or changes the sequence (Gardner, 1985). Sentence memory is proposed to highlight the interaction between short term memory and LP and detailed analysis of these results aids in the identification of the relationship. Short term memory errors are demonstrated with word errors, where the meaning is intact, while LP errors are demonstrated more when the meaning in not relayed (Vance, 2000). Each sentence was presented with increasing difficulty, and with a 1 second pause between words. Testing was discontinued when the child made one or more errors in two consecutive sentences. Each sentence that was repeated correctly was given a score of one. This raw score was again converted into an age equivalent score (Gardner, 1985).

Auditory word discrimination. In order to perform this task well, a child needed to have the cognitive skill to understand 'same' and 'different'. This tested the child's ability to discriminate paired one and two syllable random words with phonemically similar consonants (Gardner, 1985). In a study by Kraus, McGee, Carrell, Zecker, Nicol & Koch (1996), it was found that difficulties with discrimination of sounds in speech signals, often accompanies and may contribute towards a learning problem. These learning deficits were found to originate in the auditory pathways, when tested with electrophysiological measures. Thus, an ALP deficit, such as a discrimination problem, is important to identify as it can impact greatly on a child's life by causing or leading to a learning problem. Each child was instructed to face away from the researcher at approximately a 30 centimetre distance during the administration of this test. A 1.5 second delay period between the presentations of the words was utilised. The total number of words paired the 'same' by the child was recorded, and so too were the 'different' pairs. The total score of the 'different' responses of the child were converted from this raw score to an age equivalent score (Gardner, 1985).

These age equivalents or derived scores allow for the comparison of normed responses or of the child's performance relative to other persons. They allow comparison of the individual's scores with other subtests or tests (Gardner, 1985).

Phonological assessment battery (PhAB). The PhAB was designed to asses phonological processing. Phonological processing can be described as the ability to process sounds in spoken language (Frederickson, et al., 1998). The test was first developed in 1992 by educational psychologists, psychology trainers and leading academics. The test was subsequently revised and normed. It is suitable for children in the age range from 6.0 to 14.11 years who have hearing within normal limits. Thus, the selected age range, of grade 6 to 7 was suitable for both the TAPS and the PhAB. The subtests that were used in this study from the PhAB included:

The alliteration test. This test evaluated a child's ability to isolate the initial sounds in single syllable words. Each trial consists of a set of three words, where the child was instructed to name the two words that started with the same sound (e.g. with the set of words; 'lot, **m**ess, **m**ud', the words; 'mess' and 'mud' start with the same sound). The test increases in difficulty; initially starting with the words that differ with the first consonant, to words that differ with blends (e.g. 'lot, mess, mud' and 'shop, mat, shell'). A correct response is considered when the child says the two words that start the same, and any other answer is incorrect (Frederickson, et al., 1998).

The rhyme rest. This was designed to test a child's ability to identify the rhyme in single syllable words. Just as in the above test, each set consisted of three words, of which two of the words rhymed. The child was then required to say the words aloud that rhymed. The test was scored the same as in the alliteration test. Each word was presented with no

emphasis on the rhyming part of the word, as a rate of one word per second (Frederickson, et al., 1998).

In order to score the PhAB, the researcher obtained a raw score. This raw score was then converted to a standardised score. The PhAB has a mean of 100, and a standard deviation of 15. Thus:

- Standardised scores in the range from 86 to 114 are regarded as 'average'. About 68% of all children fall within this range.
- Standardised scores in the range from 115 to129 are regarded as 'above average'. About 14% of children fall within this range.
- Standardised scores of 130 or higher are 'well above average'. About 2% of children obtain such scores.
- Standardised scores in the range from 71 to 85 are regarded as 'below average'. About 14% of children fall within this range.
- Standardised scores of 70 and lower are 'very much below average'. About 2% of children obtain such low scores.

(Frederickson, et al., 1998)

Although this test did not provide age equivalent scoring methods, it nevertheless allowed the researcher to compare the results with normed data, thereby allowing for the observation of any deviation or abnormalities, specifically when exposed to noise.

Dollaghan and Campbell non-word repetition task. This non-word repetition task involved 16 non words, ranging from consonant-vowel-consonant (CVC) non-words to CVCVCVCVC non-words (Dollaghan & Campbell, 1998).

The aim of the non-word repetition task was to assess phonological memory in a non-biased manner with regard to language proficiency and vocabulary. It has been shown that the split-half reliability for non-word repetition task is high; suggesting that the 16 non-word stimuli meet accepted standards for internal consistency. This test comprises of non-word syllables that do not correspond to lexical items and thus the predictability of the phonemes is minimised. The phonemes are acoustically salient and these non-word syllables were presented with a consistent rate, accuracy and intonation to ensure reliable and valid testing (Dollaghan & Campbell, 1998).

There are currently no normative data available for this test. Thus, each child's score on the non-word repetition test was calculated on the basis of the percentage of syllables correctly obtained. The number of syllables in each non word were first counted and then added together to provide an overall score. This was then converted into a percentage.

The results of each age group in each school were added together and a mean was calculated. The results could then be examined on the normative curve, and could be explained according to standard deviations for that group of children, of that specific age, in that specific school. The mean of each age group within each school was then compared to the mean of the other schools with the corresponding age group. This made use of descriptive statistics. A three way analysis of variance (ANOVA) was also used to analyse this test.

The subtests were administered throughout the school day with the children on an individual basis. The instructions to the participants for the ALP assessments were clearly set out before testing by the researcher according to the test manuals. This was done to ensure reliability and validity. The subtests were all administered in the same order:

1. Auditory Discrimination

2. Alliteration Test
3. Auditory Number Memory Reversed
4. Rhyme Test
5. Auditory Sentence Memory
6. Non-word Repetitions Task

Frederickson, et al. (1998) mentioned that administering the alliteration and rhyme test consecutively with children below 8 years of age, may be affected as some children may have difficulty switching their focus from the initial sounds to the end sounds. Although the children tested were older than 8 years, this guideline was still taken into consideration.

Hearing Screening Instruments. This study utilised the following instruments:

- Heinz Mini Otoscope with multiple speculae
- GSI 38 Tympanometer – SN: A5063517
- GSI Screening Audiometer– SN: 466971

Noise Measurement Instruments and Method.

A poor test environment can jeopardise the behaviour of the subjects, and thus negatively affect reliability (Schiavetti & Metz, 2002). Noise measurement was thus essential to monitor noise levels and thus allow testing to be conducted in an optimal noise condition (50 dB (A) SPL or below). A SVAN 955 type one sound level meter was used to measure noise. A Rion NC74 acoustic calibrator was used to check the instrument calibration before and after the measurements was performed. The sensitivity of a sound level meter must be calibrated according to a predetermined standard. Noise measurements using the SVAN 955 type one sound level meter were taken throughout the day at each of the schools for one day at each school. The sound level meter was placed within a 5 meter radius of the testing room.

The average sound levels (LEQ), as well as maximum and minimum sound levels were recorded. The percentile was calculated (L90 – sound levels for 90% of the time and L10 – sound levels for 10% of the time). These readings allowed the researcher to understand the typical noise levels at the each school in an average day. These measurements were recorded and calculated by the Department of Education (Geography discipline) at the University of the Witwatersrand.

Additional sound level meters (Quest – SN: A5064517), supplied by the Department of Speech Pathology and Audiology from the University of the Witwatersrand were also used. These meters were placed next to each tester throughout the day. Testing was paused when the sound reached 50 dB (A) or greater. Thus by monitoring the sound levels, and ensuring that testing occurred in an environment of 50 dB (A) SPL or less, the researcher adhered to the standard of Rhoades, et al. (1998) where it was stated that testing should be 50 dB (A) SPL or less when testing for TEOAEs. As OAEs are extremely sensitive to noise, this standard was employed for the hearing screening and ALP assessment.

Other Materials. The remainder if the materials included:

- All necessary infection control and hygiene solutions.

Procedure and Protocol

Pilot study. Given that the ALP instruments (TAPS, PhAB, non-word repetition task) that were utilised in this study are not standardised for the South African population, a pilot study was conducted at a public sector school in Lenasia to investigate the validity and reliability of this instrument for its use in the main study. Hedge (1987) articulated that the reliability of a standardised test cannot be established elsewhere and from measuring other people's behaviour. It thus needs to be standardised on the population in which it is being

used. The school at which the pilot study was conducted looked to have a similar socio-economic, racial and linguistic make-up as the schools used in the research study.

Thirty children were tested (15 children from grade 6, with ten males and five females, and 15 children from grade 7, with eight males and seven females). The children had no known learning disability or reported hearing loss. However, seven children's results could not be used as they were not English first language speakers. The researcher found that the children did not perform age appropriately on the spoonerism test. This may be due to the fact that it was the last subtest in the group of tests and that the children tired. This test was thus excluded from the testing procedure in order to prevent the invalidation of the results. As the areas of verbal working memory, auditory discrimination, phonological awareness and phonological memory were still covered, which are important for learning, the remaining selected tests were still regarded as sufficient to obtain information regarding multiple areas of ALP for this population.

The results from the auditory discrimination tests, auditory number memory-reversed tests and auditory sentence memory tests were scored according to age equivalent scores. The scores from the alliteration and rhyme test were converted to standardised scores, and placed on a probability curve, ranking the children from below average to above average. With regard to the results of these tests, 84% performed age appropriately with the auditory discrimination subtest and 76% of the children scored age appropriately in the auditory number memory-reversed subtest as well as with auditory sentence memory. A hundred percent of the children performed 'average' in the alliteration tests, and 84% performed 'average' or 'above average' in the rhyme test (see Appendix A, Table 20). Results from the non-word repetition task were scored according to the procedure described above

The non-word repetition test was used as a measure of phonological memory skills. The learners performed well on the non-word repetition task. The 11 year old learners obtained an average of 90.72 with a range of scores obtained between 73 and 95 out of a total of 96. The 12 year old learners obtained an average of 97 with a range of scores obtained between 77 and 96 out of a total of 96. Their individual results correlated well to the other tests, showing validity of each of the subtests. Overall, the females' results appeared to be slightly better than the scores of the males in this pilot study.

As the children scored mostly within their age range or within the average of children their age, it did not appear that the reliability or validity was affected by race or culture, as the learners in this pilot school performed on par to the learners in America where it was standardised. These measures were therefore considered suitable to be utilised in the main research project.

Data collection. The ALP data from the noisy schools was obtained from the first phase of the RANCH-SA study. This existing data was analysed in relation to the new data which was collected from the quieter schools. Doehring (1988) stated that the situation in which the research is conducted is an important aspect of data collection. All the data was thus collected in an area with minimal distraction. Although the data collection took place in classrooms, the children did not face any posters or other such distractions throughout testing. A speech therapist and audiologist conducted the hearing screening, while two speech therapists and audiologists collected the ALP results. Noise measurements were used from the larger RANCH-SA study. The data included hearing screening, and auditory language processing assessments.

Hearing screening. Hearing screening included otoscopy, tympanometry and screening pure tone audiometry. As the procedures carried out were only for screening purposes, and not to diagnose a specific type of hearing loss or site of lesion, acoustic reflex testing and electrophysiological measures were not performed during this hearing screening. Cut off screening levels were at 20 dB HL, and failure of two or more frequencies in at least one ear was considered the baseline where the learners were referred for further assessment. A participant who failed the hearing screening measures was excluded from further ALP assessment to be used in this research because hearing loss can result in ALP difficulties, which could skew the results of this research investigating whether noise affects ALP.

Children with only type A tympanograms were included in the study, as any other types of tympanograms can show malfunctioning in the middle ear. Otitis media can cause slight hearing loss, which can go undetected in a routine hearing screening protocol. However, as mentioned previously, up to 13 to15% of school age children may have this slight hearing loss. A slight hearing loss can still cause educational problems (Nelson & Soli, 2000). Testing was only completed if noise levels did not exceed 50 dB (A) SPL, when monitored with a sound level meter. Failure of the hearing screening protocol resulted in a referral letter to consult with an audiologist regarding a potential problem. The results of the ALP assessment for each learner were only used for this research if their hearing screening measures fell within the specified range as described above.

Auditory language processing assessment. As already mentioned, the administration of tests was conducted with the children on an individual basis throughout the school day. Each test was scored at the end of the day. The researcher and the colleague are both qualified speech therapists and audiologists who administered the tests in order to standardise the testing and allow for greater reliability. The administration procedure was prescribed by

the test and thus eliminated tester bias. As mentioned, testing was conducted throughout the day. However, when an aeroplane flew over the school, testing was stopped as this noise could have impacted the results. Testing was paused when background noise levels exceeded 50 dB (A) SPL. Testing was also stopped during break time, even when the noise levels were below 50 dB (A) SPL. This was to ensure that all the children had their 'break', which attempted to prevent fatigue during the testing. TEOAEs can be performed in an environment of up to 50 dB (A) SPL of noise even though they are extremely sensitive to noise. This was thus the cut off level of noise for the ALP testing to occur. The same protocol was utilised at all the schools.

Data analysis. The study utilised various types of statistical analyses, including descriptive methods, Pearson's chi-squared tests, Fisher's tests, three-way ANOVAs, Cramer's V tests and Cohen's D tests. Each method was selected according to the type of data collected, being parametric or non-parametric, as well as the frequency of the specific data. Descriptive statistics were used in this research as it helps to examine group differences, developmental tendencies, or relationships among variables that can be measured by the researcher (Schiavetti & Metz, 2002). The arrangement of the hearing screening results, with descriptive statistics according to percentages, was thus used to organise and summarise data. Although the hearing screening was not an aim of the study, it was still noted to ensure that the assessment and results were reflective ALP difficulties and not of hearing loss.

The six different subtests were scored in various manners, namely: percentages, age equivalent scores and standardised scores, and thus different statistical measures were necessary. The age related scores, as in the auditory discrimination, auditory number memory-reversed and auditory sentence memory had scores of 'greater than12 years'. Due to this nature of scoring, non-parametric measures were utilised in order to perform statistical

measures that would not be skewed. These scores were thus divided into frequencies; scores 12 years and greater, and scores below 12 years.

Therefore, for this non-parametric data, the Pearson's chi-squared tests were done. The chi-squared tests were used to determine whether there was a significant statistical difference between the expected frequencies (children in noisy schools) and the observed frequencies (children in quieter schools) in one or more categories. Thus each of these three auditory language processing tests underwent nine different chi-squared tests comparing test scores in relation to noise levels, gender and grade. Pearson's chi-square test was found to be very robust with small expected cell frequencies, and thus was a relevant test, as some tables had extremely low frequency count (Camilli & Hopkins, 1978).

However, some of the cell counts in the above three tests were below five, and thus Fisher's exact tests were necessary. Although the chi-squared test works well with a low frequency count, it does not calculate reliable conclusions with a cell count lower than five. Thus, in this case with cell counts of below five, the Fisher's exact test was implemented, as this analysis is accurate with extremely small frequencies. The Fisher's exact tests, like the chi-squared tests, calculates the difference between the data observed and the data expected, however it is much more difficult to calculate. But, in cases with such small cell count, it was essential to use the Fisher's exact test.

With the remaining three tests, namely the non-word repetition task, rhyme and alliteration tests, data were analysed with an ANOVA, in order to obtain interactions within the data. As the scores were percentages and standardised scores, they could be analysed with more complex measures, such as analysis of variance (ANOVA) (Doehring, 1988). ANOVA is a statistical procedure which allows for the analysis of the relationships between a number

of predictor variables and enables values to be recorded (Rutherford, 2001). Because there were three variables, namely the noise levels, gender and grade, a three-way ANOVA was used. The three-way analysis of variance is an extension to the one-way analysis of variance; however, there are three independent variables (Schiavetti & Metz, 2002). Each variable was analysed separately, and well as with interactions, such as the test scores versus noise, then the scores versus noise and gender combined, and then the scores with noise, gender and grade combined, and so on with each variable. This was done separately for the three tests.

The strength of association was calculated with the Cramer's V test to assess the strength of the relationships within each test identified as significant (auditory discrimination, auditory number memory and auditory sentence memory). It was used as a post-test to determine strengths of association after chi-squared and Fisher's exact tests had determined the significance. Cramer's V values of below 0.2 represented a weak association, 0.2-0.4: moderate association, 0.4-0.6: relatively strong association, 0.6-0.8: strong association and values greater than 0.8 represented a very strong association (Cramer, 1946).

With the non-word repetition task, rhyme and alliteration tests, the effect size, which is a measure of the strength of the relationship between two variables, was calculated by Cohen's D test. This effect size indicated the magnitude of a relationship as the Cramer's V test does with the above tests. This allowed the researcher to compare which ANOVA tests were the most significant. Values of Cohen's D between 0.2 and 0.5 were considered to represent a small effect, 0.5-0.8 a moderate effect and value greater than 0.8 were considered to represent a large effect (Cohen, 1977).

