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The Application of Audiological Measures for Fitting Hearing Aids to South African Children

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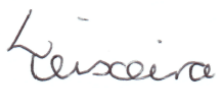
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Author's Declaration

I declare that the work in this dissertation was carried out in accordance with the Regulations of the University of the Witwatersrand. This dissertation is the result of my own work and investigations, except where otherwise indicated. Other sources are acknowledged by explicit references. A reference list is attached. This work is submitted for the degree of Masters in Audiology at the University of the Witwatersrand, Johannesburg. No part of the dissertation has been submitted for any other degree. Any views expressed in the dissertation are those of the author and in no way represent those of the University of the Witwatersrand. The dissertation has not been presented to any other University for examination either in South Africa or overseas.

Signed:



Leanne Teixeira

Date: 03/02/2012

Abstract

Objective: The appropriate application of audiological measures during paediatric hearing aid (HA) fitting ensures the fitting is effective and provides speech audibility across the frequency range. Audiological assessment may include both behavioural and objective measures, such as auditory brainstem response (ABR) and auditory steady-state response (ASSR). ABR and ASSR measures however do not have a 1:1 correlation with behavioural measures, and correction values need to be applied to estimate behavioural thresholds prior to HA fitting. No study has previously described how South African audiologists are utilising ABR and ASSR results during paediatric HA fitting. This study aimed to describe the current South African audiological clinical practice for paediatric HA fitting, with specific reference to the application of ABR and ASSR measures. ***Design:*** The study employed a quantitative, non-experimental, descriptive, cross-sectional survey research design. ***Study sample:*** Thirty-four personal interviews with audiologists were completed, seven within the private health sector and 27 within the public health sector. ***Results:*** Results indicated that limited departmental protocols exist and adherence to available protocols was questioned. There was a lack of consensus regarding the application of correction values to ABR and ASSR measures for HA fitting and the values utilised often differed significantly from recommended guidelines. There appeared to be an over-reliance on electrophysiological measures for paediatric audiological assessment, as well as a lack of adherence to recommended age-appropriate assessment guidelines. ***Conclusion****:* Findings suggest the need for promoting improved clinical practice and knowledge within the area of paediatric audiology in South Africa. The need for the development of nationally-agreed guidelines was highlighted.

Key Words: Effective amplification; ASSR; ABR; paediatric HA fitting; South Africa.

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Chapter 1: Orientation

1.1 Introduction

This chapter provides the orientation to the research. It encompasses the context of the study, the purpose of the research, definition of terms used within the context of the research, an explanation of the abbreviations used, and lastly, an outline of each of the chapters in the research.

1.2 Context of study

Lloyd, Sanders & Lehmann, (2010) discuss challenges to the South African health care system and that:

> Within South Africa, transformation of the health system has been hampered by inadequate numbers and inequitable distribution of health workers between private and public sectors and rural and urban areas, lack of appropriate skills throughout the system and poor planning and monitoring (p.171).

The inequitable distribution of resources is evident, with 55.6% of health finances being utilised in the South African private health care sector (Blecher & Harrison, 2006). This is in contrast to the percentage of the South African population accessing private health care. Only 16% of the South African population have access to the private health care system, while the remaining 84% of the population access public health care (Lloyd et al, 2010). Public health care funding in South Africa focuses on primary health care, HIV and related illnesses, infrastructure, and emergency medical services (Blecher & Harrison, 2006). The South African health care system has various challenges it still needs to address. Included in these

challenges is the early identification and appropriate management for paediatric hearing loss (HL).

It is estimated that in South Africa, 6 357 children annually are born with, or acquire a permanent HL in the first weeks of life (Utilising Statistics SA (SSA), 2011 data & Olusanya, 2008 incidence). The majority of these children are born in the public health sector. In South Africa, children with a HL are diagnosed at later ages compared to national and international recommended norms (Strauss, 2006; van der Spuy & Pottas, 2008). This is likely due to neonatal hearing screening in South Africa not yet being universally implemented, despite national guidelines on universal infant hearing screening (Health Professions Council of South Africa [HPCSA], 2007). Research indicated that in the public health sector only 2% of departments surveyed undertook universal hearing screening (Theunissen & Swanepoel, 2008). In the private sector it was found that only 14% of infant hearing screening programmes, were universal (Meyer & Swanepoel, 2011).

Paediatric audiological assessment should be led by evidence-based guidelines to ensure its effectiveness (Gravel, 2005). These guidelines highlight the importance of using appropriate audiological equipment and age-appropriate measures during early paediatric hearing loss detection and intervention (EHDI), to ensure the appropriate diagnosis and management of paediatric HL. Once a paediatric HL is identified, subsequent HA fitting should be safe, comfortable and effective (Gravel, 2000). Various international guidelines regarding the assessment and intervention for children with HL exist (Joint Committee on Infant Hearing [JCIH], 2007; American Academy of Audiology [AAA], 2003; British Columbia Early Hearing Programme

[BCEP], 2008; Baldwin, Sutton, Gravel, & Low, 2008; British Society of Audiology [BSA] & British Academy of Audiology [BAA], 2007; Modernising Children's Hearing Aid Services [MCHAS], 2005). Despite this, it has been found that in South Africa only 35% of individual audiology departments surveyed reported following a protocol for EHDI (Strauss, 2006).

Ideally, during audiological assessment, a test battery approach should be used to effectively evaluate hearing. This battery may include electrophysiological measures such as ABR and ASSR. ABR and ASSR both have applications in the audiological assessment of the paediatric population (Hall, 2004). However, as ABR and ASSR measures do not have a 1:1 ratio with behavioural audiological measures, it is important to apply correction values to the results (Stapells, 2000a; Rance, Rickards, Cohen, DeVidi & Clark, 1995; Rance et al., 2005). Application of these correction values allows audiologists to estimate behavioural thresholds prior to HA fitting. To date, no studies have described how South African audiologists utilise ABR and ASSR measures for fitting hearing aids (HAs) to children.

The study was developed taking into account various aspects of paediatric audiological assessment in preparation for subsequent HA fitting, as outlined in the BCEP (2008); and Stevens, Sutton, Wood & Mason (2007) guidelines. The lack of nationally agreed protocols or standards for paediatric HA fitting in South Africa may compromise consistent and evidence-based care offered to children with HL and their families. Due to the dearth of information on this topic, this study aimed to address the question: "What is the clinical practice of South African audiologists for fitting

HAs to paediatric clients, with specific reference to the utilisation of ABR and/or ASSR measures, and how does this practice compare to recommended guidelines?"

1.3 Definitions of terms

Frequently-used terms within the context of the study are clarified below:

ABR: An auditory brainstem response (ABR) is an auditory-evoked response to transient acoustic stimuli such as click or tone-burst (TB) stimuli. This electrophysiological recording is measured using surface electrodes attached to the forehead and near the ears (Hall & Bondurant, 2009).

ASSR: An auditory steady-state response (ASSR) is an auditory-evoked response to pure-tone (steady-state) stimuli, modulated in amplitude and/or frequency. A similar electrode configuration as utilised during ABR measurements can be used for recordings (Cone & Dimitrijevic, 2009.)

Corrected age: The age a premature baby would be if she/he had been born on her/his due date.

Correction values: The values applied to ABR and ASSR dBnHL to estimate behavioural thresholds (Bagatto, 2008). Correction values are reported in dBeHL (Cunningham, 2008).

dBeHL: Decibel estimated behavioural hearing level (Cunningham, 2008).

Early Hearing Detection and Intervention (EHDI): The early identification and management of childhood HL, as per recommended guidelines.