This research was also analysed using post hoc analysis. Post-hoc analysis, in the context of design and analysis of experiments, refers to looking at the data after the

experiment has concluded for patterns that were not specified prior to the population (Tukey, 1977). However, Fraenkel and Wallen (1993) term this research of examining a phenomenon that has already occurred as ex post facto. This post hoc or ex post facto design was used due to the fact that the data at the noisy schools were collected prior to this study, as part of the larger psychology and geography study. Post hoc analysis was also carried out with the Tukey HSD test. The Tukey's multiple comparison test is a method used to determine which means amongst a set of means differ from the rest. The Tukey HSD test was used to compare the difference between each pair of means with appropriate adjustment for the multiple testing after the ANOVA was performed (Tukey, 1977).

Data were described with tabular representations and graphs, methods frequently used for descriptive statistics. The tables described all six subtests, while graphs were used for the parametric data, as in the non-word repetition task, rhyme and alliteration tests. The main trends of the research were also summarised by measures of central tendency and variability. These central tendency measures included means, medians and modes, while variability measures included standard deviation (Doehring, 1988). These central tendency and variability measures were calculated for the non-word repetition task, rhyme and alliteration tests in order for the ANOVA calculations.

Confounding Factors

Empirical studies indicate that ALP may be confounded by background variables (e.g. language spoken at home, quality of school, etc.) and social deprivation (Haines, Stansfeld, Head & Job, 2002). For instance, previous research has found that learners from socially deprived areas have lower educational attainment than their counterparts from less disadvantaged backgrounds (Higgs, Bellin, Farrell, 1997). Another study (Haines, Stansfeld, Head & Job, 2002) investigated the effects of chronic exposure to aircraft noise on learners'

(aged 11 years) school performance, taking into consideration social class and school characteristics. Chronic exposure to aircraft noise was found to be significantly related to poorer reading and mathematical performance.

However, after adjustment for socioeconomic status, these associations were no longer statistically significant, which implied that chronic exposure to aircraft noise was associated with reading and mathematics only as a dose-response function, since socioeconomic factors confounded the association. Contrary to the above mentioned study, longitudinal studies (Bronzaft, 1981) have found that a reduction in noise exposure eliminated previously observed noise-related reading deficits, thereby suggesting that socio-economic status does not confound the relation.

The noise levels at the time of the testing can also be a confounding factor. The learners' concentration may have been disturbed every time he/she had to stop while an aeroplane flew over and until testing could resume. As testing took place throughout the school day, some children were tested earlier than others. Thus, children tested at the end of the day may have been more fatigued than children tested early in the morning. This was thus noted during the analysis of the results, however no trends were recognised.

A study by Sliwinska-Kowalska (2011) demonstrated how individual susceptibility to NIHL may vary, depending on genetic factors. The genetic factors that have been identified are oxidative stress genes, K+ recycling pathway genes and heat shock proteins genes. Individual factors can thus influence NIHL susceptibility, and it is unsure whether there are possibly genes that can influence ALPD susceptibility. Because the groups were matched, there should be equal chance for each group to have equal amounts of gene variability; however, this cannot be completely assured.

Another factor to consider is the possible effect that noise has on sleep, and in turn on ALP skills. A study by McGuire & Davies (2011) showed that aircraft noise can result in increased number of awakenings during the night. This could affect children's ability to concentrate in the day, as they may not be as attentive and awake, when compared to children who do not live near aircraft noise. Generally, children attend schools near their homes, and thus, it is likely to assume, that the children attending aircraft noise exposed schools live nearby these schools, and therefore are exposed to this chronic, intermittent aircraft noise exposure throughout the day after school and during the night. However, the results of this study are still reliable to indicate the effects of aircraft noise on ALP skills, but not necessarily in school.

Lastly, as Hedge (1987) mentioned, human behaviour can be highly variable under natural conditions. Although various considerations have been taken into account, such as the nature of the situation and the use of group comparisons, a child's behaviour can be variable from day to day. This study could not control this variability. However with the comparison of groups, each group respectively should demonstrate equal variability. Equal variability within the child's behaviour between both groups however cannot be guaranteed.

Implications

Bistrup, Hygge, Keiding and Passchier-Vermeer (2001) stated that adults are responsible for establishing settings that can support children's needs through legislation, standards and behaviour modification. Thus, this research hopes to assist with the motivation for new laws in legislation, standards and behaviour modification. Research that demonstrates the harmful effects of environmental factors, such as noise on ALP skills, and in turn on education, aims to motivate for a change of legislation in that more appropriate

specifications are developed with regard to zoning of schools as well as to the development of better acoustically designed classrooms to enhance the listening of learners.

This research aims to assist in the change of the perspectives of educators, and the people involved in the education system. Changing people's perspectives and views helps to promote better standards and quality of education. By illustrating the impact that ALP difficulties have on every day classroom tasks, such as with memory, teachers can begin to understand the importance of these skills. Behaviour modification intends to be achieved by teaching the educators in these existing schools how to compensate for children with these already existing problems, while providing them with strategies to use in the classroom.

However, although this type of behaviour modification is necessary, Martin and Clark (2003) mentioned that ALPDs affect 2 to 3% of children, and thus are prevalent in schools. If noise affects ALP, then this percentage is likely to be greater in schools exposed to noise. Thus, the provision of speech-language therapy and audiology services within mainstream schools is necessary. Therefore, the overall implications of this study intend to investigate the possible effect of noise on ALP skills. The awareness of the effects of noise, as well as the extent of ALP problems already existing in these environments, aims to serve as motivation for changes in school structuring and zoning and well as for assistance from educators and speech and hearing therapists in the rehabilitation of these processing difficulties.

CHAPTER 4

Results

Results

These research data was scored and analysed with various methods to ensure accurate interpretation of the individual tests. Various tests, such as Pearson's chi-squared tests, Fisher's exact test and three-way ANOVA were used on the subtests, while descriptive methods were also utilised with the means of tables and figures. The auditory discrimination, auditory number memory-reversed and auditory sentence memory tests were analysed with chi-squared measures and Fisher's exact test, while the non-word repetition task, rhyme and alliteration tests were analysed with three-way ANOVA. When the ANOVA led to the conclusion that there is evidence that group means differ, the Tukey's multiple comparison test was utilised to investigate which of the means were different. In order to compare the significance of each individual test performed, the effect size (Cohen's D test) was calculated with the ANOVA tables, while the strength of association (Cramer's V test) was calculated with the chi-squared tests and Fisher's exact tests results. Noise levels and percentages of children who failed the hearing screening are demonstrated in tables.

Noise Levels

Noise levels were measured in 2009 as part of the larger RANCH-SA study using a type one sound level meter. The readings were taken again in 2010, showing approximately a 1 dB shift. As there have been no environmental changes since then, such as additional aircraft activity, the noise levels measured then can be assumed reliable and were used for this study. Noise levels can be seen in Table 2.

Table 2

Noise Levels at the Noisy and Quieter Schools

Noise Metric (dBA)	School A (noisy)	School B (noisy)	School C (quieter)	School D (quieter)
Leq	69.9	63.5	55.3	54.4
Lmax	97.6	91.8	74.2	76.9
L90	50.3	46	51.1	49.8
L10	62.2	57.9	57.6	56.1

Hearing Screening

Hearing screening was included in this study in order to eliminate any interfering variables, such as hearing loss. The noisy schools had a higher percentage of children who failed the screenings, as to be expected (see Table 3).

Table 3

Percentage of Children who Failed Hearing Screening at Both Noisy and Quieter Schools

School	Average Noise Level (dB)	Percentage of children who failed hearing screening
School A	69.9 dB	27.9 %
School B	63.5 dB	27.1 %
School C	55.43 dB	5.0 %
School D	54.4 dB	23.4 %

The children who failed the hearing screening protocol were excluded from further ALP assessments and were referred for a full diagnostic assessment at various private and public institutions. Parents and caregivers decided when and where to take these children for a full diagnostic assessment.

Auditory Processing Assessments

Due to the nature of the scoring methods for the six ALP tests, different methods of analysis were utilized, namely; Pearson's chi-squared, Fisher's exact test and three-way ANOVA.

Pearson's chi-squared test was utilized to analyse the auditory discrimination, auditory number memory and auditory sentence memory tasks, due to the binary nature of the response. These tests were scored according to age equivalent scores, ranging from less than 4 years to a maximum score being greater than 12 years. As multiple learners scored greater than 12 years, data was dichotomized into nominal data, being the frequency of learners scoring 12 years and greater, and below 12 years of age. This prevented extremely skewed results.

Thus, these two distinct categories allowed for a non-parametric statistical method, being Pearson's chi-squared test. As scores were divided into 12 years and greater, and below 12 years, the results were analysed according to grade, not age. Although there are different ages in each grade, all children in the same grade should be performing at the same level, despite age, and should be paralleled. Therefore, the test measured developmental or performance age, irrespective of the chronological age. Thus, the dividing the scores in this non parametric manner still proved reliable, as this test compares grade 6 to grade 6, which should have equal scores. This was done to ensure the reliability of the analysis of the data.

Pearson's chi-squared test can be applied in several different ways, but most frequently is used to test if there is an association, or no association between two categorical variables. In this case, these variables were noisy versus quiet schools, males versus females and grade 6 learners versus grade 7 learners. When using this test, a table of expected

responses must be calculated to determine if there is no association between the two variables under consideration. The expected values are compared to the values that are actually observed in the data. If the observed and expected values are similar, then the hypothesis of no association is retained. If the observed and expected values are not similar then one can claim there is an association between the two variables (Turner, 2000).

The chi-squared test assumed that both variables are nominal: that is, the data are categorical and have no natural order. The difference between the observed and expected values is calculated as well as a characteristic called the degrees of freedom. This relates to the number of rows and columns in the table under consideration. The p-value, which is calculated from the chi-squared statistic and its degrees of freedom, is used to determine whether the observed and expected values are similar enough to be able to declare no association. A common accepted standard is to reject the hypothesis of no association between the two variables if the p-value is less than 0.05 ($p < 0.05$) (Turner, 2000).

Due to the nature of this analysis, the chi-squared test did not take into account any interaction between variables, for example the combination of gender and noise on ALP skills. The chi-squared test simply takes into account the interaction of noise alone, and then gender alone, as well as grade alone.

However, some of the frequency tables from the above chi-squared test had extremely low frequency counts of below five. In this case, it was necessary to apply the Fisher's exact test which was used in the analysis of contingency tables where sample sizes are small. If the chi-squared test is applied to data when the number of observations obtained for analysis is small, the test may produce misleading results, and thus the Fisher's exact test can be more appropriate. The Fisher's test is exact because it uses the exact probability distribution that

describes the number of successes in a sequence (exact hypergeometric distribution) rather than the approximate chi-square distribution to calculate the p-value (Bower, n.d). Therefore, it was appropriate to use this measure in this current study because there were some variables being investigated with frequencies less than five, and thus the chi-squared test would not have extrapolated reliable responses. The Fisher's test was thus the suitable measure for this specific data with low cell counts to ensure reliability is maintained.

In comparison to the auditory discrimination, auditory number memory and auditory sentence memory, with the non-word repetition, rhyme and alliteration tests, and the data were continuous, and thus ANOVA was performed.

ANOVA allows the comparison between factor variability (variability between the groups or levels of the factor) to the random or error variability (variability within the groups or samples) to determine whether there is a significant difference. If the overall ANOVA indicated a positive significant difference, then multiple comparison tests can be used to show where this difference lies. The ANOVA assumes that the data being analysed is an independent random sample from the relevant population, and that it is normally distributed around the mean for that factor level (Girden, 1992). The data from the non-word repetition, rhyme and alliteration tests fulfilled these specifications, being interval data, while, in comparison, the other above mentioned tests, being nominal data.

When analysing the data, it is important to note, that the data was gathered in random order, thus, the different schools were tested on different days and weeks, different grades within schools were tested on different days, and males and females within each grade were tested randomly. This random testing allowed for the exclusion of patterns in collection of the data which may influence the validity.

When exploring the data, it was evident that with regard to frequency analysis, the schools were quite well balanced in numbers of learners between grades, gender and the noisy versus quiet schools, which is important for reliable analysis.

Bivariate Plots

The non-word repetition task, alliteration and rhyme tests were illustrated with bivariate plots (plots of the test scores against each other, two at a time). The correlation coefficients were calculated (see Table 4), where 1 illustrates perfect correlation, and 0 indicates no correlation. A correlation above 0.5 can be understood as relatively good correlation, thus, faring well in one test generally means being successful in the other tests and vice versa.

Table 4

Correlation Coefficients for the Scores of the Non-Word Repetition Task, Repetition and Rhyme Tests (all Significant at the 0.05 Confidence Level)

Test	Correlation coefficient
Non-word Repetition Test and Alliteration Test	0.62
Non-word Repetition Test and Rhyme Test	0.62
Alliteration Test and Rhyme Test	0.97

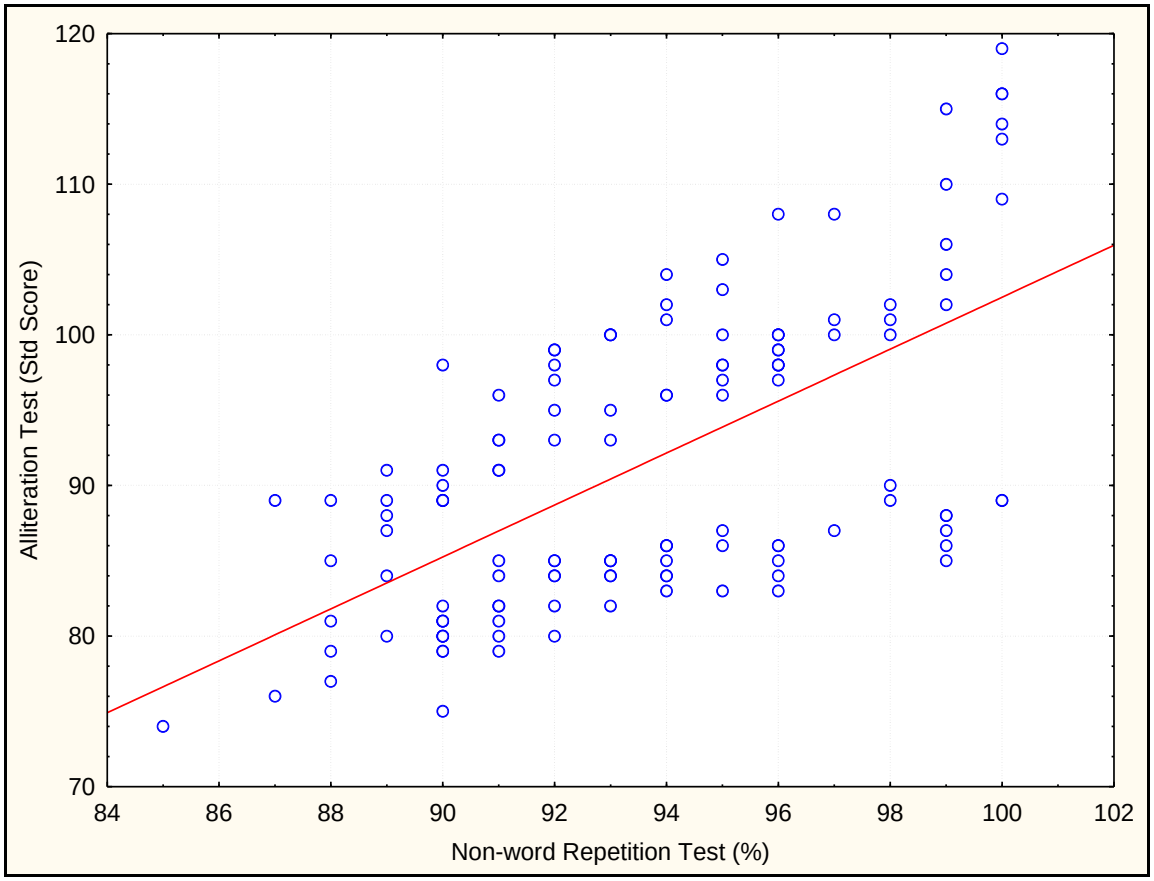


Figure 3. Scatter Plot: Alliteration Test (Standardised Score) Versus Non-Word Repetition Task (%) - Correlation Coefficient = 0.62

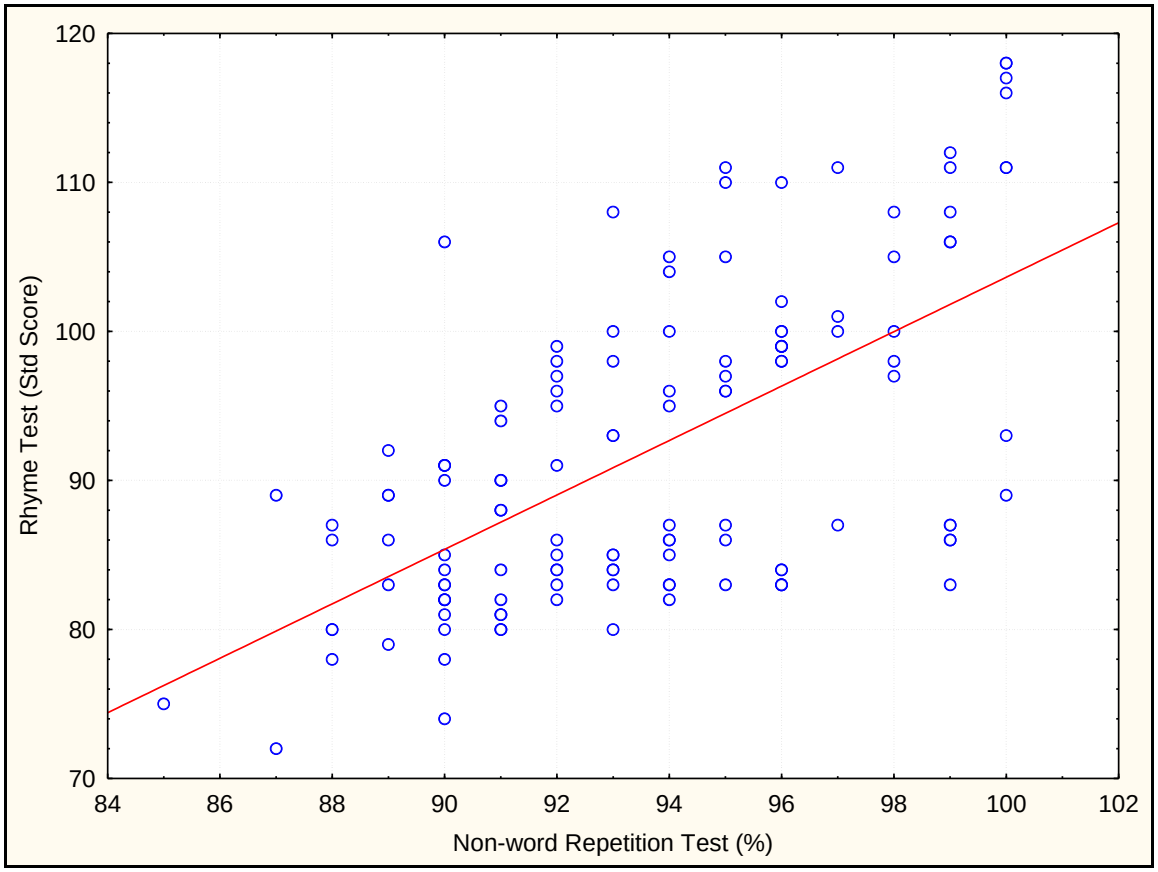


Figure 4. Scatter Plot: Rhyme Test (Standardised Score) Versus Non-Word Repetition Task (%) - Correlation Coefficient = 0.62

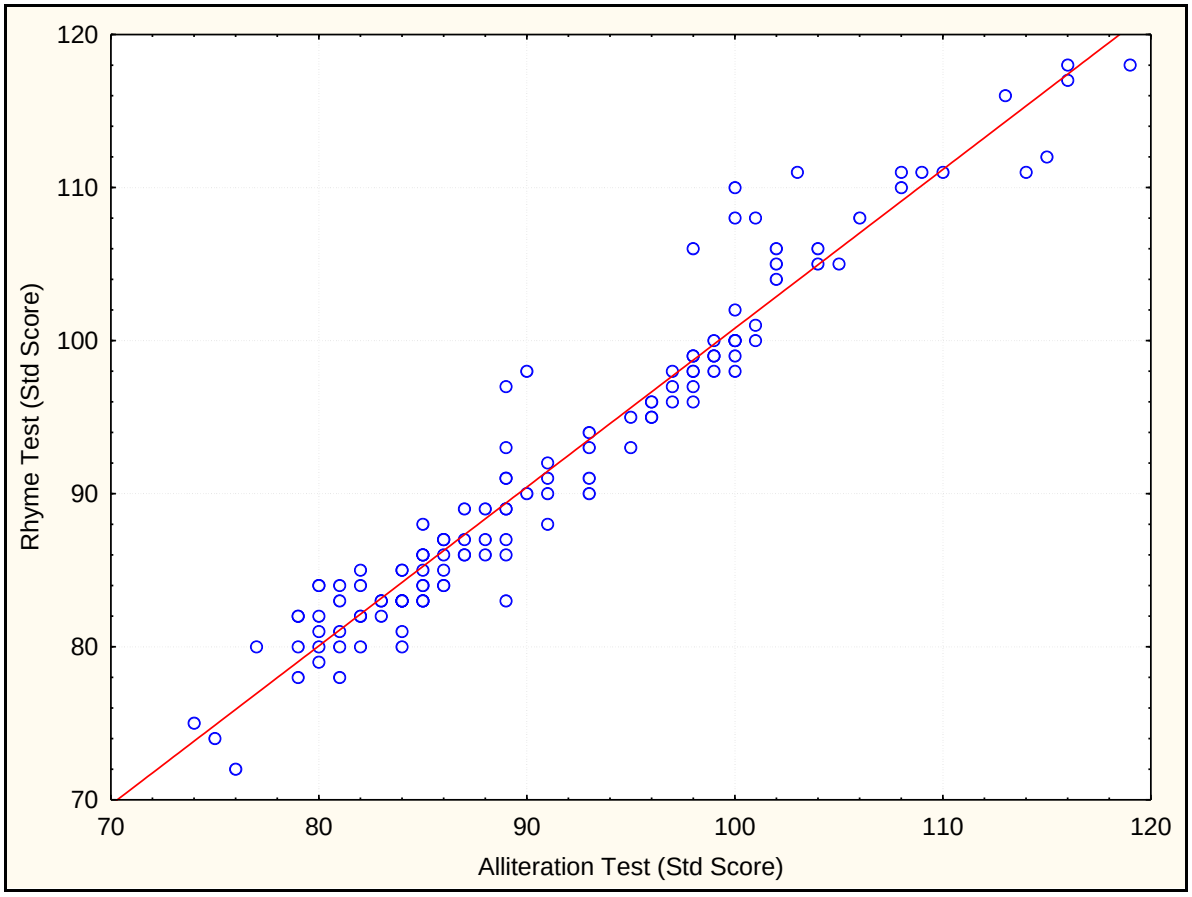


Figure 5. Scatter Plot: Alliteration Test (Standardised Score) Versus Rhyme Test (Standardised Score) - Correlation Coefficient = 0.97

Thus, with regard to the three tests, namely the non-word repetition task, rhyme and alliteration test, it is possible that the score of one test is likely an indication to the score on the other ALP test. Although the correlation coefficients were not calculated with the auditory discrimination, auditory number memory and auditory sentence memory tests, as will be described later in the results section, it is clear that all the tests were affected negatively by the aircraft noise in some manner. Thus, one can assume that if the one test is affected, it is likely that the other tests will also be affected.

Auditory Discrimination, Auditory Number Memory and Auditory Sentence Memory

As described above, the auditory discrimination test was analysed using Pearson's chi-squared test. Eleven different chi-squared tests were performed for each of the three subtests that were scored in this age equivalent score: auditory discrimination, auditory number memory and auditory sentence memory tests. The individual variables that were analysed included:

- Noisy versus quieter schools (grade 6 and grade 7 combined)
- Noisy schools grade 6 versus noisy schools grade 7
- Quieter schools grade 6 versus quieter schools grade 7
- Grade 6 versus grade 7 (both noisy and quieter schools combined)
- Noisy versus quieter schools (grade 6 only)
- Noisy versus quieter schools (grade 7 only)
- Males versus females (both noisy and quieter schools combined)
- Noisy schools' males versus noisy schools' females
- Quieter schools' males versus quieter schools' females
- Noisy schools versus quiet schools (males only)
- Noisy schools versus quiet schools (females only)

A p-value of 0.05 was utilised, and thus the null hypothesis of no association between the two variables was rejected when the calculated chi-squared value was greater than the critical chi-squared value of 3.84 for p=0.05 and one degree of freedom.

The strength of association was calculated with the Cramer's V test to assess the strength of the relationships within each test identified as significant (see Tables 7, 10 & 13). It is used as a post-test to determine strengths of association after chi-squared and Fisher's

exact test has determined significance. Cramer's V values of below 0.2 represent a weak association, 0.2-0.4: moderate association, 0.4-0.6: relatively strong association, 0.6-0.8: strong association and values greater than 0.8 represent a very strong association (Cramer, 1946).

Auditory Discrimination Tests

As mentioned, the significance of the auditory discrimination tests was calculated with the chi-squared and Fisher's exact tests, while the strength of association was calculated with the Cramer's V test.

The data from this test can also be described according to the percentages of learners scoring 12 years and greater within each grade and each gender, as thus measuring developmental age and performance (see Table 5 and 6).

Table 5

The Percentage of Learners Scoring 12 Years and Greater Within Grade 6 and Grade 7 Regarding the Auditory Discrimination Test

Grade	Noisy Schools	Quieter Schools	All schools
Grade 6	11% (n=27)	38% (n=32)	25% (n=59)
Grade 7	82% (n=34)	86% (n=36)	84% (n=70)
All grades	51% (n=61)	63% (n=68)	57% (n=129)

Table 6

The Percentage of Learners Scoring 12 Years and Greater Within Each Gender Regarding the Auditory Discrimination Test

Gender	Noisy Schools	Quieter Schools	All schools
Male	48% (n=31)	56% (n=34)	52% (n=65)
Female	57% (n=30)	71% (n=34)	64% (n=64)
Both genders	51% (n=61)	63% (n=68)	58% (n=129)

The results of the chi-squared tests and Fisher's exact tests are described according to the p-value. The values below the 0.05 level, as indicated in Table 7 showed a positive association:

Table 7

Summary of the Chi Squared Tests, Fishers Exact Test and Cramer's V Tests Conducted for the Auditory Discrimination Subtest

Auditory Discrimination Test	Calculated X^2 (p-value)	Cramer's V
Noisy vs. quiet schools	2.03 (0.155)	
Grade 6: Noisy vs. quiet schools	5.38 ** (0.020)	0.30
Grade 7: Noisy vs. quiet schools	0.19 (0.666)	
Grade 6 vs. Grade 7 (noisy and quiet)	45.4 ** (<0.001)	0.59
Noisy schools: Grade 6 vs. Grade 7	30.6 ** (<0.001)	0.71
Quiet schools: Grade 6 vs. Grade 7	17.2 ** (<0.001)	0.50
Male vs. female learners	1.83 (0.176)	
Noisy schools: male vs. female learners	0.42 (0.517)	
Quiet schools: male vs. female learners	1.58 (0.209)	
Quiet schools: male vs. female learners	0.37 (0.546)	

**Significant results

These results indicated that the overall relationship between the auditory discrimination test and noise levels was not significant. However, for the grade 6 learners, the quieter schools had a higher percentage of children (38%) who scored 12 years or greater than with the noisy schools (11%). The association with this test is moderately strong (Cramer's V = 0.30). The corresponding test for grade 7 did not show a significant relationship (see Table 7).

With the comparisons involving gender, there were no significant differences between the results for male and female learners either overall or stratified according to noise levels of schools (see Table 7).

When comparing the grade 6 results versus the grade 7 results, it was found that the grade 7 learners had a higher percentage of learners (84%) who scored 12 years or greater on this test than the grade 6 learners (25%). The association is relatively strong (Cramer's V = 0.59). This trend persists when one compares grade 6 learners and grade 7 learners within the noisy schools (82% versus 11%) and within the quieter schools (86% versus 38%). In these cases respectively, the associations are strong (Cramer's V = 0.71) and relatively strong (Cramer's V = 0.50) (see Table 7).

In summary, the auditory discrimination tests were affected by noise, and grade levels in some manner; the more noise or lower the grade, the poorer the auditory discrimination results.

Auditory Number Memory

The auditory number memory tests were examined using the same methods as the above auditory discrimination tests, including chi-squared tests, Fisher's exact tests and Cramer's V tests.

The data from this test can also be described according to the percentages of learners scoring 12 years and greater within each grade and each gender (see Table 8 and 9).

Table 8

The Percentage of Learners Scoring 12 Years and Greater Within Grade 6 and Grade 7 Regarding the Auditory Number Memory Test

Grade	Noisy Schools	Quieter Schools	All schools
Grade 6	0% (n=27)	16% (n=32)	8% (n=59)
Grade 7	44% (n=34)	86% (n=36)	66% (n=70)
All grades	25% (n=61)	53% (n=68)	40% (n=129)

Table 9

The Percentage of Learners Scoring 12 Years and Greater Within Each Gender Regarding the Auditory Number Memory Test

Gender	Noisy Schools	Quieter Schools	All schools
Male	32% (n=31)	44% (n=34)	38% (n=65)
Female	17% (n=30)	62% (n=34)	41% (n=64)
Both genders	25% (n=61)	53% (n=68)	40% (n=129)

As with the auditory discrimination tests, the results of the chi-squared tests and Fisher's exact tests are described according to the p-value. The values below the 0.05 level, as indicated in Table 10 showed a positive association:

Table 10

Summary of the Chi Squared Tests, Fishers Exact Test and Cramer's V Tests Conducted for the Auditory Number Memory Subtest

Auditory Number Memory Test	Calculated X^2 (p-value)	Cramer's V
Noisy vs. quiet schools	10.8 ** (0.001)	0.29
Grade 6: Noisy vs. quiet schools	4.61 (0.032)*	
Grade 7: Noisy vs. quiet schools	13.7 ** (<0.001)	0.44
Grade 6 vs. Grade 7 (noisy and quiet)	43.4 ** (<0.001)	0.58
Noisy schools: Grade 6 vs. Grade 7	15.8 ** (<0.001)	0.51
Quiet schools: Grade 6 vs. Grade 7	33.8 ** (<0.001)	0.70
Male vs. female learners	0.06 (0.802)	
Noisy schools: male vs. female learners	2.00 (0.157)	
Quiet schools: male vs. female learners	2.13 (0.145)	
Quiet schools: male vs. female learners	0.96 (0.326)	

* Fisher's exact test was not significant at p= 0.05.
**Significant results

It can thus be observed that the overall results of the auditory number memory test for noisy versus quiet schools was significant (53% versus 25%). The association is moderately strong (Cramer's V = 0.29). When comparing the noisy versus quiet schools (grade 7 only), the quieter schools had a higher percentage of learners (86%) who scored 12 years or greater than the noisy schools (44%). The association is relatively strong (Cramer's V = 0.44). The corresponding test for grade 6 learners did not show a significant association (very low percentage who scored 12 years and greater for both the noisy and quieter schools) (see Table 10).

There were no significant differences between the results for male and female learners overall or stratified according to noise levels of schools. However, female learners performed significantly better in quieter schools with the strength of the association being relatively strong (Cramer's V = 0.46). Male learners, however, showed no significant relationship with noise levels (see Table 10).

When comparing the grades, the grade 7 learners had a higher percentage of learners (66%) who scored 12 years or greater than the grade 6 learners (8%). The association is relatively strong (Cramer's V = 0.58). This trend persists when one compares grade 6 learners and grade 7 learners within noisy schools (44% versus 0%) and within quieter schools (86% versus 16%). The association is strong in both these measures (Cramer's V = 0.51 and 0.70 respectively) (see Table 10).

It can be observed that, like the auditory discrimination tests, from these auditory number memory results, it is evident that noise and grade levels do have an impact on auditory number memory scores, however, with this test, the gender effect can also be observed.

Auditory Sentence Memory

The auditory sentence memory was the third test analysed using the chi-squared and Fisher's exact test procedure. Again, a p-value of 0.05 was utilised. The data from this test were also described according to the percentages of learners scoring 12 years and greater within each grade and each gender (see Table 11 and 12).

Table 11

The Percentage of Learners Scoring 12 Years and Greater Within Grade 6 and Grade 7 Regarding the Auditory Sentence Memory Test

Grade	Noisy Schools	Quieter Schools	All schools
Grade 6	33% (n=27)	81% (n=32)	59% (n=59)
Grade 7	71% (n=34)	89% (n=36)	80% (n=70)
All grades	54% (n=61)	85% (n=68)	71% (n=129)

Table 12

The Percentage of Learners Scoring 12 Years and Greater Within Each Gender Regarding the Auditory Sentence Memory Test

Gender	Noisy Schools	Quieter Schools	All schools
Male	52% (n=31)	76% (n=34)	65% (n=65)
Female	57% (n=30)	94% (n=34)	77% (n=64)
Both genders	54% (n=61)	85% (n=68)	71% (n=129)

As with the above two tests, the results can be observed according to the p-value (see Table 13).