Protocols/guidelines: These terms refer to developed recommendations and standards for clinical practice and are used interchangeably in the report.

1.4 Abbreviations

ABR : auditory brainstem response
ANSD : auditory neuropathy spectrum disorder
ASSR : auditory steady-state response
BC : bone conduction
CM : cochlear microphonic
dB : decibels
dBeHL : decibel estimated hearing level, i.e. corrected ABR/ASSR threshold
dBnHL : decibel normalised hearing level, i.e. uncorrected ABR/ASSR threshold
DPOAE : distortion product otoacoustic emission
EEG : electroencephalography
EHDI : early paediatric hearing loss detection and intervention
HA : hearing aid
HAs : hearing aids
HL : hearing loss
Hz : hertz
OAEs : otoacoustic emissions
peSPL : peak equivalent sound pressure level
ppeSPL : peak pressure equivalent sound pressure level
REAR : real-ear aided response
RECD : real-ear-to-coupler difference
REIG : real-ear insertion gain
REM : real-ear measure
REMs : real-ear measures
RET : reference equivalent threshold
REUR : real-ear unaided gain
SPL : sound pressure level
S-REAR : simulated real-ear aided response
TB ABR : tone-burst auditory brainstem response testing
TEOAE : transient-evoked otoacoustic emission
VRA : visual reinforcement audiometry

1.5 Chapter outlines

The research will be presented in five chapters.

Chapter 1 provides a basic orientation and motivation for the study, the definitions of terms used within the framework of the research, the abbreviations used, and lastly an outline of the chapters in the study.

Chapter 2 provides the conceptual framework for this study. It commences with an overview of the prevalence of paediatric HL and early detection and intervention for paediatric HL. This is followed by a discussion on the importance of using evidence-based guidelines/protocols, appropriate audiological equipment and age-appropriate audiological measures to ensure effective assessment and intervention. The application of correction values to ABR and ASSR measures, in order to estimate behavioural thresholds for paediatric HA fitting, is also highlighted. The chapter concludes with a discussion of the verification stage of the HA fitting process.

In **Chapter 3,** the methodology is set out and includes a description of research aims, design and phases. Participant selection and description, as well as the research measure utilised are presented. Ethical considerations - reliability and validity, as well as data analysis methods employed, are discussed.

Chapter 4 provides an overview of the results obtained and includes a critical discussion of these results. The findings are reported in relation to the aims of the study. Data is organised, analysed and interpreted so that conclusions can be drawn

regarding the current clinical practice for paediatric HA fitting (with specific reference to ABR and ASSR measures), in the South African context. The discussion of the results is integrated throughout the chapter. Factors contributing towards the outcomes of the research are suggested.

In **Chapter 5,** the conclusions and critical evaluation of the study are presented, followed by the implications and recommendations for future research.

The **Appendices** supply important information for the understanding of the data collection and analysis procedure, and replication of the study.

1.6 Summary

This chapter provides the rationale for the study by describing background information. It includes the definitions of terms used within the context of this research, as well as an explanation of the abbreviations used. The chapter concludes with an outline of the different chapters by which means the aims of the study are realised.

Chapter 2: Literature Review

2.1 Introduction

This chapter critically discusses literature relevant to this study. Information regarding the prevalence of paediatric HL and EHDI will be discussed. Literature regarding protocols, audiological equipment, as well as audiological measures used for paediatric audiological assessment and HA fitting, is also presented. Various aspects regarding ABR and ASSR measures are considered, including the application of correction values to ABR and ASSR measures in order to estimate behavioural thresholds. Lastly, the verification stage of the HA fitting process will be discussed.

2.2 South African context

South Africa is a developing country with an estimated population of 50 586 757 (SSA, 2011). It is a country facing many challenges, one being HIV/AIDS. It is estimated that in South Africa, the overall HIV prevalence rate is 10.6% (SSA, 2011). It is known that "HIV/AIDS creates enormous strains on under-resourced health care systems….." (McPherson, 2008, p. 13). Included in health care system resource challenges experienced in South Africa, is the inequitable distribution of human and financial resources between the private and public health care systems. The private health care system provides medical care for only 16% of the South African population, through medical aid schemes (Lloyd et al., 2010). Despite this small proportion of the population being served in the private health care sector, 55.6% of health finances are utilised by this sector (Blecher & Harrison, 2006).

The South African public health care sector also experiences a great shortage of human resources (Padarath, Ntuli & Berthiaume, 2003). In 2010, a total of 1545 audiologists, and dual-qualified speech therapists and audiologists, were registered with the Health Professionals Council of South Africa (HPCSA) (HPCSA, 2010). Of these, only 396 were employed in the public health care sector (Human Resources for Health South Africa Strategy [HRH], 2011). This effectively translates to a ratio of 0.08 professionals per 10 000 South Africans (HRH, 2011). Considering this ratio, it is therefore evident that it would be challenging to meet the needs of South African children with HL.

2.3 Incidence of hearing loss

The incidence of permanent childhood HL in developed countries such as the United States of America (USA), is reported to range between 1.39 to 4.4 children per 1 000 screened (Davis, Davis & Mencher, 2009). This is in contrast to developing countries such as South Africa, where the incidence rates are much higher, ranging from 1.5 to 222 per 1 000 children (Davis et al., 2009). The large range in reported incidences could be attributed to the definitions of HL used, lack of large scale robust studies and the challenge of comparing studies with inconsistencies in the methodology and type of HL researched (Davis et al., 2009). The estimated incidence of children born with or acquiring a bilateral permanent HL (>40 dBHL) in sub-Saharan Africa in the first few weeks of life, is estimated at six per 1 000 births (Olusanya, 2008). This figure is higher than the figures of two to four per 1000 births reported for industrialised countries (Olusanya, 2008).

It is estimated that approximately 1 059 417 babies were born in South Africa during 2011 (SSA, 2011). Utilising the incidence reported by Olusanya (2008), it is therefore estimated that in South Africa, approximately 6 357 children annually are born with, or acquire, a permanent HL in the first weeks of life. These figures highlight the importance of early detection of HL and intervention for these children. EHDI can, however, not be realised without adequate resources, in the form of staffing, equipment, and HAs.

2.4 Early hearing detection and intervention

EHDI is associated with improved language development of children with HL (Yoshinago-Itano, Sedey, Coulter & Mehl, 1998). It has been found that early enrolment in a comprehensive early intervention programme results in improved vocabulary and verbal reasoning skills of these children at age five years (Moeller, 2000).

The JCIH developed comprehensive guidelines regarding the implementation of EHDI (JCIH, 2007). These guidelines encourage universal newborn hearing screening and recommend that the hearing of all children be screened by one month of age. If a HL is suspected, these children should undergo a full audiological evaluation by three months of age, and appropriate intervention be provided by six months of age. The Position Statement on EHDI in South Africa, developed by the HPCSA in 2007, is similar, as it recommends that in a hospital setting, HL is confirmed by three months of age and intervention provided by six months of age. However, in a primary health care clinic-based setting, HL should be identified by four months and intervention provided by eight-months of age. Intervention may involve monitoring

of middle ear effusion, aetiological evaluation, referral to early intervention services and HA fitting (JCIH, 2000 as cited in HPCSA, 2007).

With the introduction of newborn hearing screening, infants and children are undergoing audiological evaluation at younger ages (Haplin, Smith, Widen, & Chertoff, 2010). In the USA, Haplin et al. (2010) found that their clinical caseload of newborns increased from 25% to 80%, after universal newborn hearing screening was introduced. A benefit of newborn hearing screening is that infants with a hearing loss are diagnosed significantly earlier, than children who are referred for audiological assessment at a later stage (Durieux-Smith, Fitzpatrick & Whittingham, 2008). A review of 709 records of children born with a permanent HL or acquiring an early-onset HL, found that children undergoing hearing screening were diagnosed at an average age of 6.3 months. In contrast, children referred for assessment were only diagnosed at the average age of 39.5 months (Durieux-Smith et al., 2008). In addition, it was found that children with greater degrees of HL were identified at younger ages than children with milder degrees of HL.

Newborn hearing screening in South Africa is not yet universal. A survey exploring EHDI in the public health care sector in South Africa (N=44), found that only 27% of South African hospitals were conducting newborn hearing screening (Theunissen & Swanepoel, 2008). Of these hospitals, only one department (2%) conducted universal newborn hearing screening, whilst the rest only screened high risk babies and neonatal intensive care unit (NICU) graduates. In a similar study, Meyer and Swanepoel (2011) surveyed obstetric units in the private health care sector (N = 160) in South Africa. It was found that only 53% of private obstetric units were

providing newborn hearing screening, with universal newborn hearing screening only being offered by 14% of these units. Challenges reported by these units included that newborn hearing screening was not included in birthing packages given to families, and not supported by other health care staff or medical aid schemes.

It is evident that within South Africa, the age of identification of HL, initial HA fitting and enrolment in an early intervention programme, is late, relative to recommended national and international guidelines (HPCSA, 2007; JCIH, 2007) (See Table 2.1). There also appears to be a large time delay between the age of identification and enrolment in early intervention programmes (van der Spuy & Pottas, 2008; Venter & Viljoen, 2008 as cited in Swanepoel, Störbeck & Friedland, 2009).

The age range at identification of HL and initial HA fitting for South African children is large, possibly due to differences in private vs. public health care services (van der Spuy & Pottas, 2008), but is most likely due to newborn hearing screening in South Africa not yet being universal.

Table 2.1

Ages of Identification of Childhood HL, Initial HA Fitting and Enrolment in an Early Intervention (EI) Programme

Study	***N***	***Age at Identification (months)***	***Age of enrolment in an EI programme (months)***	***Age at initial HA fitting (months)***
van der Spuy & Pottas (2008)	54	23 (*SD* =17; range = 2-27)	31 (*SD* = 19)	28 (*SD* = 19)
Strauss (2006)	35	27% younger than 6 months. 16% between 6-12 months. 24% between 12-24 months. 30% over 30 months.	--	Less than 50% in first year of life
Teixeira (2011)	29*	--	--	7% younger than 6 months. (*n*=2) 3% between 6-12 months. (*n*=1) 10% between 12-18 months. (*n*=3) 3% 18-24 months. (*n*=1) 7 % 2-3 years (*n*=2) 14 % 3-4 years (*n*=4) 11 % 4-5 years (*n*=3) 31 % 5-6 years (*n*=9) 14 % 6-7 years (*n*=4)
Venter & Viljoen (2008) as cited in Swanepoel, Störbeck & Friedland (2009)	20	31	43	39
Theunissen and Swanepoel (2008)	76	--	--	Less than 7% (5/76) by 6 months of age. 70% (53/76) older than 12 months

**Includes all initial fittings for permanent hearing losses fitted over 12 month period (acquired and congenital aetiologies) (public health sector)*

In South Africa, challenges for audiology services are numerous. The inequitable distribution of audiologists between the public and private health sectors results in the South African public health care sector being hugely understaffed (Swanepoel, 2006). Despite the fact that the private sector may have more resources available, different challenges exist for the implementation of newborn hearing screening, such as the lack of support by hospital administration, medical aids, as well as medical staff working with infants after birth (Meyer & Swanepoel, 2011). Without universal newborn hearing screening, HL will inevitably be identified later than national and international recommendations.

2.5 Protocols

The use of evidence-based practice guidelines ensures that audiological assessment and intervention in paediatric audiology is as effective as possible (Gravel, 2005). There are various international gold standards regarding the assessment and intervention for children with HL (JCIH, 2007; AAA, 2003; BCEP, 2008; Baldwin et al., 2008; BSA & BAA, 2007; MCHAS, 2005).

In South Africa, the Position Statement on EHDI (HPCSA, 2007), describes the age at which intervention should be initiated, as well as what early intervention should involve. This guideline, however, only includes limited information on how audiological results should be used for HA fitting. It further does not include standards for paediatric HA fitting, ABR and ASSR assessment, or estimation of audiological thresholds from ABR and ASSR results for paediatric HA fitting. The need for national guidelines was highlighted by a survey that found that only 35% of

individual audiology departments (*n*=34) followed a protocol for EHDI for infants and children (Strauss, 2006).

Once a child has been identified as having a HL, amplification (such as HAs) is usually recommended. HA selection and fitting forms part of a complete audiological management programme (Gravel, 2000). The HA fitting process involves four stages: (i) Assessment/Prescription; (ii) Selection; (iii) Verification; and (iv) Validation - (Boothroyd, 2000, Cunningham, 2008). The precise completion of all of these stages assists in ensuring that the HA fitting is as accurate and effective as possible. This will provide the infant or child with access to auditory stimuli to allow for oral speech and language development. Paediatric HA fitting should be safe, comfortable and effective (Gravel, 2000). It should ensure audibility of speech at comfortable listening levels across the frequency range (Ching, 2002; Gabbard & Schryer, 2008). A guideline for HA fitting assists in directing this often complex and challenging process. The lack of availability of nationally agreed and easily-accessible audiological guidelines in South Africa, may compromise the provision of high standard, consistent and evidence-based care.

Evidence-based guidelines assist in clinical management, and improve the effectiveness, efficiency and quality of services (Moodie et al. 2011). There are several evidence bases which have varying degrees of strength (Cox, 2005). The strongest of these evidence bases are randomised controlled studies, systematic reviews, meta-analyses of randomised controlled studies, or other high quality research. The remaining evidence bases are: non-randomised controlled studies; non-intervention studies, namely: cohort studies, case-control studies and cross-sectional

surveys; followed by case reports and expert opinion, in descending order from strongest to weakest evidence bases. It is important for clinicians to develop and utilise guidelines utilising an appropriate and strong evidence-base to ensure effective audiological assessment and management.

2.6 Audiological measures utilised for paediatric HA fitting

The goal of paediatric audiological assessment is to determine whether a permanent HL is present and, if required, to initiate a management plan as directed by the child's family (BCEP, 2008). This process involves the application of a test-battery approach, including various audiological measures, to determine the exact nature of the HL, as well as evaluating the integrity of the auditory pathway (Diefendorf, 2009). This ensures that an accurate diagnosis is made, based on valid and accurate ear and frequency-specific hearing thresholds (Hodgson, 1994; BCEP, 2008).

Audiological measures utilised may vary according to the age, cognitive ability and physical ability of the infant or child (Diefendorf, 2009). Case history and clinical observation are important components of the audiological assessment of children of all ages. Both these components provide the clinician with an understanding of a child's overall development, which will guide audiological procedures used during assessment (Diefendorf, 2009). Otoscopy, another essential component, allows the clinician to determine whether any obstructions exist in the ear canal, contra-indicating the insertion of probes in the ear during audiological assessment (Diefendorf, 2009).

A test battery for audiological assessment of children from birth to six months may, in addition, include family report and observations; high frequency (1000 Hz) tympanometry and acoustic reflexes; otoacoustic emissions (OAEs); ABR (Gravel, 2000); cochlear microphonic (CM) and ASSR (Stevens et al., 2007). Behavioural testing can usually be included as part of the test battery from five to six months of age (Madell, 2008).