Table 13

Summary of the Chi Squared Tests, Fishers Exact Test and Cramer's V Tests Conducted for the Auditory Sentence Memory Subtest

Auditory Sentence Memory Test	Calculated X^2 (p-value)	Cramer's V
Noisy vs. quiet schools	15.1 ** (<0.001)	0.34
Grade 6: Noisy vs. quiet schools	13.9 ** (<0.001)	0.49
Grade 7: Noisy vs. quiet schools	3.66 (0.056)	
Grade 6 vs. Grade 7 (noisy and quiet)	6.59 ** (0.010)	0.23
Noisy schools: Grade 6 vs. Grade 7	8.41 ** (0.004)	0.37
Quiet schools: Grade 6 vs. Grade 7	0.79 (0.375)	
Male vs. female learners	2.22 (0.137)	
Noisy schools: male vs. female learners	0.16 (0.692)	
Quiet schools: male vs. female learners	4.22 (0.040)	
Quiet schools: male vs. female learners	4.38 ** (0.036)	0.26

**Significant results

The overall relationship between the sentence memory test and noise levels was significant (85% of learners scored 12 years or greater in the quieter schools versus 54% in the noisy schools). The association is moderately strong (Cramer's V = 0.34). For grade 6 learners, the quieter schools had a higher percentage of learners (81%) who scored 12 years or greater than the noisy schools (33%). The association here is relatively strong (Cramer's V = 0.49). The corresponding test for grade 7 did not show a significant relationship.

Within the gender results, there were no significant differences between the results for male and female learners either overall or stratified according to noise levels of schools. However, both groups of learners performed significantly better in quieter schools while the

strength of the association being relatively strong for females (Cramer's V = 0.44) while only moderately strong for males (0.26).

The grade variable showed that grade 7 learners had a higher percentage of learners (71%) who scored 12 years or greater than the grade 6 learners (33%) in noisy schools. The association is moderately strong (Cramer's V = 0.37). This trend was not significant when comparing the grade 6 learners within quiet schools. Overall, the grade 7 learners had a higher percentage of learners (80%) who scored 12 years or greater than the grade 6 learners (59%). The association is also moderately strong (Cramer's V = 0.23).

Thus, in conclusion, the tests that showed the strongest association with noise levels was the sentence memory test for grade 6 learners and the number memory test for grade 7 learners, as well as both of these tests for only female learners. The auditory discrimination resulted in four out of the eleven tests having a positive association, while the auditory number memory and auditory sentence memory tests had associations in six tests. These three tests were further compared as seen in Table 14.

Table 14

Comparison between Auditory Number Discrimination, Auditory Number Memory and Auditory Sentence Memory

Schools	Auditory Discrimination	Auditory Number Memory	Auditory Sentence Memory
Noisy versus quieter (both grades)		Moderate	Moderate
Grade 6: Noisy vs. quiet schools	Moderate		Relatively strong
Grade 6 vs. Grade 7(noisy and quiet)	Relatively strong	Relatively strong	Moderate
Noisy schools: Grade 6 vs. Grade 7	Strong	Relatively strong association	Moderate
Quiet schools: Grade 6 vs. Grade 7	Relatively strong	Strong association	
Female learners: Noisy vs. quiet schools		Relatively strong association	Relatively strong association

Non-word Repetition Test

A three-way analysis between subjects ANOVA with interactions was conducted to compare the effect of gender, school grade (grade 6 and 7) and noise level (noisy and quieter schools) on the Non-word Repetition Test.

The effect size, which is a measure of the strength of the relationship between two variables, was also calculated by Cohen's D test. This effect size indicated the magnitude of a relationship just as the Cramer's V test did with the above tests. These results allowed the researcher to compare which ANOVA tests were the most significant. Values of Cohen's D between 0.2 and 0.5 are considered to represent a small effect, 0.5 to 0.8 display a moderate effect and a value greater than 0.8 is considered to represent a large effect (Cohen, 1977).

A confidence interval of less than 0.05 is considered significant. A table of means together with their 95% confidence intervals for all groups in the non-word repetition task is shown below (see Table 15):

Table 15

Mean and Confidence Intervals for the Non-Word Repetition Task

Grade	Quieter		Noisy	
	Male	*Female*	*Male*	*Female*
Grade 6	91.3 *± 1.1 ** (n=16)	92.9* ± 1.5** (n=16)	91.4* ± 1.3** (n=16)	91.5*± 1.1** (n=11)
Grade 7	95.6* ± 1.7** (n=18)	96.5* ± 1.6** (n=18)	95.7* ± 1.8** (n=15)	93.1* ± 2.0** (n=19)

* Mean
**Confidence interval

The results of this ANOVA demonstrated a significant interaction at the $p<0.05$ level between gender and noise level [$F(1, 121) = 5.56$, $p = 0.020$] (see Table 15). The main effect of noise level was also significant [$F(1, 121) = 4.8$, $p = 0.031$] while the main effect of gender was not significant [$F(1, 121) < 0.01$, $p > 0.05$] (see Table 15). Post hoc comparisons using the Tukey HSD test indicated that the mean score for the female learners in the quieter schools (mean = 94.7, standard deviation = 3.5) was significantly different to that of female learners in the noisy schools (mean = 92.5, standard deviation = 3.5). The effect size is moderate (Cohen's D = 0.64). However, there was no significant difference between the test scores of male learners in the quiet and noisy schools. The scores of the female learners did not differ significantly from those of the male learners in either the quiet or the noisy schools.

There was also a significant effect of school grade on the test scores at the $p<0.05$ level [$F(1, 121) = 40.6$, $p < 0.001$] (see Table 17). The mean score for learners in grade 7

(mean = 95.2, standard deviation = 3.7) was significantly higher than that of learners in grade 6 (mean = 91.8, standard deviation = 2.4). The effect size is large (Cohen's D = 1.1). However, all other two- and three-factor interactions were not significant at the $p < 0.05$ level (see Table 16). When analysing these results, no outliers were identified, contributing to the validity by not skewing the data.

Table 16

The Results of the Analysis of Variance Analysing the Non-Word Repetition Task

Effect	Degrees of freedom	Non-word Repetition Test (%) SS	Non-word Repetition Test (%) MS	Non-word Repetition Test (%) F	Non-word Repetition Test (%) P
Intercept	1	1099545*	1099545*	118842.1*	0.000000*
Grade	1	375*	375*	40.6*	0.000000*
Noise Level	1	44*	44*	4.8*	0.030651*
Gender	1	0	0	0.0	0.967983
Grade*Noise Level	1	7	7	0.8	0.381763
Grade*Gender	1	24	24	2.6	0.109690
Noise Level*Gender	1	51*	51*	5.6*	0.020005*
Grade*Noise Level*Gender	1	8	8	0.9	0.352727
Error	121	1120	9		
Total	128	1638			

*Statistically significant results

Figure 6 and Figure 7 demonstrate the significant results on the non-word repetition task, indicating 95% confidence intervals. Thus, in summary, noise levels combined with gender differences affected ALP in terms of the non-word repetition task (percentages decrease with the presence of noise for female learners). It can be observed, that grade level impacts statistically on this task as well.

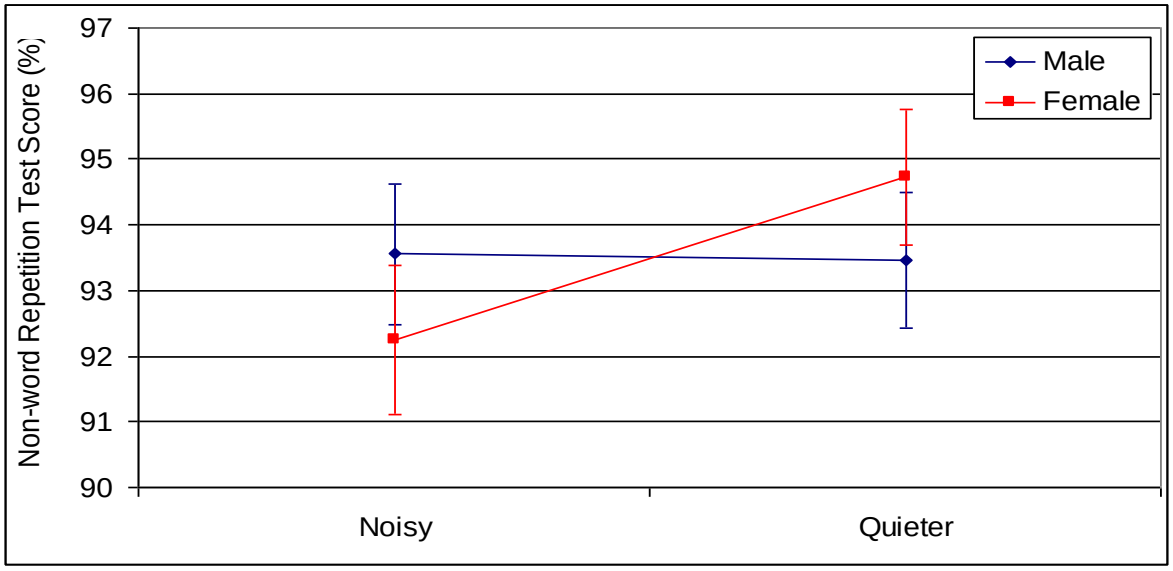


Figure 6. The Significant Effect of Noise Combined with Gender on the Non-Word Repetition Task



Figure 7. The Significant Effect of Grade on the Non-Word Repetition Task

* The bars indicate 95% confidence intervals.

Alliteration Test

Again, a three-way between subjects ANOVA with interactions was conducted to compare the effect of gender, school grade (grade 6 and 7) and noise level (noisy and quieter

schools) on the Alliteration test, as in the above non word repetition task. A table of means together with their 95% confidence intervals for all groups is shown below (see Table 17).

Table 17

Mean and Confidence Intervals for the Repetition Task

Grade	Quieter		Noisy	
	Male	*Female*	*Male*	*Female*
Grade 6	95.0* ± 3.2** (n=16)	98.3*± 4.2** (n=16)	82.9*±1.5** (n=16)	81.9*± 2.3** (n=11)
Grade 7	99.6* ± 3.6** (n=18)	102.2*± 3.9** (n=18)	85.4* ± 1.5** (n=15)	82.7*± 1.9** (n=19)

* Mean
**Confidence interval

When performing the ANOVA, the data in the quieter schools was more widely distributed than in the noisy schools. Therefore, a reciprocal transformation of the response variable was carried out in order to stabilise the variance, although the significant effects were the same for the analysis of variance of both the raw and transformed data. There were however no outliers.

Results indicated a significant interaction at the $p < 0.05$ level between gender and noise level [$F(1, 121) = 6.41$, $p = 0.013$] (see Table 18). The main effect of noise level was also significant [$F(1, 121) = 276.1$, $p < 0.001$] while the main effect of gender was not significant [$F(1, 121) = 0.01$, $p > 0.05$] (see Table 18). Post hoc comparisons using the Tukey HSD test indicated that the mean score for the female learners in the quieter schools (mean = 100.4, standard deviation = 8.0) was significantly higher than that of female learners in the noisy schools (mean = 82.4, standard deviation = 3.8). The effect size is large (Cohen's D = 2.9). Likewise, the mean score for the male learners in the quieter schools (mean = 97.4, standard deviation = 6.9) was significantly higher than that of male learners in the noisy schools (mean = 84.1, standard deviation = 3.0). The effect size is large (Cohen's D = 2.5).

The scores of the female learners did not differ significantly from those of the male learners in either the quiet or the noisy schools. The interaction effect (which is weak) arises from the difference in slope: the difference in scores between the noisy and quiet schools is greater for female than for male learners.

There was again a significant effect of school grade on the test scores at the $p < 0.05$ level [$F(1, 121) = 9.0$, $p = 0.003$] (see Table 17). The mean score for learners in grade 7 (mean = 92.6, standard deviation = 10.4) was significantly higher than that of learners in grade 6 (mean = 90.2, standard deviation = 9.1). The effect size is small (Cohen's D = 0.25). There were no further significant interactions at the $p < 0.05$ level with the other two and three factor interactions (see Table 18).

Table 18

The Results of the Analysis of Variance Analysing the Alliteration Test

Effect	Degrees of Freedom	Alliteration Test Score SS	Alliteration Test Score MS	Alliteration Test Score F	Alliteration Test Score P
Intercept	1	0.015522*	0.015522*	39486.58*	0.000000*
Grade	1	0.000004*	0.000004*	9.02*	0.003247*
Noise Level	1	0.000109*	0.000109*	276.14*	0.000000*
Gender	1	0.000000	0.000000	0.01	0.940674
Grade*Noise Level	1	0.000000	0.000000	0.85	0.357965
Grade*Gender	1	0.000000	0.000000	0.56	0.456442
Noise Level*Gender	1	0.000003*	0.000003*	6.41*	0.012616*
Grade*Noise Level*Gender	1	0.000000	0.000000	0.14	0.707879
Error	121	0.000048	0.000000		
Total	128	0.000166			

*Statistically significant results

Figure 8 and Figure 9 demonstrate these significant results, as described above, on the alliteration task, indicating 95% confidence intervals. Therefore, again, it is evident that noise

levels, combined with gender differences affect ALP in terms of the alliteration task. It can be observed that grade level impacts statistically on this task as well.

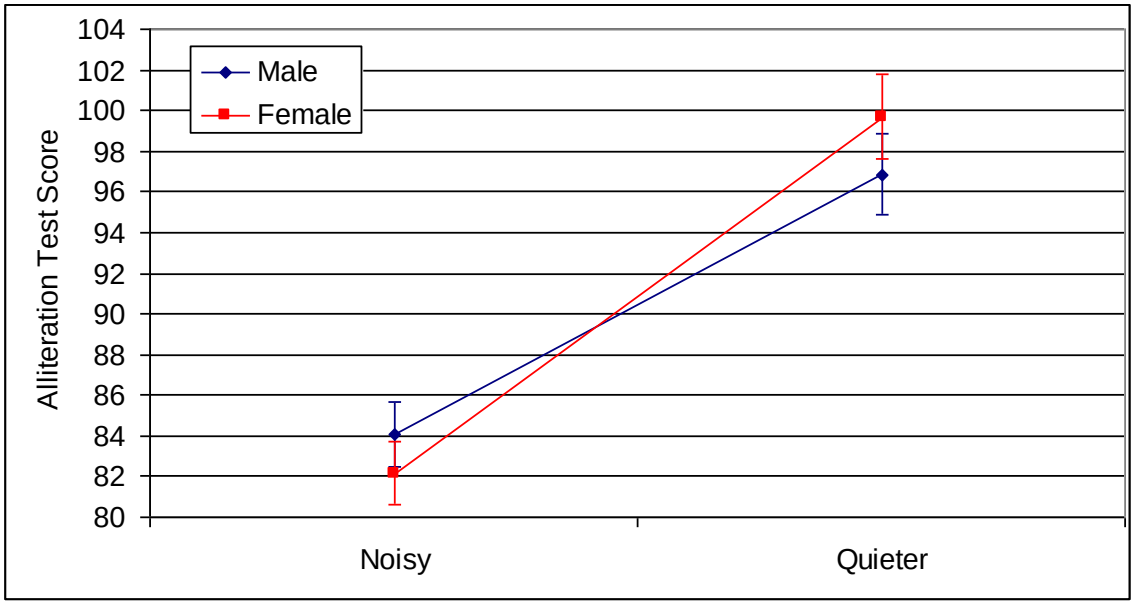


Figure 8. The Significant Effect of Noise Combined with Gender on the Alliteration Test

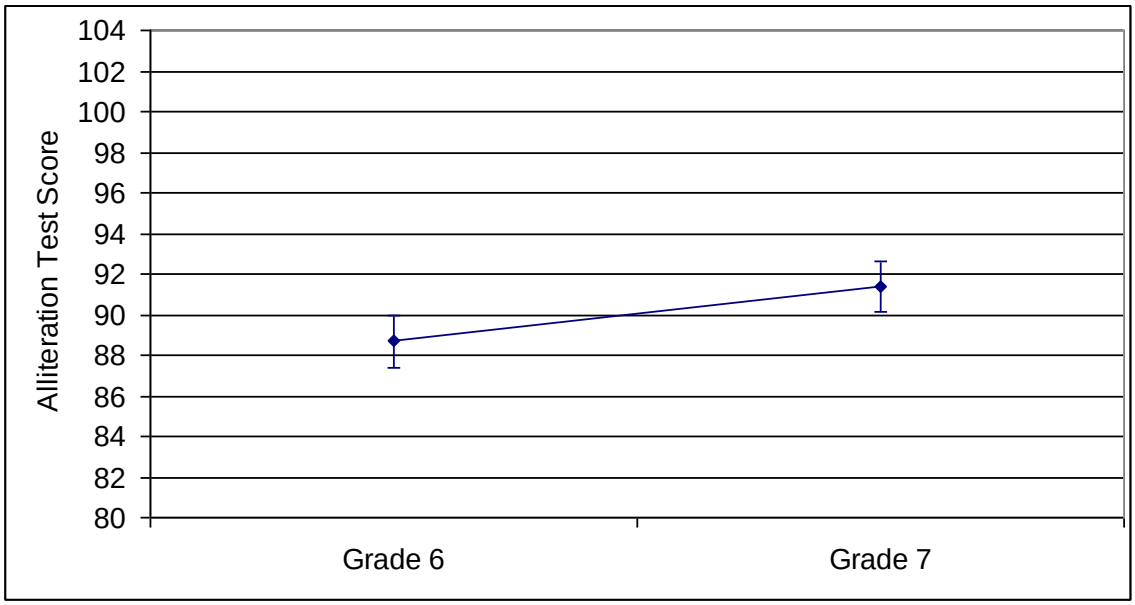


Figure 9. The Significant Effect of Grade on the Alliteration Test

*The bars indicate 95% confidence intervals.