2.6.1 Tympanometry measures

In order to accurately evaluate the middle ear status of a child, it is recommended that different frequency probe tones be used during immittance testing of infants less than six months corrected age (Baldwin et al., 2008; BCEP, 2008). It is recommended that until an infant is six months corrected age, a 1000 Hz probe tone be used during tympanometry, while from six months of age a 226 Hz probe tone should be used (Baldwin, et al., 2008; BCEP, 2008). Tympanometry results should be considered in conjunction with case history, otoscopy, as well as considering the degree and shape of HL (Shanks & Shohet, 2009).

Despite the above-discussed recommendations, the South African study by Theunissen and Swanepoel (2008) found that during diagnostic evaluation for children from birth to six months of age, only 77% (*n*=10) 'always' required tympanometry measures, while the remaining 23% (*n*=3) of the participants 'sometimes' required these measures. For children between seven to 36 months of age, promisingly, all participants (*n*=13) required tympanometry measures.

2.6.2 Otoacoustic emission measures

"OAEs are sounds that originate in the cochlea and propagate through the middle ear and into the ear canal where they can be measured using a sensitive microphone" (Prieve & Fitzgerald, 2009, p. 497). Distortion product (DP) and transient-evoked (TE) OAEs, are two types of OAE measurements often used clinically and are so named due to the difference in stimuli used to evoke the OAE. OAEs can be used as part of a test battery to determine the site of lesion of a HL, i.e. neural or sensory, as well as being a useful tool during newborn hearing screening (Prieve & Fitzgerald, 2009). They are of particular benefit in the evaluation of auditory neuropathy spectrum disorder (ANSD). For individuals with this condition, evoked OAEs are normal, while ABRs and acoustic reflexes are abnormal or absent (Prieve & Fitzgerald, 2009).

2.6.3 Behavioural measures

From five to six months corrected age, behavioural testing in the form of visual reinforcement audiometry (VRA), can be included as part of the audiological test-battery (Madell, 2008; Tweedy & Booth, 2009). VRA audiometry is an audiological method during which a child is conditioned to turn to a sound, at which time a visual reward is provided (Tweedy & Booth, 2009). As the child grows older, behavioural audiological assessment techniques are adjusted to utilise play audiometry, which may be more appropriate to the child's cognitive ability. Play audiometry is usually attempted from 25 to 36 months of age (Hodgson, 1994). During play audiometry, the child is conditioned to respond to sound stimuli with a play action, e.g. placing a block in a bucket (Tweedy & Booth, 2009).

2.6.4 ABR measures

Electrophysiological measures, such as an ABR, are typically used for assessing hearing in infants younger than six months of age, due to the infants' developing trunk and neck control (Hall, 2004). ABR is an audiological assessment measure which can be described as an onset response appearing as a set of vertex-positive waves occurring after the onset of a stimulus (Burkard & Don, 2007). An ABR is measured using surface electrodes placed on the forehead and earlobes (Hall & Bondurant, 2009). ABR testing can be completed utilising post-aural headphones (air conduction), insert-phones (air conduction), or bone conduction (BC) transducers.

ABR measurements can be evoked using click or tone-burst (TB) stimuli (Hall & Bondurant, 2009). For most clinically-used transducers, the click stimulus reflects the best threshold between 750 to 4000 Hz, and when the HL is similar across frequencies will best indicate hearing sensitivity between the 2 to 4 kHz range (Sininger & Hyde, 2009).

Click ABR does not provide frequency-specific information and TB stimuli between 500 and 4000 Hz should therefore be used for this purpose (Sininger & Hyde, 2009). Frequency-specific ABR measures (tone-bursts) allow one to estimate the degree and shape of a HL to assist in HA fitting (AAA, 2003). If a child's air conduction thresholds are above acceptable levels for discharge and a conductive HL is suspected, then BC ABR testing should be completed (Stevens et al., 2007).

ABR may also provide useful audiological information for children where behavioural results cannot be obtained (Hall & Bondurant, 2009). It is recommended

that to confirm a permanent hearing impairment, at least one ABR is completed as part of a test battery for children younger than three years of age (JCIH, 2007).

Performing an ABR during audiological assessment has various benefits. ABR measures provide information regarding the site of lesion of a HL i.e. conductive, neural or sensory loss (Hall, 2004). It also provides audiological threshold information across the frequency range, allowing for accurate estimation of HL (AAA, 2003). This is true for a variety of degrees of HL between the mild to severe range, but an ABR is less able to pin-point exact thresholds for a more severe to profound HL (Hall, 2004). ABRs can, however, not be used to estimate behavioural thresholds in individuals with ANSD (Sininger, 2007).

It is recommended that ear-specific, high and low frequency information be obtained as the minimum audiological information during assessment, prior to HA fitting, although HA fitting may commence while this information is being obtained (AAA, 2003). In order to obtain a range of frequency-specific information during tone-burst ABR (TB ABR) testing, it is recommended that ABR testing commence with 4kHz, followed by 1kHz, then 2kHz and lastly 500 Hz (Stevens et al., 2011).

It appears that within the South African context comprehensive and age-appropriate audiological assessment for children is not always completed. A study investigated the use of click, TB and BC ABR testing by South African audiologists (N=13) for testing infants from birth to six months of age, as well as children seven to 36 months of age (Theunissen & Swanepoel, 2008). During diagnostic ABR testing, more participants reported completing click ABR than TB ABR testing. For infants

less than six months of age, 31% (*n*=4) of the participants indicated that they 'always' completed click ABR and 31% (*n*=4) reported that they 'sometimes' completed click ABR. In contrast, TB ABR was 'always' completed by 15% (*n*=2) of the participants and 'sometimes' by 23% (*n*=3) of the participants. For infants younger than six months of age, electrophysiological measures such as TB ABR should be used, as behavioural audiometry is not yet feasible (Sininger, 2007). Therefore, this limited use of frequency-specific ABR measures suggests that HA fitting performed by the participants in the study may be inaccurate due limited frequency-specific ABR results being available. Theunissen & Swanepoel (2008) found that for both age groups, only 23% (*n*=3) of the participants reported 'sometimes' requiring BC ABR. None of the participants indicated that they 'always' required BC ABR. This is despite the recommendation that if air conduction thresholds are raised, it is important to use BC ABR to determine whether there is a conductive component to the HL (Stevens et al., 2007).

CM is a useful pre-neural response generated by the cochlear hair cells and can be measured during ABR testing, assisting in the diagnosis of ANSD (Schoonhoven, 2007). This is specifically pertinent as patients with ANSD present as absent ABR and present OAE's and/or CM (Schoonhoven, 2007).

2.6.5 ASSR measures

"The auditory steady-state response (ASSR) is a periodic electrical response from the brain, evoked by a periodically, varying continuous acoustic signal, typically sinusoidally modulated tone." (Rickards, 2008, p. 1). ASSR is able to estimate frequency-specific hearing thresholds in infants and children (Cone & Dimitrijevic,

2009). Thresholds are objectively detected by equipment during assessment (Cone & Dimitrijevic, 2009). This is in contrast to ABR testing, during which threshold level identification is subjective and determined by the clinician completing the testing.

Air and BC transducers can be used during ASSR assessment (Small & Stapells, 2008a). Test stimuli can be amplitude modulated (AM), frequency modulated (FM) or both AM and FM modulated (mixed modulation) (Picton, 2007).