Rhyme Test

Lastly, another three-way between subjects ANOVA with interactions was conducted to compare the effect of gender, school grade (grade 6 and 7) and noise level (noisy and quieter schools) on the Rhyme test. A table of means together with their 95% confidence intervals for all groups is shown below (Table 19):

Table 19

Mean and Confidence Intervals for the Rhyme Test

Grade	Quieter		Noisy	
	Male	*Female*	*Male*	*Female*
Grade 6	96.8* ± 4.2** (n=16)	98.1* ± 5.0** (n=16)	83.0*±1.5** (n=16)	82.5*±2.4** (n=11)
Grade 7	100.4* ± 3.9** (n=18)	102.5*± 4.3** (n=18)	85.8*± 2.6** (n=15)	82.8*±2.5** (n=19)

* Mean
**Confidence interval
Grey Shaded Area: fall into 'below average' category

When performing the ANOVA, once again a reciprocal transformation of the response variable was carried out in order to stabilise the variance, although the significant effects were the same for the analysis of variance of both the raw and transformed data. There were again no outliers.

There was a significant effect of noise level on the test scores at the $p < 0.05$ level [$F(1, 121) = 201.6$, $p < 0.001$] (see Table 20). The mean score for learners in quieter schools (mean = 99.6, standard deviation = 8.5) was significantly higher than that of learners in noisier schools (mean = 83.6, standard deviation = 4.3). The effect size is large (Cohen's D = 2.4).

There was also a significant effect of school grade on the test scores at the $p < 0.05$ level [$F(1, 121) = 5.6$, $p = 0.020$] (see Table 20). The mean score for learners in grade 7 (mean = 93.1, standard deviation = 11.1) was significantly higher than that of learners in grade 6 (mean = 90.7, standard deviation = 9.9). The effect size is large (Cohen's D = 2.9). All the other 2- and 3-factor interactions were not significant at the $p<0.05$ level.

Table 20

The Results of the Analysis of Variance Analysing the Rhyme Test

Effect	Degrees of freedom	Rhyme Test Score SS	Rhyme Test Score MS	Rhyme Test Score F	Rhyme Test Score P
Intercept	1	0.015395*	0.015395*	28150.94*	0.000000*
Grade	1	0.000003*	0.000003*	5.57*	0.019871*
Noise Level	1	0.000110*	0.000110*	201.55*	0.000000*
Gender	1	0.000000	0.000000	0.14	0.711686
Grade*Noise Level	1	0.000000	0.000000	0.73	0.395644
Grade*Gender	1	0.000000	0.000000	0.28	0.596282
Noise Level*Gender	1	0.000001	0.000001	2.37	0.126260
Grade*Noise Level*Gender	1	0.000000	0.000000	0.65	0.423313
Error	121	0.000066	0.000001		
Total	128	0.000186			

*Statistically significant results

Figure 10 and Figure 11 demonstrate the significant results on the rhyme task, indicating 95% confidence intervals. In comparison to the above two tests, this rhyme test shows a significant effect of the noise alone, without the interaction of gender. But similarly to the above two tasks, the rhyme task also illustrates that grade level has a statistical impact as well.

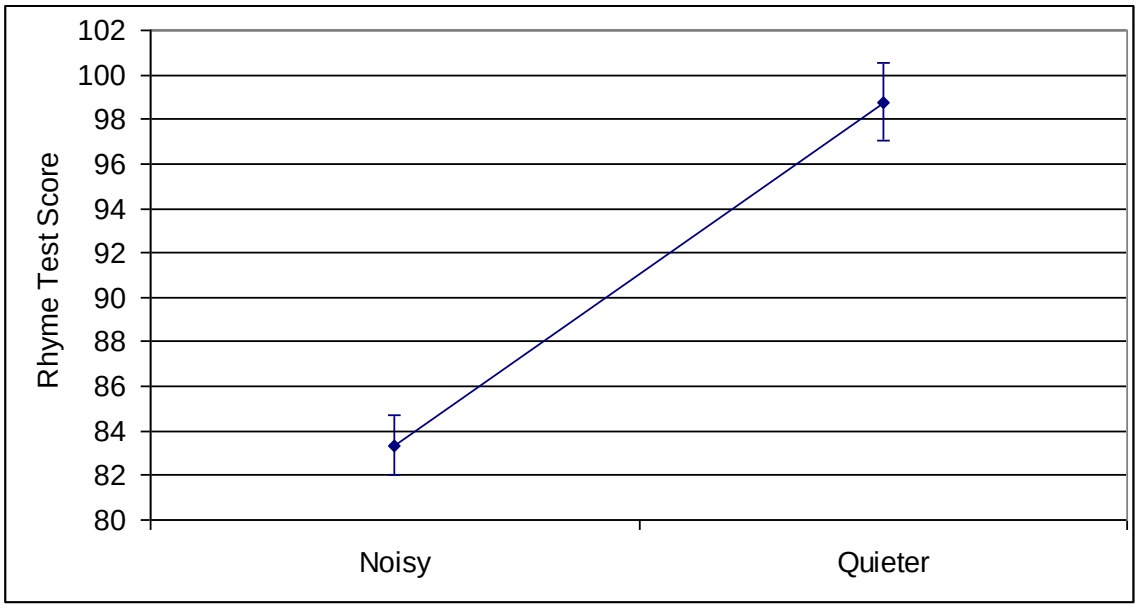


Figure 10. The Significant Effect of Noise on the Rhyme Test

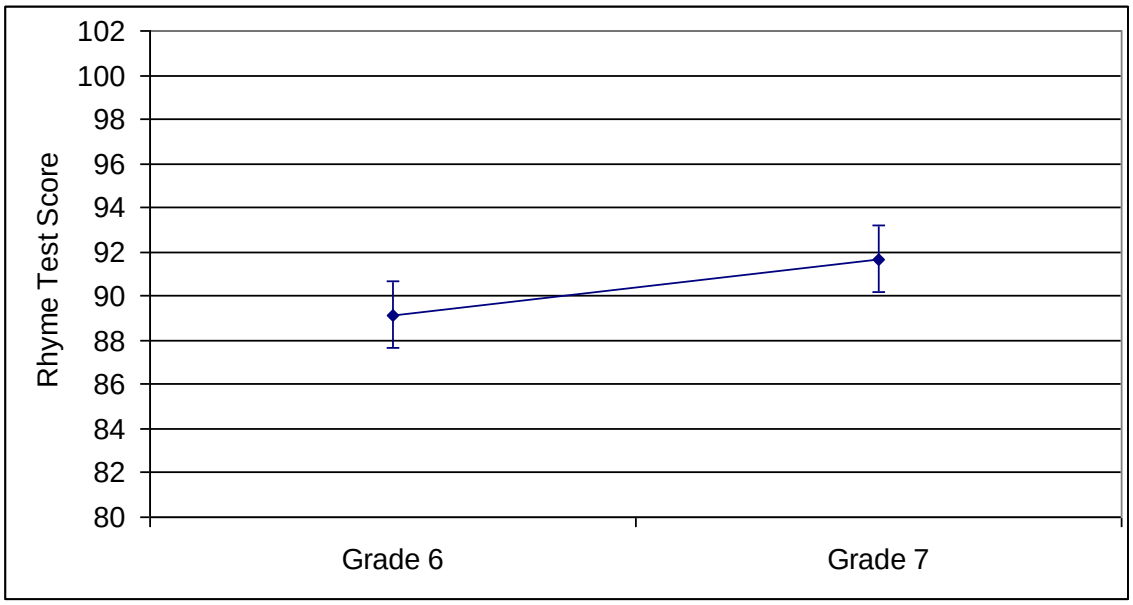


Figure 11. The Significant Effect of Grade on the Rhyme Test

*The bars indicate 95% confidence intervals.

Overall, the largest effects (as measured by Cohen's D) were for the noise x gender interaction for the Alliteration test and for the noise effect for the Rhyme Test.

In conclusion, ALP skills, as demonstrated on the six subtests carried out in this study, were significantly poorer for the learners from aircraft noise exposed schools, when compared to learners at quieter schools. All these effects indicated a decreased ability to perform these ALP tasks, after long term exposure to aircraft noise, when hearing is within normal limits. These results however will be explained in more detail in the next section.

CHAPTER 5

Discussion

Discussion

The two sub-aims will be discussed separately, integrating the results of every subtest to answer the questions, and eventually leading to the conclusion of the main aim. The discussion will expand on the results in more detail, while making use of descriptive analyses including percentages and means.

Sub-Aim 1: To investigate verbal working memory, auditory discrimination, phonological memory and phonological awareness using standardised auditory language processing measures.

Sub-Aim 2: The examination of possible differences in auditory language processing abilities between males and females in noisy and quieter schools.

The main topic under investigation in this dissertation has been to investigate the effects of aircraft noise on ALP difficulties, as previous research has shown that environmental noise can have negative effects on health and cognition. The apparent effects of this aircraft noise can be seen in different ways amongst the six different subtests.

Also, due to the nature of the statistical procedures utilised, the auditory discrimination, auditory number memory and auditory sentence memory tests can be compared by strength of association or Cramer's Value, while the non-word repetition task, rhyme and alliteration task can be compared by means of effect size or Cohen's D value. Because of the different statistical procedures used, it is difficult to compare the six different subtests with one another, and thus the auditory discrimination, auditory number memory and auditory sentence memory subtests were compared with one another using Cramer's V test,

while the non-word repetition task, rhyme and alliteration subtests were compared with one another using the Cohen's D test.

These ALP skills under investigation, as mentioned earlier, are skills imperative for reading, which are vital in the schooling environment. These ALP skills also have a broader function and are essential for general learning as it influences cognitive development which may also influence social and emotional development (Bellis, 2002).

Auditory Discrimination

Auditory discrimination is the ability to differentiate phonemes in spoken language (Wepman, 1960) between non-speech and speech sounds as well as between words with a single different phoneme, using auditory cues only. Difficulties with discrimination can affect the child's ability to spell correctly, interpret information, and read, which can indirectly affect many other areas of learning. Fine-tuned auditory discrimination has been shown to make a major contribution to language learning (Elliot, Hammer & Scholl, 1989). Therefore, this skill appears valuable in the classroom situation and the presence of noise may compromise this discrimination ability and further affect reading and language learning.

The auditory discrimination test used in this study, a subtest of the TAPS, was scored at both the noisy and quiet schools. Chi-squared and Fisher's exact tests were utilised to examine the effect of noise, gender and grade. Each statistical test was then examined further, observing the strength of association, i.e. which variable being tested had the strongest association. The Cramer's V test was used in this test; with values of below 0.2 representing a weak association, 0.2-0.4 representing a moderate association, 0.4-0.6 expressing a relatively strong association, 0.6-0.8 demonstrating a strong association and values greater than 0.8 representing a very strong association (Cramer, 1946).

The grade 6 learners in the quieter schools appeared to score better than the grade 6 learners in the noisier schools. The noise effects amongst the grade 7 learners were not significant. The individual chi-squared tests conducted showed the following associations, of different strengths:

- Noisy schools' grade 6 versus noisy schools' grade 7: Strong association (Cramer's V = 0.71)
- Quieter schools' grade 6 versus quieter schools' grade 7: Relatively strong association (Cramer's V = 0.50)
- Grade 6 versus grade 7 (both noisy and quieter schools combined): Relatively strong association (Cramer's V = 0.59)
- Noisy schools versus quieter schools (grade 6 only): Moderate association (Cramer's V = 0.30).

Thus, it can be observed that the grade effect appears to be the strongest, while the noise affect seems to be the weakest, however still statistically significant. The grade effect was expected, because, as a child matures, so does his/her skills and development. Already in 1960, Wepman reported that a weakness in auditory discrimination skills can be problematic as most auditory discrimination skills should be developed by 8 years of age, or by the end of grade 3 (Wepman, 1960). More so, as in the study by Jensen and Neff (1993), intensity discrimination is generally achieved by 5 years of age, while frequency and duration discrimination is often achieved by age 6. The learners in this study were already in grade 6 and 7, and thus a weakness here, could have already had a large effect of their educational development, such as with further learning. Again in 1960, Wepman reported that if a child struggles to distinguish sounds, he/she may have difficulty learning the phonemes which may play an important part in reading (Wepman, 1960).

As mentioned, ALP is a complex skill, involving both bottom-up and top-down processing. One may hypothesize that because auditory discrimination is one of the first skills to develop, it is a relatively basic skill compared to the other ALP skills, that it may not involve such complex top-down integration or processing. However, Diekhof, Biedermann, Ruebsamen and Gruber (2009) describe how auditory deviancy detection (discrimination) comprises both automatic and voluntary processing as observed with an fMRI. Discrimination was observed to involve a fronto-parietal network of attentional processing as well as activation in the putamen, anterior cingulate and middle temporal cortex. As discussed in the literature review, this complex processing was proposed by Richard (2001), when he described language processing. Thus, auditory discrimination, although it may develop relatively early in comparison to other ALP skills, still relies on complex processing, and thus, the addition of noise may further complicate the processing.

The ALP skill of auditory discrimination was shown to be affected by aircraft noise. Already in 1966, Clark & Richards indicated that auditory discrimination can also be affected by socioeconomic status (Clark & Richards, 1966). This variable was compensated for in this study, as the two groups of learners from noisy and quieter schools were matched according to socioeconomic status. But it is important to consider, that children from low socioeconomic areas combined with attendance at noise exposed schools are possibly more vulnerable to develop auditory discrimination problems.

In addition to socioeconomic status, auditory status and HIV/ AIDS may affect ALP skills. Reichman (1983) disclosed how a conductive hearing loss may also affect auditory discrimination abilities. As mentioned by Bankaitis (as cited in Khoza, 2009), HIV/ AIDS may cause a conductive hearing loss, largely because of the current otitis media. HIV/ AIDS cases are extremely prevalent in South Africa, as already in 2008, it was reported by Lubbe

that 5.3 million people were affected in South Africa. Although this study did not investigate the effects of HIV/AIDS on ALP, it is a factor that must be considered, as it may exacerbate a problem caused by aircraft noise.

In a population vulnerable to opportunistic ear infections, which can cause a conductive hearing loss, auditory discrimination is likely to be affected in many learners. With these children already struggling with auditory discrimination and at a risk for academic difficulties, many are concurrently exposed to aircraft noise, which as seen in these results, also appears to negatively impact auditory discrimination abilities. Thus, in a country which is already at a disadvantage, it is essential that this noise factor is managed or avoided.

With multiple influencing factors that can possibly affect discrimination abilities such as socioeconomic status, HIV/AIDS and hearing status, the addition of noise can not only cause auditory discrimination difficulties, but exacerbate possibly existing ones. Although this study used matched groups, it is an aspect to consider that auditory discrimination can be affected by other areas. As auditory discrimination is important for language learning and reading ability, it can influence further development of other classroom abilities, such as difficulty with reading, which can result in problems processing written information, which is to a large extent used in the school environment.

Auditory Number Memory

When basic learning skills are hindered, such as the ability to memorise sounds, a child may not be able to understand and process the information and subsequently, learning and the development of further cognitive skills may be stunted. Auditory memory involves attending to the teacher, receiving information presented orally, understanding the information, storing the information mentally, and subsequently recalling this information.

Difficulties with auditory memory can have serious consequences, as the learner only manages to recall parts of the information in the classroom. In many instances, auditory memory difficulties can go unnoticed by the educator as the children appear to be attending and listening to the teacher. However, with an auditory memory problem little of the information is stored accurately (Cusimano, 2001). This allows one to understand the importance to recognise factors that may influence the success of auditory memory, such as noise.

In this study auditory number memory appeared to be affected in more ways from the aircraft noise, than the auditory discrimination subtest. The results of the grade 6 and 7 learners combined were better in the quieter schools, in contrast to the auditory discrimination, where only the grade 6 learners were affected by the noise. Females also performed better in the quiet environment. The auditory number memory tests showed the following results with difference in the significance:

- Noisy schools versus quieter schools (grade 6 and grade 7 combined): Moderate association (Cramer's V= 0.29)
- Noisy schools' grade 6 versus noisy schools' grade 7: Relatively strong association (Cramer's V= 0.51)
- Quieter schools' grade 6 versus quieter schools' grade 7: Strong association (Cramer's V=0.70)
- Noisy schools versus quieter schools (grade 6 only): Relatively strong association (Cramer's V = 0.44).
- Noisy schools versus quiet schools (females): Relatively strong association (Cramer V=0.44)
- Grade 6 versus grade 7 (both noisy and quieter schools combined): Relatively strong association (Cramer's V = 0.58).

As in the auditory discrimination test, this auditory number memory test shows the strongest association when comparing grades, with the weakest effect comparing males in noisy schools to males in quieter schools. However, one would expect these differences between grades, as processing skills develop with academic maturity. The grade effect was calculated to help eliminate interactions that that could affect the reliability of the results indicating that ALP measures appear to be negatively affected by noise. Thus, by assessing the effect of grade, one can analyse the other results effectively and reliably.

Children with an ALPD struggle particularly with verbal demands, in comparison to other nonverbal tasks, which can be understood as a child with auditory memory problems may miss parts of the verbal information presented. This can result in learners with ALPDs to have a lower verbal IQ than performance IQ. Hands-on exercises such as laboratory exercises may be an area these children excel in as these exercises provide other tactile and visual cues to compensate for the lack of auditory information that is being processed (Bellis, 2002). However, children can spend up to 45% of their day engaged in listening activities in the classroom (Palmer, 1997), and thus verbal memory is extremely important, and difficulties could result in missing out on a great deal of information, and in turn may affect academic performance. Therefore, it may be necessary for teachers to implement the use of some visual cues to help children with auditory memory problems.

Auditory memory, as mentioned above, is vital in the classroom. Reading ability can be a reflection of poor working memory, such as with auditory number memory (Daneman & Carpenter, 1980). Leea, Ngb, Nga and Lima (2004) expressed that working memory not only contributes to general reading ability and literacy, but also to arithmetic performance. This study by Leea, et al. (2004) indicated a greater influence of working memory for algebraic word problem solving than did executive function capacity. The effect of deficits with

working memory can extend throughout the academic structure, influencing general language skills as well as mathematical performance.

This mathematical performance being affected can possibly be understood and explained as deficits arising from working memory, such as in the phonological loop. This phonological loop, as described earlier by Baddeley (1992a), stores and rehearses speech based information, and thus is part of ALP. The storage of digits, following the manipulation and reversal of the order as in the auditory number memory task – reversed, is thus making use of the phonological loop. Andersson and Lyxell (2006) described how children with mathematical difficulties performed poorly on tasks tapping into the central executive and phonological loop, such as with auditory memory, and thus involving aspects of ALP. Hence, a deficit in working memory, as described with the phonological loop can impact on mathematical capability. Mathematics often requires the manipulation of digits mentally, such as when children learn their multiplication routines. This manipulation requires memory. Thus, this aircraft noise, causing difficulties in working memory, as seen with this number memory task, may not only be impacting on literacy, but also with mathematical performance.

Peters, Vastfjall, Slovic, Merttz, Mazzocco and Dickert (2006) discussed how literacy and numeracy are basic life skills. If these basic life skills are negatively affected, they can domino to possibly have an effect on an individual's life outside of the school environment, such as in daily activities requiring literacy and numeracy skills, for example working with money and reading legal. As mentioned by Taylor, Muller and Vinjevold (2003), South Africa already has disturbingly low levels of reading and numeracy, and yet these low level skills in some cases appear to possibly be exacerbated by noise. Therefore the results of this study indicate a possible reason that may be contributing to such low levels of numeracy in

the South African general population. By managing noise in schools, possibly, governing bodies can provide for therapeutic services to help improve auditory number memory skills, and in turn assist in the improvement of numeracy and life skill development.

Auditory Sentence Memory

The assessment of auditory sentence memory is used to assess another component of working memory, specifically the linguistic elements, compared to the digits in the number memory test. Sentence memory is an important skill within the classroom, as much of the teaching is carried out verbally, and thus it is essential for a learner to follow the verbal explanations and instructions. Theunissen, Swanepoel and Hanekom (2009) described that tests of sentence recognition in noise constitute a crucial tool for the assessment of auditory skills that are representative of everyday listening occurrences.

When scoring the auditory sentence memory tests, as in the above auditory number memory test, the scores of the grade 6 and 7 learners combined were superior in the quieter schools. The fact that the grade 7 learners performed better than the grade 6 learners is to be expected, as Kiese-Himmel (2010) disclosed a statistically significant improvement in sentence repetition with the increase of age. This grade factor was measured in order to understand the effect of grade, and therefore prevent it from affecting the calculations of the effect of noise alone, in order to make reliable conclusions. The grade 6 learners alone also exhibited improved performance in the quieter schools, as with the auditory discrimination test. Both males and females had better results in the quiet schools as well. The associations in this test appear weaker when compared to the number memory test.

- Noisy schools versus quieter schools (grade 6 and grade 7 combined): Moderate association (Cramer's V = 0.34).

- Noisy schools' grade 6 versus noisy schools' grade 7: Moderate association (Cramer's V = 0.37).
- Grade 6 versus grade 7 (both noisy and quieter schools combined): Moderate association (Cramer's V = 0.23).
- Noisy schools versus quieter schools (grade 6 only): Relatively strong association (Cramer's (Cramer's V = 0.49).
- Noisy schools versus quiet schools (males): Moderate association (Cramer's V=0.26).
- Noisy schools versus quiet schools (females): Relatively strong association (Cramer's V = 0.44).

It is difficult to understand the exact neural basis of sentence processing, as sentence processing involves phonological, syntactic as well as semantic information (Friederici, 2002). As sentence memory also utilises some semantic processes, sentences may be easier to recall, as the integration of context may aid the memory process, in contrast to random words or numbers. This could possibly explain the reason why sentence memory was not affected as strongly when compared to number memory from the aircraft noise exposure.

However, even though the associations with sentence memory may not be as strong as with the number memory task, the decreased performance in areas such as auditory memory may impinge on learning during class as the learner may find it difficult to retain the information presented by the educator. This could also impact on a child's sequencing abilities. Therefore, learning in a noisy environment seems to hinder the development of ALP skills. According to Richard (2001), problems with auditory processing can possibly result in academic difficulties which may also have social, psychological and emotional ramifications.

Non-Word Repetition Task

As auditory discrimination and working memory are important skills for reading, literacy and overall learning, so too is the ability to remember a sequence of phonemes. Phonological memory is important for learning, especially for vocabulary acquisition. As mentioned earlier, a study by Gathercole and Baddeley (1990) suggested that immediate phonological memory processes are directly involved in the learning of new vocabulary. Non-word repetition was also affected by noise, as described in the ANOVA which demonstrated a significant interaction between gender and noise level. The main effect of noise level was also significant while the main effect of gender was not significant

This test was affected in the following ways:

- Interaction between gender and noise level: Moderate effect (Cohen's D = 0.64) as well as overall effect of noise.
- Grade 7's compared to grade 6's: Large effect (Cohen's D = 1.1).

Grade level was most significantly affected, while the gender and noise interaction was also still significant. This grade difference, as with all of the other tests is to be expected.

One cannot compare whether the non-word repetition task was affected equally more, or less by the noise levels than the above three tests, as different statistical procedures were utilised due to the nature of the data. However, the main effect of noise was observed overall. Therefore, noise appears to have affected ALP skills, and because of the nature of the test, it should not be biased with regard to income and educational levels. This ensures validity of the results (Dollaghan & Campbell, 1998).

Also, Montgomery (1995) found a positive correlation between subjects' performance on the nonsense word repetition and sentence comprehension tasks. As the sentence memory

task, as well as the phonological memory task were both affected by the aircraft noise, validity of the testing procedures appear accurate. Sentence comprehension, as mentioned above, is necessary for literacy. This test therefore provides information regarding a child's ability to learn new vocabulary as well as literacy development. This test confirms the above results; that aircraft noise seems to be affecting childrens' ability to learn.

Montgomery (1995) further shows that children with SLI have diminished phonological working memory capacity and that this capacity deficit compromises their sentence comprehension efforts. As with the auditory number memory test, one can observe the domino effect; where difficulty in one area indirectly affects another area. Thus, difficulty with the non-word repetition test may not only affect acquisition of vocabulary, but many other areas as well, and therefore in this study, noise may impinge on other learning factors affecting academic achievement, and thus preventing further opportunities.

Non-word repetition tasks have not only shown to correlate to auditory sentence memory, but also with all other language-based memory measures, such as auditory digit span, word span, sentence repetition, fluency, and also with memory for sequences of hand movements (Laws, 1998). Gathercole, Willis, Baddeley and Emslie (1994) displayed a positive link between non-word repetition and language development. Laws (1998) also described a significant relationship between non-word repetition and receptive vocabulary, language comprehension, and reading. Therefore, poor performance on the non-word task in this study may also be an indication of possibly poor performance with other areas, demonstrating the widespread consequences of aircraft noise, and the large effect it may be having on overall educational achievement.

Rhyme Test

As discussed earlier, phonological awareness is essentially the understanding of how speech sounds are used in words. PA includes rhyme and alliteration tasks, and is strongly linked to learning and literacy development (Bryant, MacLean, Bradley & Crossland, 1990) as it has been found that the sensitivity to rhyme leads to awareness of phonemes, which in turn affects reading. It also indicates that rhyme makes a direct contribution to reading which is independent of the link between reading and phoneme awareness. This study by Bryant, et al. (1990) indicated that phonological awareness, which includes both rhyme and alliteration, contributes to reading development.

Unlike the non-word repetition task, which indicates that phonological memory affects reading, language comprehension, and vocabulary acquisition, the rhyming skill is mostly important for reading development. A study was conducted with pre-school children to investigate whether phonological memory and rhyme awareness explain a common phonological processing skill or different phonological abilities. The factor analysis showed that rhyme and phonological memory tasks shared a common phonological processing constituent. However, other analyses established that the two types of the phonological processing task were differentially linked with reading and vocabulary development.

This study revealed that rhyme is not linked to vocabulary knowledge, however is strongly linked to reading ability. The tasks thus reflect separate cognitive skills which make differential contributions to reading and vocabulary development (Gathercole, Willis & Baddeley, 1991). The assessment of rhyme is essential to assess whether noise has a more general effect on ALP skills, or whether it is more specific, i.e. if reading is affected, yet vocabulary acquisition is normal, it is likely to be a result of a rhyming problem in comparison to a phonological memory problem.

However, in this current study, rhyme, phonological memory as well as various other skills were affected, indicating a more diverse effect of the aircraft noise. The rhyme test in this study exposed no interactions with noise, grade and gender, but was affected from noise alone. Grade was affected, however, as mentioned earlier, was not a factor being investigated, yet simply scored to increase validity of the results. This test emphasises to what extent aircraft noise can possibly affect reading development, and therefore success in the classroom.

Alliteration Test

With regard to alliteration, the identification of the initial sound develops post rhyme development (Hepenstall, 2004). As in the non-word repetition task, results of the alliteration subtest indicated a significant interaction at the $p<0.05$ level between gender and noise level. The main effect of noise level was also significant while the main effect of gender was not significant:

- Scores in quieter schools were significantly higher than that of learners in noisier schools: Large effect (Cohen's D = 2.4).
- Grade 7 scores were significantly higher than those of learners in grade 6: Large effect (Cohen's D = 2.9).

The grade effect was the most significant, as the above tests, with the noise effect not far behind. Again, this difference in grade performance is to be expected because often, auditory processing skills develop as children mature (Shminky & Baran, 1999).

As alliteration can affect reading and spelling, the poor performance in this test of learners in the noisy schools, in combination with the above tests, are likely to result in reading and spelling difficulty at school (Juel, 1994). This current study investigated children

in grade 6 and grade 7, soon to be attending high school, where higher levels of cognition and independence are required. Difficulty with reading can compromise education greatly.

It is difficult to compare the three ANOVA tests to one another because of interactions. Grade level was the only consistent significant factor across all the three ANOVA tests. However, within these three tests, the alliteration test showed the most significant effect of noise, the main topic under investigation.

Thus, it is evident that learners attending schools located in close vicinity to airports appear to have poorer ALP skills than learners in quieter schools. Lower scores were observed in all the six subtests with the learners in the noisy schools, compared to the quieter schools. As mentioned in the introduction by Watson and Miller (1993), as well as throughout this document by various researchers, auditory processing of speech is strongly related to long term and short term memory. Other ALP skills may affect reading, and as Ferrer, et al. (2007) stated, reading is very closely linked to cognition and learning (Ferrer, et al., 2007). These ALP skills can also affect working memory, which according to Baddeley (1992b) is a constituent of the phonological loop which is related to other aspects of memory and cognition. We can see that these ALP skills can be related to cognition, and thus may affect a child's academic performance.

Auditory language processing, the topic under investigation in this study assists in the development in multiple areas, including literacy, numeracy, spelling, cognition and overall language development. South Africa is a country where there is a high dropout rate of learners at schools, for various reasons, such as pregnancy (Grant & Hallman, 2006), poverty and academic difficulty. Many children have repeated grades due to their poor grounding in basic education. South Africa is faced with numerous obstacles in the education system,

hindering children to achieve a basic level of education, including literacy and numeracy (Blaine, 2010). The addition of environmental noise, such as aircraft noise, appears to be exacerbating educational achievement, which is already a major problem in South Africa. The identification of these environmental obstacles can be compensated for, as with school design, teaching methods, planning further school construction away for noise, as well as various other considerations. Thus, although South Africa has several barriers to achieving optimal education, by decreasing noise levels and/or compensating for these levels can assist in the challenge of the promotion of successful education.

As mentioned in the introduction, the study of performance amongst genders is useful as this can assist to develop the knowledge amongst educators and therefore assist in the implementation of different strategies within the classroom to influence an ideal method of education for both males and females. It is important to understand the differences between genders, not to victimise a particular gender, but because there has been research demonstrating that there are differences with their ALP skills, as mentioned by Richard (2001), so it appears important to ensure both genders are accounted for when examining the effects of noise on ALP. Thus, the awareness of the effects of noise within the classroom can raise awareness for educators to tailor strategies taught within the classrooms to maximise learning for both genders, which can include the provision of more visual stimuli to females in these situations. The consideration of these differences can allow for optimal results for all learners, regardless of gender.

As mentioned before, ALP abilities appear to be different between genders. The majority of children with CAP disorders are male (75%) (Richard, 2001). However, in a study by Evans, et al. (2001), when learners were exposed to noise, males reported lower perceived stress symptoms on a standardized index. Furthermore girls, but not boys,

displayed diminished motivation and evidenced more reported stress in a standardized behavioural protocol. Thus, it could be expected that males may actually perform better in noisy environments. Recognising differences with regard to ALP skills in gender performance may assist to mould teaching methods in a more supportive manner. The gender results from the subtests are described below.

Auditory Discrimination

Gender did not appear to statistically affect any areas of the auditory discrimination results. Even though the results were not affected statistically, there did seem to be some effect when described descriptively. The overall results of the females were better when compared to the males, in both the noisy and the quieter schools. Therefore, it may be important to provide more visual stimuli in the classroom, in order to help the males compensate for the noise difficulty. In the above mentioned articles, males show less stress when exposed to noise, which would suggest that males may perform better in noisy schools.

However, when the results in this dissertation were scored, this did not appear to be the case. The results here, in this research, are in contrast to the idea that males may perform better than females in noisy environments as they show less stress under the taxing noisy conditions. They did not however perform better in noisy schools, when compared to quieter schools, yet were affected less than the females by the noise. The male learners performed better in the quieter schools, with 56% scoring 12 years or greater, and 48% scoring 12 years or greater in the noisy schools. This is consistent to the idea that children would perform better in quiet environments than noisy environments.

Fifty-seven per cent of the females in noisy schools scored 12 years or greater, and 71% of the female learners scored 12 years or greater in the quieter schools. The difference in

percentage is much larger between the noisy schools and quiet schools, specifically with the female learners. This can possibly be explained according to Evans, et al. (2001), that when learners are exposed to noise, males reported lower stress symptoms on the standardized index and females showed diminished motivation when exposed to noise. This could possibly account for the much greater difference.

Furthermore, as mentioned, the majority of children with ALP disorders are males. Thus, generally, females perform better on the ALP tests. It is evident from this subtest, that although there was not a statistical difference, there was a higher percentage of females who scored 12 years or greater, in both the noisy and quieter schools.

Auditory Number Memory

As with auditory discrimination, there were no significant differences between the results for male and female learners in this study overall with regard to noise levels of schools. However, female learners performed statistically better in quieter schools with the strength of the association being relatively strong, consistent with the literature that females generally have better ALP than male counterparts.

Male learners showed no statistically significant relationship with noise levels, however, 44% of males scored 12 years or greater in the quieter schools, and 32% scored 12 years or greater in the noisy schools. Therefore, when described descriptively, there is a difference between males in noisy schools and males in quieter schools. As in the auditory discrimination test, the difference in scores of each gender between the noisy and quieter schools is much larger with the female learners. Seventeen per cent of female learners scored 12 years or greater in the noisy schools, compared to a score of 62% for female learners in quieter schools.