ASSR stimuli are pure tone (steady-state) rather than transient (brief) as is used in ABR testing. ASSR testing can therefore be undertaken at higher intensity levels (Hall & Bondurant, 2009). Unlike ABR, ASSR is able to provide useful threshold information even for severe to profound HL (Hall, 2004). As with ABR, for individuals with ANSD, ASSR is unable to accurately estimate behavioural thresholds (Rance & Briggs, 2002; Rance et al., 2005).

2.7 Correction values applied for HA fitting

Once ABR and ASSR testing has been completed, appropriate correction values should be applied to results (Bagatto, 2008; Cunningham, 2008; Stevens et al., 2007 & Stevens et al., 2011). Correction values are the values applied to ABR and ASSR results in order to accurately estimate behavioural thresholds, measured as dB estimated hearing level (dBeHL), for HA fitting (Bagatto, 2008). The equation to estimate behavioural thresholds from electrophysiological thresholds can be depicted as follows: *dBnHL - frequency-specific correction = dBeHL* (Cunningham, 2008). Estimation of behavioural thresholds is also important for appropriate counselling, in

terms of providing parents with appropriate information regarding the degree of their child's HL (Moodie & Moodie, 2004).

An infant ear canal results in a higher sound pressure level (SPL) in the ear canal due to its smaller size (BCEP, 2008, Moodie & Moodie, 2004). Subsequent behavioural thresholds may therefore suggest a 'worsening' of thresholds, when in reality the child's ear canal size has increased, as the canal becomes more adult-like. This is an important consideration when counselling parents, as well as during HA selection (Moodie & Moodie, 2004). As the ear canal grows, additional HA gain is required to ensure HA prescription targets are met. The HA should therefore be able to provide sufficient gain as the infant grows older (Moodie & Moodie, 2004).

There are various studies and guidelines discussing the differences between ABR and/or ASSR results and behavioural thresholds, and the correction values which should be applied to estimate behavioural thresholds from ABR and ASSR (Stapells, 2000a; Bagatto, 2008; Picton, Dimitrijevic, Perez-Abalo & Van Roon, 2005; Stevens et al., 2007; Stevens et al., 2011; Rance, et al. 1995; BCEP, 2008; Rance et al., 2005). For physiological testing, "The difference between estimated and actual thresholds varies with several parameters, among the most important of which are the frequency of the sound, the degree of HL, the age of the subjects, and the duration of the recording" (Picton et al., 2005, p. 141). Many real-ear systems (e.g. Audioscan^{TM}) allow the clinician to enter values in dBnHL or dBeHL, so that, if desired, the conversion from dBnHL to dBeHL values is done automatically by the equipment using embedded correction values (Cunningham, 2008).

Various recommended correction values for ABR and ASSR are discussed below. It should be noted that the values discussed are displayed as they should be applied to ABR and ASSR dBnHL values, with no additional change in sign required (i.e. positive or negative). For example, if an ABR threshold= 60dBnHL, and the recommended correction value = -20dB, this results in a 40dBeHL threshold (i.e. estimated behavioural threshold).

2.7.1 Correction values for ABR

There are two considerations when applying correction values to ABR results, namely ABR offsets and stimulus corrections. An *ABR offset* is the difference between the ABR threshold and behavioural audiological threshold, whilst *stimulus corrections* are differences in thresholds which may occur according to the transducer used during assessment, e.g. (insert earphones, vs. headphones vs. bone conductors) (Stevens et al., 2011). Therefore, different correction values may need to be applied depending on the age of the patient and type of transducer used during testing. This is important, as the SPL in the ear canal in an infant differs between insert earphones and headphones when the same dBnHL stimulus level is presented to the ear (Stevens et al., 2011).

A meta-analysis of 32 studies (*N*=1203) compared the differences between ABR thresholds and behavioural thresholds (Stapells, 2000a). It was found that for individuals with sensori-neural HL, TB ABR thresholds were 5 to 15 dB higher than pure tone behavioural thresholds in adults, and -10 dB to +10 dB in infants and young children. Results across the 32 studies were found to be consistent, despite varying transducer methods (insert vs. headphone), calibration values, test parameters, varying

ages for behavioural and ABR child testing, as well as interpretation of results. Ninety-five percent (95%) confidence intervals were within +/-5 dB.

The ABR correction values applied to dBnHL values obtained after ABR testing, as recommended by Bagatto (2008), to estimate behavioural thresholds from ABR results, are shown in Table 2.2.

Table 2.2

ABR dBnHL to dBeHL Correction Values (Bagatto, 2008)

	500 Hz	*1000 Hz*	*2000 Hz*	*4000 Hz*
Correction value (dB)	-20	-15	-10	-5

The ABR correction values recommended by the Newborn Hearing Screening Programme (Stevens et al., 2007) in the United Kingdom, vary slightly from those suggested by Bagatto (2008) (See Table 2.3). When testing an infant less than three months of age, it may be necessary to apply two correction factors (stage one and two), whereas for an infant older than three months, only one set of correction factors needs to be applied (Table 2.3).

Table 2.3

Stevens et al. (2007) dBnHL to dBeHL Recommended Correction Values

	Click	***500 Hz***	***1000 Hz***	***2000 Hz***	***4000 Hz***
		Stage one Correction Values (under 3 months only) (dB)			
Insert	+10	+5	+5	+5	+10
Bone	See table 2.4 for correction factors	Currently no published data for bone vibrator. It is therefore recommended that no correction factor is used until data is available.			
		Stage two Correction Values (all ages) (dB)			
Insert, earphone, BC	-5	-20	-15	-10	-5

Although the Stage two guidelines in Table 2.3 are for results >40 dBnHL, it is recommended that currently the same correction values be used for thresholds between 35-40 dBnHL (Stevens et al., 2007). These correction values were reviewed in 2011 (Stevens et al., 2011).

The recommended level suggesting satisfactory hearing for ABR is ≤30 dBeHL and therefore correction values recommended by Stevens et al. (2011) are for thresholds of ≥ 30 dBeHL. Research has suggested that in the case of ABR thresholds of < 30 dBeHL (thus normal hearing), there may be a greater difference between ABR and behavioural thresholds than in the case of sensori-neural HL - in both adults and children (Stapells, 2000a). However, as the greater correction value is unlikely to change clinical management for patients with thresholds < 30 dBeHL, separate correction values are therefore not provided by Stevens et al. (2011).

The values in table 2.4 should be added to click bone-conduction stimulus levels (dBnHL) to give the actual stimulus level in a neonate's ear. This additional

correction value is required due to the infant's age and lack of skull fusion (Stevens et al., 2007) (See Table 2.4).

Table 2.4

Click BC ABR Correction Values to Give the Effective Stimulus Level - Stevens et al. (2007)

Gestational Age	***36 weeks***	***40 weeks***	***46 weeks***	***52 weeks***
Correction value (dB)	12	8.5	5.5	3

The Stevens et al. (2007) correction values were reviewed in 2011 (Stevens et al., 2011). Tables 2.5 to 2.8 show the correction values for various transducers and age groups, as per the revised guideline. The values given combine stimulus offset and stimulus correction values to convert dBnHL values to dBeHL, and do not have two stages as with the 2007 guideline.

Table 2.5

ABR Insert & Headphone Correction Values (in dB): Babies Tested <12 Weeks (84 days) Corrected Age (C.A.) (Stevens et al., 2011).