The difference between the 32% and 44% in the noisy and quieter schools with males respectively is much smaller than the female difference. This can be explained again by Rogers, et al. (2003), as he stated that females seem to show diminished motivation with background noise, while males are generally more able to accept this background noise. The literature also purported that the prevalence of ALP disorders is greater in males, and thus males' performance with ALP tests is poorer. However, this is not seen in the noisy schools in this study, as 32% of male learners in the noisy schools scored 12 years or greater, while only 17% of female learners scored 12 years or greater in the noisy schools.

Auditory Sentence Memory

With regard to the gender results, there were no statistically significant differences between the results for male and female learners according to noise levels of schools. However, both groups of learners performed significantly better in the quieter schools with the strength of the association being relatively strong for females while only moderately strong for males. This is different to the auditory discrimination and auditory number memory tests, as the females showed more effect when comparing noisy and quieter schools. However, the above subtests were described from the percentages, and not the Cramer's V test which analyses the strength of association.

Non-Word Repetition Task

The ANOVA tests, as completed with the non-word repetition task, analysed interactions with gender, as well as the gender effect alone. The results of this ANOVA demonstrated a significant interaction at the $p<0.05$ level between gender and noise level. The main effect of noise level was also significant while the main effect of gender was not significant. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the female learners in the quieter schools (mean = 94.7, standard deviation = 3.5) was

significantly different to that of female learners in the noisy schools (mean = 92.5, standard deviation = 3.5). The effect size is moderate (Cohen's D = 0.64). However, there was no significant difference between the test scores of male learners in the quiet and noisy schools. The scores of the female learners did not differ significantly from those of the male learners in either the quiet or the noisy schools.

Rhyme Test

This test showed no effect of gender, when compared within an interaction or analysed alone. However, when the results were analysed on a descriptive level, the males in grade 6 in the quieter schools performed better than the males in grade 6 in the noisy schools, with a mean of 96.8 and 83.0 respectively. It is possible to see a similar difference with females in grade 6 in the quieter schools compared to the noisy schools, with means of 98.1 and 83.0 respectively. This can also be seen when comparing males with males in noisy schools versus quieter schools in grade 7, with means of 100.4 and 85.8 respectively and with females in grade 7, compared with noisy and quieter schools (means 102.5 and 85.8 respectively).

Alliteration Test

Results indicated a significant interaction at the $p<0.05$ level between gender and noise level. The main effect of noise level was also significant while the main effect of gender was not significant. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the female learners in the quieter schools (mean = 100.4, standard deviation = 8.0) was significantly higher than that of female learners in the noisy schools (mean = 82.4, standard deviation = 3.8). The effect size is large (Cohen's D = 2.9), and more than in the non-word repetition task whether it is moderate. Likewise, the mean score for the male learners in the quieter schools (mean = 97.4, standard deviation = 6.9) was significantly higher than that of male learners in the noisy schools (mean = 84.1, standard deviation = 3.0).

The effect size is large (Cohen's D = 2.5). The scores of the female learners did not differ significantly from those of the male learners in either the quiet or the noisy schools. The interaction effect (which is weak) arises from the difference in slope: the difference in scores between the noisy and quiet schools is greater for female than for male learners.

Although females may exhibit more stress and decreased motivation with noise as seen in the literature, the noise did not seem to affect the results differently between genders; that males would score higher than females when exposed to noise. However, the differences between the males' results in noisy and quieter schools were smaller than the difference between the females' results in noisy and quieter schools. This was seen when described descriptively, not according to specific statistical procedures. However, even though the differences were not significant, both genders were still affected to some extent by the aircraft noise, which is a reason for educators to implement strategies to assist both genders in the classroom, in the presence of background noise.

Hearing and Noise

As Feuerstein (2002) explained, noise exposure can cause a permanent threshold shift resulting in noise induced hearing loss. These hearing losses are becoming increasingly common in the younger generation due to leisure activities that include listening to loud music, as well as a result of environmental noise exposure, such as aircraft noise. Although the aim of this study was to investigate aircraft noise on ALP abilities, the hearing screening results were also recorded with the noise levels in the respective schools.

As described previously, the children in the noisier schools had a higher prevalence of hearing loss than the quieter schools. The noisiest school had the largest amount of children who failed the hearing screening. However, the quietest school, at an average level of 54.4

dB (A) showed 23.4 % of children who failed the screening, while the other quieter school, at an average level of 55.43 dB (A) had only 5% of children who failed the hearing screening. As children were matched according to socioeconomic status, these should not be factors that contribute to this discrepancy.

In a study at Vanderbilt University, it was found that 14.3% of learners from a national sample of school age children were identified with a hearing loss. In another study completed in economically disadvantaged communities in Texas with children from pre-kindergarten through to grade 8, 9% of learners failed the hearing screening (Kidd-Proctor & Herrington, 2006). Chen, Chen, Hseih & Chiang (1997) found in Taiwan, that 68.7% of residents living near the airport were identified with a hearing loss, while only 6.7% of people living further from the airport were identified with a hearing loss.

Although these statistics were completed on slightly different, yet overlapping populations, the statistics obtained from this study in South Africa, when compared to America, seems significantly higher, in both the noisy schools, as well as one of the quieter schools, but were lower than the statistics found in Taiwan. These South African statistics were also completed in the summer season, which is not typically a season where many children have flu-like and congested symptoms which could contribute to a high percentage of children that fail the hearing screening in the quiet schools.

The reasoning for the considerable difference between the quiet schools was thus not able to be obtained. Nonetheless, it is important to obtain full diagnostic audiograms on the children who failed the hearing screening in order for management. It would also be interesting to investigate their auditory thresholds in further studies, rather than just obtaining a ‘pass’ or ‘fail’ in the screening. By obtaining full diagnostic measures, one might be able to

observe a pattern in the loss which may give insight to the large discrepancy between the quieter schools.

Acceptable noise levels are also discussed by the American Speech and Hearing Association (ASHA) (1996) in the central auditory processing technical report, as described previously in this dissertation. ASHA stated that 30 dB (A) is an acceptable acoustical standard for unoccupied classrooms. The signal in a typical classroom may vary from moment to moment, depending on the teachers' voice, students' voices and general activity. Thus the SNR may vary momentarily. Ideally though, it should be +15 dB.

However, classrooms with high background noise levels will have poor SNRs. Although occupied classrooms are of interest; they are generally controlled by the teacher, such as by ensuring there is not too much noise from the learners all talking at once. Ideally, the noise level of an occupied classroom should be no more than 40 dB (A) (Knecht, et al., 2002). The noise levels measured in this study were readings taken from outside the classroom, within a 5 metre radius from the testing area. Thus these measurements mainly examined the environmental noise levels such as aircraft noise, and included maximum, minimum, average noise levels, as well as noise levels at the tenth and ninetieth percentiles.

Additional sound level meters were placed inside the classroom at the time of testing, in order for the researcher to pause testing when noise levels were above 50 dB (A). The noise within the classroom would have been greater when combined with general classroom activity. Thus, these noise level readings taken from outside the classroom, even within the quieter schools are not ideal, and thus appropriate procedures need to be implemented to increase the SNR or decrease the background noise, specifically for those children with a hearing loss.

This study researched the effect of aircraft noise on ALP skills of learners with hearing thresholds within normal limits. From the results of the subtests, scores appeared poorer at the schools exposed to aircraft noise, demonstrating the effect of this noise on ALP skills, which can affect many areas important for learning and cognitive development, such as literacy, numeracy and overall language development. These results were from the learners with normal hearing. The hearing screening results show that over and above the children identified with ALP difficulties with normal hearing screening results, there may be more children with ALP difficulties resulting from a hearing loss, and possibly confounded by noise.

CHAPTER 6

Conclusion

Conclusion

This study seems to demonstrate that children who attend schools closer to airports and to airport noise seem to score poorer on the ALP tests than their counterparts in schools further away from airports and airport noise. As possibly interfering extraneous variables that may have influenced the results were accounted for, it appears as though the exposure to this chronic, yet intermittent aircraft noise may have an effect of children's ALP abilities in learners as indicated in the six subtests used in this study. The scores were lower at the noisy schools when compared to the quieter schools. Thus, this section of the research paper will discuss issues of a developing country such as South Africa and its implications on the education system, as well as recommendations that should be implemented to assist in the improvement and/or management of these identified ALP difficulties resulting from the aircraft noise exposure.

In the recent UK RANCH follow up study investigating the long-term effects of aircraft noise exposure on children's cognition, children who attended noise exposed primary schools had poorer reading comprehension scores than the children who attended non aircraft noise exposed school at 15-16 years of age (Clark, Head & Stansfeld, 2011). Thus, it is essential to address this problem in schools in South Africa, because it can be clearly seen from the UK RANCH study that the ALPD problems are unlikely to resolve themselves in high school. The conclusion will therefore advise ways to increase the SNR in existing noise exposed schools, as well as methods for future developing schools.

Skills in a Developing Country

The Committee of Inquiry in a Comprehensive Social Security System for South Africa found that between 45 and 55% of all South Africans live in poverty (Martin & Rosa, 2002). Poverty is a common socioeconomic issue facing all developing countries. Already in

1977, Wallach, Wallach, Dozier and Kaplan explained that disadvantaged childrens' difficulties to read often stem from inadequate skill in phoneme analysis, and not always from discrimination problems, as discussed previously. Thus, many children living in poverty, when confronted with noise that has been shown to affect discrimination, are at an even greater disadvantage. Therefore, it can be suggested that vulnerable learners who attend noisy schools may be at even greater risk for ALPDs since the noise may compound the other matters.

Noise exposure in developing countries often exceeds the World Health Organisation guidelines which have shown to cause health, sleep, cognitive and psychological problems. However, this increase in noise exposure is often a consequence of industrialisation, urban growth, poverty related migration of poor people into the affordable, yet noise exposed areas. It is important to develop guidelines to assist in preventing these matters in developing countries, such as in South Africa. Such guidelines would need to include the application of best practices, stakeholder commitment, cost effectiveness and risk assessment, which is essential to be guided by relevant and recent research (Finegold & Schwela, 2011). Therefore, it is important for this study to contribute to the development of these possible guidelines, by providing evidence of the impact of aircraft noise on ALP skills, and the importance of these skills on learning and academic achievement.

Zoning

Primarily, the results of this research aim to assist in the prevention of the development of possible ALPDs, and subsequently to assist in the treatment of already existing ALPDs in schools in South Africa. In order to aid the prevention of ALPDs, the results of this research aim to motivate for a change of legislation for more appropriate specifications with regard to zoning of schools away from noisy areas and the standardisation

of acceptable noise levels. Although the Durban International Airport was relocated away from the schools used in this study, and thus rezoning would not be applicable for these specific schools, zoning legislation is still an important factor for future construction of schools and airports, as well as a consideration for already existing schools, such as schools located near the Cape Town International Airport and O.R. Tambo International Airport, to name a few. In South Africa, a country with developmental challenges, where successful education is seen as a hope for future development, addressing factors that can compound learning difficulties, such as ALP difficulties brought on by environmental noise, may provide opportunities for successful learning.

Sound Treatment

From the results of this study, it is apparent that the listening environment plays an important role in the development of ALP skills and thus academic development. Salathiel, Steele and Edwards (2010) stated that good acoustics have a positive impact on all students. It is therefore important to understand the acoustics of already existing classrooms, and to advocate methods to improve them. It is also important to be familiar with the ideal acoustic environment for future schools.

Hoy and Hoy (2006, p. 89) stated that "the first step in learning is paying attention". The improvement of the SNR, through a variety of measures, can help maintain a child's attention, and therefore decrease the possibility of an ALPD, as the learner would expend less energy on blocking out other distractions. In a study carried out in Finland, room acoustic design was shown to affect cognitive work performance, acoustic satisfaction and perceived workload (Haapakangas, Kokko, Hyona, Hoongisto, Oliva, Keranen & Hakala, 2011). Although this study was completed on adults, ideas of the importance of acoustic design can be extrapolated to be relevant to children in schools.

The ANSI/Acoustical Society of America (ASA) standards for 'Acoustical Performance Criteria, Design Requirements and Guidelines for Schools' include specifications for maximum background noise of 35 dB (A) and reverberation time of 0.6 seconds for unoccupied classrooms, as well as sound insulation between classrooms (Salathiel, et al., 2010). ASHA (1996) recommends 30 dB (A) for an unoccupied classroom.

In some schools in South Africa, learning takes place in prefabricated buildings with very thins walls; while other schools, although made of brick buildings, have poor acoustics such as thin windows and doors, and limited posters and carpets to absorb the sounds that do not aid in achieving an acceptable SNR for the children to learn. Although the layouts and environments are important, it is necessary to make accommodations depending on budget and recourses (Higgins, et al., 2005), which is a common issue in South Africa.

The promotion of health is what nations should aspire to, rather than solely focussing on providing treatment of symptoms, problems and diseases, such as therapy. Cost effective sound dampening within better developed schools can include limiting mechanical noise, such as clocks, computers and fluorescent lights that are constantly plugged into the electricity source. Floors with hard surfaces can be covered with carpets, rugs, or any other type of padding to help to absorb the noise. These changes are also applicable in schools with limited resources. Acoustic ceiling tiles are an excellent way to facilitate noise absorption. However these tiles can be costly, and so any fabric or artwork suspended from the ceiling can assist in dampening noise. Windows can be covered with blinds, shades or posters, while walls can be covered with cork bulletin boards, egg cartons, carpet squares or any other soft surfaces to absorb the unwanted sound. Some sort of lining, such as rubber, should be placed at the bottom of the door to minimise outside noise. The placement of rubber tips at the bottom of

desks in an uncarpeted classroom can prevent the unwanted sounds when desks shift (Hamaguchi, et al., 2002).

Although it is costly, an FM system or infrared system, as mentioned earlier by Waldowski (2002) and Hamaguchi, et al. (2002), is also useful to increase the SNR and help to compensate for the background noise levels for children with ALPDs. As mentioned by Kuk (2011), hearing aids may also be of assistance for children with ALPDs. These assistive devices may also assist in overall listening and learning for children without ALPDs, and can possibly assist in the prevention of an ALPD.

Thus, the implementation of at least some of the above recommendations can assist in improving the SNRs in classrooms, and thus improve the listening environments. These listening environments are important for all classrooms, whether exposed to aircraft noise or not. However, within schools located near airports, these implementations are essential to try and prevent ALPDs.

Teachers and education in South Africa

Despite the apparent negative effect of aircraft noise on hearing and ALP abilities, South Africa has several other challenges that interfere with education. South Africa has 11 official languages, which creates challenges regarding the language of education. Although the language policy makes use of an additive approach to bi- or multi-lingualism, whereby the first language is maintained and used as a basis for the learning of another language, there are still multiple English second or other language (ESOL) speakers within the classroom. Learning in another language, apart from one's first language can result in the learner struggling academically, which can cause further confidence and self-esteem to be impinged on (O'Connor & Geiger, 2010).

Although The Language Policy and Plan for South Africa (Ngubane, 2003) strongly encourages learners to learn in their first language, the data collected in the study by O'Connor & Geiger (2010) demonstrated that 41% of educators had more than 60% ESOL learners in their classes. Therefore, many children may struggle in the classroom due to language issues. For this reason, English First Language learners were selected for this study to avoid skewed results from testing ESOL learners utilising tests standardised on EFL learners. However, the restricted sample size in this study was a result to the limited number of EFL learners in the classes, whereby the language of instruction is English. This demonstrates the extent of the number of ESOL learners being taught by English instruction.

It is important to realise that the environmental noise can impact even more, specifically with children who already struggle. As evident from the results of this study, multiple EFL learners demonstrated poorer ALP skills, than their counterparts in quieter schools. This leads to the idea of how many ESOL learners are affected by noise, when they may already be struggling from being taught in a language other than their mother tongue. This emphasises the need for changes to minimise environmental noise, specifically in South Africa.

Due to the possible increase of prevalence of ALPDs resulting from noise, in conjunction to language differences, teachers need to be trained about ALPDs; the identification and management. There are many management techniques that can be incorporated within the classroom by the teacher, to manage the disorder and prevent the enhancement of the problem. Training of teachers regarding ALPDs would allow for the support of carry-over skills learnt in therapy.

Teachers should understand the importance of preferential seating in the management of ALPDs, while memory can be addressed by teaching learners skills such as chunking, verbal chaining, mnemonics, rehearsal, paraphrasing and summarising. These memory skills are important for children with and without ALPDs, as they are important study skills to be used throughout the schooling system as well as in higher education institutions. Other areas of difficulty, such as restricted vocabulary, can be addressed with skills for contextual derivation of word meaning, whereas poor listening comprehension can be remediated with measures to teach the ability to induce a formal schema to aid organisation, integration and prediction. Phonemic analysis and segmentation can aid with reading, spelling and listening problems, while self-control, self-monitoring, self-evaluation, self-instruction, and problem solving can help with maladaptive behaviours.