	Click	***500 Hz***	***1000 Hz***	***2000 Hz***	***4000 Hz***
Insert	+5	-15	-10	-5	0
Headphones	-5	-20	-15	-10	-10

Table 2.6

ABR BC Correction Values (in dB): Babies Tested <12 weeks (84days) C.A. (Stevens et al., 2011)

Gestational age	***Corrected Age***	***Click***	***500 Hz***	***1000 Hz***	***2000 Hz***	***4000 Hz***
36 weeks	-4 weeks	+7	Do not use	Do not use	-5	-5
40 weeks	0 weeks	+3.5	Do not use	Do not use	-5	-5
46 weeks	6 weeks	+0.5	Do not use	Do not use	-5	-5
52 weeks	12 weeks	-2	Do not use	Do not use	-5	-5

As seen in table 2.6, Stevens et al. (2011) do not recommend that 500 Hz and 1000 Hz BC tone burst testing be conducted for infants less than 12 weeks corrected age. This is due to literature indicating large and uncertain correction values at these frequencies. There are adult-infant differences for BC stimuli for both ABR and ASSR, which vary according to age and frequency (Small & Stapells, 2008b).

Table 2.7

ABR Correction Values (dB): Babies 12 to 24 Weeks C.A. (Stevens et al., 2011)

	Click	***500 Hz***	***1000 Hz***	***2000 Hz***	***4000 Hz***
Insert phones	0	-20	-15	-10	-5
Headphones and BC	-5	-20	-15	-10	-10

Table 2.8

ABR Correction Values: Babies Tested After 24 weeks C.A. (Stevens et al., 2011)

	Click	***500 Hz***	***1000 Hz***	***2000 Hz***	***4000 Hz***
Insert phones, headphones and BC transducers	-5	-20	-15	-10	-10

The BCEP (2008) set of calculations, to be applied to ABR dBnHL thresholds to estimate behavioural thresholds, are listed in table 2.9.

Table 2.9

ABR dBnHL to dBeHL Correction Values (dB) (BCEP, 2008)

	500 Hz	***1000 Hz***	***2000 Hz***	***4000 Hz***
Air conduction	-15	-10	-5	-0

The BCEP (2008) recommends that the air conduction correction value be reduced by 5 dB for estimating thresholds above 70 dBnHL, if a 5 dB step size is used to determine the dBnHL threshold. Similarly, it is at the audiologist's discretion to reduce the correction value by 5 dB if the electroencephalogram (EEG) noise level is very low and the response judged as a threshold is minimal.

There are various factors affecting where a threshold is detected during ABR testing. These factors may include: ABR equipment parameters (e.g. filter settings, repetition rate, stimulus envelope, averaging), ABR testing procedure (i.e. clinician response detection requirements and testing method), as well as EEG noise levels (BCEP, 2008). These factors may influence the final comparison between ABR estimated thresholds and behavioural thresholds. It is recommended that whatever

correction values are applied, that the same institution's recommended testing protocol and test parameters be used.

2.7.2 Correction values for ASSR

Correction factors should also be applied to ASSR results to estimate behavioural hearing levels for HA fitting (Stevens et al., 2007; Stevens et al., 2011). Estimations of behavioural thresholds based on ASSR dBnHL thresholds can be done in two ways, namely by regression formulae or correction values. Correction values should be applied to ASSR results to estimate behavioural thresholds. Recommended correction factors for estimation of behavioural thresholds from ASSR results, are listed in Table 2.10 (Stevens et al., 2007).

Table 2.10

dBnHL to dBeHL Correction Values (dB) for ASSR (Stevens et al., 2007)

Transducer	***500 Hz***	***1000 Hz***	***2000 Hz***	**4000 Hz**
Stage one correction values (under 3 months only)				
Insert	+5	+5	+5	+10
BC	Currently no published data for BC. It is therefore recommended that no correction factor is used until data is available.			
Stage two correction values (all ages)				
Insert, earphone, BC	-20	-15	-15	-15

The updated Stevens et al. (2011) guideline has ASSR correction values for infants < 12 weeks only, which are shown in Table 2.11. This guideline does not provide ASSR correction values for the BC transducer. This is due to limited research in the area (Stapells, Herdman, Small, Dimitrijevic & Hatton, 2005).

Table 2.11

ASSR Correction Values (dB): Babies <12 Weeks C.A. - Stevens et al. (2011)

	500 Hz	***1000 Hz***	***2000 Hz***	***4000 Hz***
Insert phone	-20	-20	-15	-15
Headphone	-25	-25	-20	-25

The formulae used to predict behavioural thresholds from ASSR thresholds at various carrier frequencies are provided in Table 2.12. The formulae were developed based on a study completed on 25 children with a moderate to profound HL, and 35 adults with hearing ranging from normal hearing to profound HL (Rance et al., 1995). Post-aural headphones or insert phones were utilised during the study, for ASSR measures. For behavioural measures, testing was usually completed using post-aural headphones, but for three younger children free-field speaker testing was used.

Table 2.12

Formulae for dBnHL to dBeHL Conversion (Air Conduction) (Rance et al., 1995)

	250 Hz	***500 Hz***	***1000 Hz***	***2000 Hz***	***4000 Hz***
Formulae Y(x)=	1.477x-53.469	1.295x-40.197	1.182x-26.070	1.045x-19.463	1.193x-23.581
Note: Y=Predicted behavioural threshold; x= ASSR threshold					

Prediction of behavioural thresholds from ASSR is less variable in more severe hearing losses and at higher frequencies (Rance et al., 1995). For individuals with normal hearing, there is a greater difference between ASSR and behavioural thresholds when compared to those with a HL (Picton et al., 2005). As the degree of HL increases, the difference between ASSR and behavioural thresholds decreases (Rance et al., 2005).

A study on adult subjects by Dimitrijevic et al. (2002) examined the differences between pure tone thresholds and ASSR measures (mixed modulation: modulation frequencies between 80 to 95Hz), in 31 adults with sensori-neural HL and 14 adults with normal hearing. Subject characteristics for the study are summarised in table 2.13.

Table 2.13

Subject Characteristics (Dimitrijevic, et al. 2002)

	Hearing impaired participants	***Normal hearing participants***
Subjects (*N*)	31	14
Age range	32 to 86 years	23 to 63 years
Total ears tested	59	28 ears
500, 1000 & 2000 Hz pure tone average	46dBHL	--
Range of HL	15 to 87 dBHL	Normal hearing. Thresholds ≤ 25dBHL
Degree of HL (according to PTA)	≤25dNHL: 7 ears (loss at 4kHz) 26-40dBHL:17 ears 41-60dBHL:19 ears 61 to 90dBHL: 16 ears	
Type of loss (ears)	SNHL= 44 Mixed HL= 12 Normal hearing= 3	

Selected results from Dimitrijevic et al.'s (2002) study can be seen in table 2.14. As seen in table 2.13, subjects had a variety of hearing sensitivities. It is important to remember that ASSR thresholds vary according to degree of HL and frequency (Picton et al., 2005; Rance et al., 1995). Subjects in this study were not further divided into various HL categories, when comparing behavioural and ASSR thresholds. This study also showed a difference between physiological and behavioural thresholds, as seen in table 2.14.

Table 2.14

Differences Between Behavioural Thresholds and ASSR Thresholds (Dimitrijevic et al., 2002)

		dB Difference (SD)			
Hearing Sensitivity (n)	*Carrier Frequency*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*
Sensori-neural HL (31)	Air conduction	13 (11)	5 (8)	5 (9)	8 (11)
Normal Hearing (14)	(insert earphones)	17 (10)	4 (11)	4 (8)	11 (7)
Normal Hearing (11)	BC	22 (8)	14(5)	5 (8)	5 (10)

For infants (0-3 months) with normal hearing, Rance et al. (2005) found that ASSR threshold/behavioural threshold differences at 500 and 1000 Hz were significantly higher than at 2000 and 4000 Hz. They also found that thresholds at 4000 Hz were at significantly higher sensation levels compared to 2000 Hz (See Table 2.15).

Table 2.15

Differences Between ASSR and Behavioural Thresholds for Normal Hearing Infants (0-3 Months Corrected Age) (Rance et al., 2005)

		Test Frequency			
		500 Hz	*1000 Hz*	*2000 Hz*	*4000 Hz*
Difference	*Mean* (dB)	30.4	31	22.4	27.5
	SD (dB)	6.7	6.2	6.7	7.5

The differences between ASSR thresholds and behavioural thresholds for infants with a sensori-neural HL are presented in Table 2.16. It is evident that the difference between ASSR and behavioural thresholds decreases as the degree of HL increases (Rance & Briggs, 2002).

Table 2.16

Differences Between ASSR and Behavioural Thresholds for Infants with a Sensori-neural HL (1-8 months) (Rance & Briggs, 2002)

		Test Frequency			
ASSR Level (dBHL)	*Difference in dB*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*
60 to 75	*Mean*	9.6	9.8	5.8	4.0
	SD	13.9	11.1	15.7	16.8
80-95	*Mean*	4.1	3.6	3.3	5.8
	SD	12.1	8.2	5.6	5.5
100+	*Mean*	5.5	5.0	3.3	1.5
	SD	7.7	6.3	7.1	7.7

Differences between ASSR thresholds and behavioural thresholds also change with age. Rance & Tomlin (2006) conducted a longitudinal study (*n*=20) to track the developmental changes of ASSR thresholds in full-term infants, with normal hearing. Their findings showed that there were developmental changes in ASSR thresholds in the first 6 weeks of life. The 500 Hz thresholds obtained were found to be statistically significantly lower at six weeks of age compared to previous assessments at younger ages. Although not statistically significant, ASSR thresholds at 4000 Hz appeared to decrease with increasing age. They also found that the ASSR thresholds at six weeks of age were still developing and thus were not yet fully mature. This study highlights the importance of considering the differences in infant electrophysiological responses due to maturational changes when fitting HAs to infants and children.

It is evident from the above discussed literature, that if appropriate correction values are not applied to ABR and ASSR results, HA fitting may result in under- or over-amplification. This may impede optimal auditory/oral speech and language development.

2.7.3 ABR and ASSR: Acceptable dBnHL levels suggesting normal hearing

Various guidelines provide recommended levels that suggest satisfactory or normal hearing during ABR and ASSR assessment (Stevens et al., 2007; Stevens et al., 2011; Van Maanen & Stapells, 2009).

Tone-burst ABR thresholds at or below 30 dBeHL, at 4000 Hz in both ears, is the recommended level suggesting satisfactory hearing (Stevens et al., 2011). The pre-dated Stevens et al., (2007) guideline recommends utilising click ABR as a reference for discharge, with 25 dBnHL for insert phones as the acceptable threshold for discharge (i.e. 30 dBeHL) (See Table 2.17 for extrapolated acceptable levels for discharge across stimulus type (Stevens et al., 2007). The BCEP's (2008) minimum required levels during ABR assessment for all ages are also shown in Table 2.17. The BCEP (2008) does not provide different correction values for infants of different ages.

Table 2.17

Acceptable ABR dBnHL & dBeHL Values for Satisfactory Hearing Stevens et al., (2007) & BCEP, (2008)

	Click	***Tone Bursts***			
		500 Hz	*1000 Hz*	2000 Hz	4000 Hz
Inserts		*Under 3 months (Stevens et al., 2007)*			
dBnHL	25	45	40	35	25
dBeHL	30	30	30	30	30
		Over 3 months (Stevens et al., 2007)			
dBnHL	35	50	45	40	35
dBeHL	30	30	30	30	30
		Air conduction (BCEP, 2008)			
dBnHL	n/a	35	35	30	25
dBeHL	n/a	20	25	25	25
		Bone conduction (BCEP, 2008)			
dBnHL	n/a	20	n/a	30	n/a
dBeHL	n/a	n/a, no BC correction values given			

For ASSR, the recommended air conduction minimum testing levels suggesting normal hearing are: 50, 45, 40, and 40 dB HL at 500, 1000, 2000 and 4000 Hz respectively, (Van Maanen & Stapells, 2009). These authors found that at 500 Hz ASSR thresholds were significantly poorer compared to higher frequencies, possibly due to poorer neural synchronisation (Rance et al., 1995). The greater difference between 500 Hz ASSR thresholds and behavioural thresholds, compared to other frequencies, was also confirmed in other studies (Dimitrijevic et al., 2002; Luts, Desloovere, Kumar, Vandermeersch & Wouters, 2004).

Knowledge of acceptable levels suggesting normal hearing during ABR and ASSR assessment are important. This will ensure a streamlined service where clinical time is not wasted by completing testing at unnecessarily low stimulus levels, without affecting the clinical management for the patient.

2.7.4 ABR and ASSR reporting

It is important that the reported ABR and ASSR results include both dBnHL and dBeHL values, as well as the correction values used (Stevens et al., 2011; BCEP, 2008). Numerical ABR data, as well as a summary and interpretation of results, should be included (BCEP, 2008). It is recommended that formal ABR reports sent to external referral sources include at least two of the following three measures: a) nHL data; b) correction values; c) dBeHL levels (estimated hearing thresholds) (BCEP, 2008). A thorough and transparent report assists the clinician undertaking HA fitting to understand what levels should be used for the fitting. This will avoid potential over- or under-amplification through the inappropriate use of correction values.

It has been found that ABR and ASSR reports written by South African audiologists do not conform to these guidelines. An audit conducted by Moodley, Grimshaw, and Störbeck (2010), found that the majority of ASSR reports (67%; *n*=12) only included the manufacturer's estimated behavioural audiogram. Twenty two percent (*n*=4) of the reports only provided a summary of the results but did not provide any ASSR values. The remaining results were reported in dB (5.5%; *n*= 1) and in dBnHL (5.5%; *n*= 1).

More variability was noted by Moodley et al. (2010) for the audited ABR reports (*N*=65). The majority of reports (47%, *n*=31) only reported the results in dB, whilst 26% (*n*=17) of results were reported in dBnHL. Nine percent of the results reviewed (*n*=6) included comments but did not provide any test values. The remaining results were reported in: (dBHL; dBnHL & dB; as well as 'unknown' = 5% each, *n*=3 each) and (dBSPL; as well as dBnHL & dBHL= 1.5% each, *n*=1 each).

2.8 Verification and validation of hearing aid fitting

Verification is a vital stage of the paediatric HA fitting process (MCHAS, 2005; AAA, 2003) and should be included during initial HA fitting, as well as HA review appointments (MCHAS, 2005). The goals of HA fitting are (i) Adequate audibility of speech sounds without loudness discomfort or risk of cochlear damage, (ii) High fidelity sound to optimise speech intelligibility, (iii) Maintenance of high fidelity sound in differing room acoustics, and (iv) High fidelity sound for different speakers as well as listening environments (Boothroyd, 2000).

To assist in attaining the above-mentioned goals, verification in the form of real-ear measures (REMs) should be undertaken. It has been stated that "The most reliable and efficient method for assessing the performance provided by amplification is real-ear measures" (Valente & Valente, 2009, p. 858). REMs are a method of HA output verification, during which a small, flexible probe-tube microphone is placed in the ear canal, allowing for real-ear aided gain and maximum output of a HA to be measured (Stelmachowicz & Hoover, 2009).