Teachers should be informed to address poor motivation with failure confrontation. The child should also be encouraged to use visual and auditory input to maximize comprehension (Chermak & Musiek, 1992). All these strategies are useful in the classroom for all children, yet are specifically beneficial for children with ALPDs. Providing training for teachers within mainstream schools would be greatly beneficial to assist children with already existing ALPDs, whether it be from environmental noises, or resulting from other learning difficulties, or differences in language of instruction. Assisting with managing these disorders within the classroom would promote educational success, possibly, without the need for referral to further remedial schooling.

Speech-Language Therapists and Audiologists

The ALP data from aircraft-noise-exposed-schools can be extrapolated to other schools exposed to different types of excessive and continuous noise, such as schools located near railway lines or by busy roads or highways. These results can suggest some

recommendations for education. One of the recommendations could suggest the need to motivate and advocate for the provision of speech-language therapy and audiology services within mainstream schools.

The role of these speech and hearing therapists would include the responsibility to inform educators about ALPDs, as well as assist in the remediation of children with already existing APLDs, in addition to the promotion of methods to improve the SNR within the classroom and thus assisting in the prevention of further APLDs. The speech-therapists and audiologists employed by the health department in the hospitals and clinics in South Africa may not treat ALPDs because as S. Bolton, the Head of the Speech Therapy and Audiology Department at Chris Hani Baragwaneth Hospital, explained, free health care is available for children below 6 years of age and because of limited available resources, services are focused on this younger age group. Therefore, children over 6 years, with 'school age language problems' cannot be treated in government hospitals due to these aforementioned limited facilities (personal communication, May 16, 2011). Although ALP is not simply a 'school age language problem', it tends to generally be grouped in this category within state hospitals. Thus, it is extremely necessary for posts to be opened within schools, as currently, these children are not being treated and provisions for this noise are not being addressed.

Recommendations for policy formation

The evidence collected, as presented in the results section, showed that aircraft noise appears to affect ALP abilities. The research aimed to motivate for changes to assist with the prevention of possible ALPDs, by considering sound treatment of schools as well as motivating the educational governing bodies for new legislation with regard to zoning and architectural design of classrooms, and consideration for methods to improve the SNR within learning environments. Noise guidelines are essential, which should include maximum

permitted noise exposure levels and policies to insist on noise assessments and controls as part of environmental health programmes. These guidelines must by be developed from risk assessments including land use planning, education and public awareness, control options and mitigation measures (Schwela & Finegold, 2011). It is also important to consider the treatment of already existing ALPDs. This treatment could be implemented by the education department, by providing speech therapy and audiology posts within mainstream schools, and by training the educators about ALPDs as well as educating school staff and management bodies about the sound treatment of existing schools.

Recommendations for further research

It is important to note, that in an ever-changing world, no design solution will last forever, and thus ongoing research and involvement is always necessary for on-going support and change (Higgins, et al., 2005). Thus the implications for further research should include the investigation of living environments on ALP skills. This study investigated the impact of the learning environment on ALP skills, and did not consider living environments, as children are assumed to attend schools close to their homes and thus generally stay in similar socioeconomic areas. However, it would be beneficial to investigate other possible confounding variables such as living conditions, including difficult emotional circumstances, health status such as HIV/AIDS, as well as individual style which may influence the attitude, the attendance rate at schools and thus the outcome of the learners.

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Appendix A

Table 21

Pilot Study Results Carried Out to Assess the Appropriateness of the Standardised Tests on South African Children

Learner	Age	Grade	Gender	Auditory Discrimination (Age Score)	Number Memory (Age Score)	Sentence Memory (Age Score)	Alliteration (Standardised Score)	Rhyme (Standardised Score)
4	12	7	F	12	12	12	100-average	93–average
5	12	7	F	12	12	10.8	100-average	89-average
7	12	7	M	11.6	11.5	10.8	100-average	83-↓ average
8	12	7	F	12	12	12	100-average	93-average
9	12	7	M	12	12	12	100-average	103-average
10	12	7	F	12	12	12	100-average	95-average
11	12	7	M	11.6	10.4	10.8	100-average	95-average
12	12	7	F	>12	>12	12	100-average	124-↑average
13	11	6	F	11.6	11.5	10.8	86-average	101-average
14	11	6	F	11.6	10.4	10.8	86-average	103-average
15	11	6	M	11.6	11.5	12	86-average	101-average
16	11	6	M	8.11	10.4	10.8	83-↓average	84-↓ average
17	11	6	M	11.6	11.5	12	100-average	107-average
18	11	6	M	11.6	11.5	12	86-average	103-average
19	11	6	M	11.6	10.4	10.8	100-average	103-average
20	11	6	M	11.6	11.5	12	86-average	98-average
21	11	6	F	12	12	12	100-average	127-↑ average
22	11	6	M	10.4	10.8	10.8	100-average	107-average
23	12	6	M	12	12	12	100-average	103-average

Appendix B

Ethics Certificate

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa

Tel: +27 11 717-3007 • Fax: +27 11 717-3009 • E-mail: enquiries@educ.wits.ac.za • Website:

Protocol: 2008ECE.

14 August 2008

Dr. Paul Goldschagg
WSoE
L264

Dear Dr. Goldschagg

Application for Ethics Clearance

I have a pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has agreed to approve your application for ethics clearance submitted for your proposal entitled:

Aircraft Noise and Children's Cognition and Health: a Before and After Study

Recommendation:

Ethics clearance is granted

Yours sincerely

Matsie Mabeta
Wits School of Education

Appendix C

Auditory Language Processing Referral Letter

SPEECH PATHOLOGY AND AUDIOLOGY
School of Human & Community Development
Faculty of Humanities
University of the Witwatersrand
Private Bag 3, WITS, 2050

Tel: (011) 717 4577 Fax: (011) 717 4572

Dear Parent/ Caregiver,

Thank you for allowing your child, _____ to participate in our study.

Your child participated in a variety of auditory processing assessments which are designed to check his/her memory of verbal information, as well as the ability to process different sounds. The results from these assessments suggest reduced scores. Although this could be due to a number of reasons, I recommend that he/she be assessed fully by a Speech Language Therapist and Audiologist. The therapist will be able to provide therapy and assist your child in developing his/her auditory and phonological processing skills. The nearest Speech Language Therapist and Audiologist are:

- Public sector:
  - ✓ **Prince Mshilyeni Memorial Hospital**
    Mangosuthu Highway, Unit V, Umlazi
    Nivashni - 031 907 8200
  - ✓ **R.K.Khan Hospital**
    Annamarie - 031 459 6255
- Private sector:
  - ✓ **Kingsway Hospital**
    Tanya Rose Gabriel – 031 904 7000
  - ✓ **Isipingo Hospital**
    Karishma Manick– 031 913 7000

All the teachers at the school have also been provided with strategies to try and help your child at school.

Please feel free to contact me should you have any further queries.

Thank you again for allowing your child to participate in this worthwhile study.

Sincerely,

Cara Hollander

_____
Speech Therapist and Audiologist
Cell: 082 815 8878
Email: chollander@netactive.co.za

Appendix D

Hearing Screening Referral Letter

SPEECH PATHOLOGY AND AUDIOLOGY
School of Human & Community Development
Faculty of Humanities
University of the Witwatersrand
Private Bag 3, WITS, 2050

Tel: (011) 717 4577 Fax: (011) 717 4572

Dear Parent/ Caregiver,

Thank you for allowing your child, _____ to participate in our study.

Your child participated in a variety of hearing screening assessments which are designed to check if there may be a problem with his/her hearing. The results from these tests suggest there may be a problem. Although this could be due to a number of reasons, I recommend that he/she be assessed fully by an Audiologist. The Audiologist will be able to identify the full extent of the problem and will then be able to assist in the management of this problem.

The nearest Speech Language Therapist and Audiologist are:

- Public sector:
  - ✓ **Prince Mshilyeni Memorial Hospital**
    Mangosuthu Highway, Unit V, Umlazi
    Nivashni - 031 907 8200
  - ✓ **R.K.Khan Hospital**
    Annamarie - 031 459 6255
- Private sector:
  - ✓ **Kingsway Hospital**
    Tanya Rose Gabriel – 031 904 7000
  - ✓ **Isipingo Hospital**
    Karishma Manick– 031 913 7000

Please feel free to contact me should you have any further queries.

Thank you again for allowing your child to participate in this worthwhile study.

Sincerely,

Cara Hollander

_____

Speech Therapist and Audiologist
Cell: 082 815 8878
Email: chollander@netactive.co.za

Appendix E

Teacher Information Booklet

SPEECH PATHOLOGY AND AUDIOLOGY

School of Human & Community Development

Faculty of Humanities

University of the Witwatersrand

Private Bag 3, WITS, 2050

Tel: (011) 717 4577 Fax: (011) 717 4572

TEACHER INFORMATION BOOKLET

(Adapted from Bellis, 2003)

What is an Auditory Processing Disorder?

Speech comprises of acoustic signals that reach the external ear. As soon as the sound enters the external auditory canal, it passes through to the middle ear and then to the inner ear. It is here that the early stage of analysis begins. However, listening to complex signals such as speech, involves the awareness of a 'whole', in comparison to the individual acoustic signals that enter the ear. Thus, the auditory system needs to integrate the component parts of the signal into structures that can be interpreted to meaning.

Auditory processing (AP) can be described in two different ways. There is much discussion as to which is the best understanding to allow one to comprehend auditory processing in its fullest capacity. The proposal of 'bottom up' processing is one way to understand auditory processing. This definition implies that the processing is mainly due to the interpretation of the signal from all the anatomical structures. Simply, the sound passes through the entire auditory system, from the external ear to the brain, and is then processed. This definition of auditory processing is making use of the auditory system mechanisms. Thus an auditory processing disorder, according to this model, can be a result of a malfunction in any area of the central auditory pathway (Bellis, 2003).

In contrast to this model, the 'top down' model describes auditory processing to form part of a higher neuro-cognitive process. This model employs the higher function to integrate auditory stimuli and provide meaning to these signals (Bellis, 2003). According to this description, auditory processing is a complex process and can be described as the search for meaningful organization of the acoustic signal (Cooke, 1993).

An auditory processing disorder is not a disorder of hearing. However, one can have an auditory processing disorder as well with abnormal hearing. However, an auditory processing disorder is often present when hearing is normal. These children often seem to be 'not listening' or 'not paying attention'. However, although they can hear speech, they struggle to process the sound to give it

meaning. This thus affects their entire functioning and performance academically, socially and emotionally.

Teachers are extremely important tin the remediation of these children identified with an auditory processing disorder. Unfortunately, many of the identified children in this study will not have access to a speech language therapist and audiologist. This may be due to the fact of limited transport as well as many public hospitals are overloaded and can only provide therapy for a child infrequently.

Thus, this booklet will provide you, as teachers with some ideas of how to help these children in the classroom.

Management of Auditory Processing Disorders in the Educational Setting

Auditory Processing Disorders can partly be managed in the educational setting. Management can be divided into three main categories, some of which are extremely important in the classroom:

1) Environmental Modifications and teaching suggestions designed to improve the child's access to auditory information.
2) Remediation techniques designed to enhance discrimination. Transfer of information and other auditory functions
3) Provision of compensatory strategies designed to teach the child how to overcome residual dysfunction and maximise the use of auditory information.

The goal of these management techniques is to increase the child's ability to use information presented in the auditory mode.

Many children with auditory processing disorders have poor motivation. By the time a child is identified with having this disorder, he or she may have experienced failure in listening situations for so long that a prevailing attitude exists in which the child feels that he or she is stupid and that nothing can be done to remedy the situation. These children may also have behavioural problems due to the frustration they have experienced and constantly experience.

(Bellis, 2003)

Environmental Modifications and Classroom Based Strategies

It is important to remember that the child learns, not necessarily how he/she learns. In the later years in school, children are often required to take their own notes. The manner of teaching requires the child to listen to the message, write it down, and then focus on listening again. Often, the child needs to listen while he/she writes. For a child with an auditory processing disorder, this can be detrimental. The child struggles to process auditory information, and then does not learn. Although the skill of note-taking is essential for children to learn, it is important to make provisions for the children with an auditory processing disorder, It would be beneficial to provide the child with the written notes, so that he/she can learn from them at a later stage, and will allow the child to focus fully on the teacher. The more **visual** the information is presented, the better (diagrams, pictures and written information *in conjunction* with the auditory input.

Children with auditory processing problems generally have trouble hearing and focusing in noise. Therefore, there are ways in which the teacher can improve the sound access. The child must be **seated** whether he/she can make use of all the visual input, while minimally being distracted from others and other noise. If there is a fan in the class, it is important to seat the child away from the fan. The fan noise, even though barely noticeable to many, can be highly distracting for these children.

It is also beneficial for the teacher to constantly **check if the child understands** after instructions are given. The checks may be visual; watching if the child understands and is following correctly, or they may be verbal. However, simply asking a child to repeat an instruction is often ineffective. This is because often the children can repeat verbatim without understanding. It is more beneficial to ask the child to paraphrase the instruction.

Multimodality cues are also very important. Visual and tactile cues are beneficial. However, they must match precisely, in content and timing, with verbal information. This otherwise can be confusing.

For a child with an auditory processing disorder, it can be useful to **pre-teach** the new information and the new vocabulary. This is not always practical however due the full schedules and huge classes. The teacher can thus introduce the new vocabulary to the whole class before teaching the new subject.

The teacher can try and **slow down** when she speaks, and constantly **repeat and rephrase** the information.

Although children with auditory processing activities can hear, they are unable to give the sound meaning. Sometimes, in the class, the sound, because of poor **acoustics** is not heard clearly. Although the sound may appear clear to someone without the disorder, it may be heard poorly by someone with the disorder. There are ways in which we can make simple adjustments in the classroom, to enhance the acoustics. This will allow more 'absorption' of the sounds, and less reverberation. One can do this by putting a carpet on the floor, posters on the wall, curtains on the windows; basically, lining the brick surfaces with substances such as paper, carpet and material that allow for better absorption of sound.

(Bellis, 2003)

Remediation Activities

The purpose of remediation is to try to alleviate the disorder through specific activities. This is difficult to give as a classroom strategy, as different activities are used for different children, depending on the area of difficulty identified in the full assessment. There are many different types of activities, and only a few will be mentioned. However, this is a broad outline of the activities that *therapists* use, and are not necessarily appropriate for every child.

Auditory Closure Activities

The purpose of auditory closure activities is to teach the child to fill in the missing gaps in spoken words in order to understand the meaning as a whole.

- *Missing Word Exercises*

These activities are designed to help the child learn how to use the context to fill in the missing word in a message. It is best to begin with familiar subject matter and move to new information.

For example:

'When I am hungry, I _____'

'Jill ____ the ball with a bat'

- *Missing Syllable Exercises*

Once the child has shown that he/she can predict the missing word based on context, the clinician can move to the omission of syllables.

For example:

'There are 26 letters in the alpha_____.'

'Types of sports: Crick__ , Soc ____, Base ____.'

- *Missing Phoneme Exercises*

This is carried out in similar fashion to the missing syllable exercises, moving from easy to more difficult.

For example:

'I like to __atch __elevisio__.'

'Animals: __onke__, ti__er.'

- *Vocabulary Building*

Building vocabulary can also help with auditory closure: teaching the child words that can be used to fill in the gaps. One of the most effective ways of learning the meaning of vocabulary is through contextual derivation, or utilising the surrounding context to predict meaning.

(Bellis, 2003)

Phoneme Training

A child with an auditory decoding deficit will not only have difficulty with auditory closure, but also with phonemic decoding skills. These exercises therefore assist the child learn to develop accurate phonemic representation and to improve speech to print skills.

It is firstly important to teach the child to discriminate sounds accurately, and to identify when he/she has failed to do this. The child must first learn to discriminate individual sounds, and then move to the discrimination of minimal pairs (eg. hat/cat) and slowly increase in complexity.

Then it is important to move to *speech to print* skills; connecting the phoneme learned auditorily to the written letter symbol.

Prosody Training

Children with temporal patterning problems are therefore undergo specific training in recognition and use of prosodic aspects of speech, such as rhyme, stress, and intonation. A task that can be done at school is reading aloud daily, with special emphasis on animation. Reading aloud not only helps with reading and also to re-auditorize and re-inforce the use of rhythm, stress and intonation in expressive language.

(Bellis, 2003)

Compensatory Strategies

With the use of compensatory strategies, we try to teach the child to be an active rather than passive listener. The child must accept that he/she has a problem, and thus must make use of specific strategies to help him/her.

Some strategies, that a child can be taught, or used in the classroom can include:

Chunking – breaking long messages into smaller component parts and grouping lie concepts together.

Verbal Rehearsal – repetition and re-auditorisation of the message

Paraphrasing – having the child reiterate the message in his/her own words.

It is very useful to help increase motivation and self confidence of the child. One of the ways we can do this is teaching the child about his/her disorder, and showing him/her that he/she is not stupid, but just have difficulties. They need to take control of their disorder and learn to ask for repetition and rephrasing if the instruction is understood.

(Bellis, 2003)

If you have any questions, please feel free to contact me on chollander@netactive.co.za

Thank you so much for all your help and co-operation while I was conducting my research!