REMs, such as real-ear-to-coupler differences (RECDs) and real-ear aided response (REAR), are useful paediatric HA verification methods (MCHAS, 2005). A RECD measurement is the difference in dB across the frequency range between the SPL measure in the person's occluded ear (using either the person's ear mould or insert foam) and the SPL recorded in a 2-cc coupler (Bagatto, 2001). RECD measurements help derive accurate prescription targets by accounting for the individual's ear acoustics.

REAR is a useful paediatric REM technique as it does not require the child to sit still for as long as for other REMs (BSA & BAA, 2007). There are two REAR methods; (i) Measured, in-situ REAR (i.e. in the child's ear) and (ii) estimated, coupler-derived REAR or Simulated-REAR (S-REAR) (BSA & BAA, 2007). S-REAR measurements are a method whereby measured or estimated RECDs can be used to evaluate a HAs real-ear aided gain and maximum output using HA text box measures, rather than undertaking these measurements with the HA on the child's ear (BSA & BAA, 2007). Both RECDs and REAR assist in accounting for the child's distinct ear acoustics during the HA fitting process (MCHAS, 2005). It has been

found that due to their smaller ear canals, RECD values in children are significantly different compared to adults (Bagatto, 2001).

The efficacy of a HA fitting is also determined by the validation thereof. This can be achieved by using outcome measures such as aided speech and soundfield testing; standardised questionnaires; behavioural observation; as well as evaluation of communication development (MCHAS, 2005). Although validation in the form of aided sound-field measurements can assist in evaluating the audibility of soft sounds, it should not be used to verify the electroacoustic characteristics of HAs (AAA, 2003). As both verification and validation of a HA fitting is important, clinicians should not rely on one measure in isolation.

The accuracy of HA fitting to South African children is questioned. A study examined the accuracy of HA fitting (N=31 ears) for 20 children, and found that only 50% had their HA fitting previously verified using REMs through real-ear insertion gain (REIG) (Strauss & van Dijk, 2008). The REIG method is, however, inappropriate for infants and young children, mainly as it does not account for the child's individual ear acoustics, and assumes average adult real-ear unaided gain (REUG) to generate targets for fitting (AAA, 2003). During the study, using simulated REMs and measured RECDs on the 31 ears, it was found that only 13% (n=4 ears) had four or more relative outputs within their acceptable tolerance range of -5 to +5dB (Strauss & van Dijk, 2008).

2.9 Calibration of ABR and ASSR

The accuracy of audiological assessment can be assured by appropriate equipment calibration (Wilber, 1994). This also applies to ABR and ASSR measures. Until recently, there were no internationally-agreed reference equivalent threshold (RET) values for calibration of click and TB stimuli for ABR. In 2007, the ISO 389-6 (2007) internationally-recommended guidelines were published. These guidelines should be used for calibration of ABR equipment, as it facilitates the comparison of results and standardisation across centres undertaking ABR testing. (Lightfoot, Sininger, Burkard & Lodwig, 2007).

There are currently no internationally agreed ASSR calibration data (G. Lightfoot, personal communication, March 22, 2010 & January 15, 2012). ASSR stimuli have often been calibrated in dBHL using (ANSI, 1996) standards, as the stimuli are continuous and similar to long duration pure tone stimuli used for behavioural audiometry (Stapells et al., 2005).

2.10 Summary

South Africa is a diverse country with various challenges in the health care system. It is estimated that 6357 children are born with, or acquire a permanent HL in the first weeks of life. Unfortunately, South African children with a HL are late-identified compared to recommended guidelines (Strauss, 2006; Theunissen & Swanepoel, 2008). This is possibly due to newborn hearing screening in South Africa not yet being universal.

In South Africa there are currently no nationally agreed protocols or standards for paediatric HA fitting, ABR and ASSR assessment. The use of age-appropriate and evidence-based measures should be encouraged during paediatric audiological assessment and HA fitting. Correction values should be applied to ABR and ASSR measures to estimate behavioural thresholds prior to HA fitting (Bagatto, 2008; Rance et al., 1995).

The current study was developed considering various aspects of the paediatric HA fitting process. There is limited national information regarding how clinicians utilise ABR and ASSR measures for paediatric HA fitting and how clinical practice varies compared to recommended guidelines. It is important to compare and critically evaluate current South African clinical practice in these areas in order to recommend guidelines, as evidence-based practice assists in improving efficient and high quality care (Moodie et al., 2011). Non-optimal HA fitting as part of EHDI may result in delayed speech and language development, as EHDI results in improved language ability development for children with HL (Yoshinago-Itano, et al., 1998). Due to limited information being available, this study questioned: "What is the clinical practice of South African audiologists for fitting HAs to paediatric clients, with specific reference to the utilisation of ABR and/or ASSR measures"?

Chapter 3: Methodology

3.1 Introduction

This chapter describes the research aims, design and phases. Participant selection and description will be presented, as well as the research measure utilised. Ethical considerations and aspects of reliability, validity and data analysis are explained.

3.2 Research aims

3.2.1 Main Aim

To describe the current South African audiological clinical practice for paediatric HA fitting, with specific reference to ABR and ASSR measures.

3.2.2 Sub-aims

The main aim was achieved by the following sub-aims:

a. To determine the presence of paediatric HA fitting protocols utilised by audiologists.
b. To determine the presence of ABR and/or ASSR assessment protocols utilised by audiologists.
c. To determine the availability of clinical audiological equipment used by audiologists for paediatric assessment and HA fitting.
d. To describe the audiological measures utilised for paediatric HA fitting to South African children.

e. To describe how audiologists utilise ABR and ASSR measures for paediatric HA fitting, by identifying the correction values applied to results to derive estimated behavioural thresholds.

3.3 Research Design

The research employed a quantitative, non-experimental, descriptive, cross-sectional survey research design to achieve the aims of the study.

Quantitative research involves using a measure to specify, observe and measure data numerically (Maxwell & Satake, 2006; Cresswell, 2003). The use of a structured quantitative research design using predominantly closed-set response options assisted in reducing researcher bias, which occurs when the outcomes of a study are influenced by the researcher's expectations and beliefs (Gravetter & Forzano, 2003). This study involved gathering data using structured face-to-face interviews.

Descriptive research, a non-experimental approach to research, is useful in describing single variables, or in the case of the current study, various variables (Gravetter & Forzano, 2003). It is further useful in looking at relationships and patterns in data (Rudestam & Newton, 2001). As there was no manipulation of variables, the current study can be described as non-experimental (Salkind, 2009). The descriptive research design utilised in the study was a survey research design, utilising a self-developed questionnaire administered through face-to-face interviews, which assisted with ensuring high response rates (Gravetter & Forzano, 2003).

Cross-sectional research involves examining various groups of people at one point in time (Salkind, 2009). A cross-sectional approach assisted in achieving the aim of the study to describe the current clinical practice of audiologists. One of the disadvantages of a cross-sectional approach is that it does not allow the researcher to describe changes in clinical practice over time (Gravetter & Forzano, 2003).

The research design served the purpose of the study, which was to describe the current South African audiological clinical practice for paediatric HA fitting, with specific reference to ABR and ASSR measures.

3.4 Research Phases

The research process involved three phases, as shown in figure 3.1. The first phase, the development phase, was used to develop the research tool, identify potential participants for inclusion in the main study and obtain permission from the Gauteng Department of Health to conduct the study. The second phase, the pilot study, was essential in refining the research tool and data collection procedures. The final phase was the main study.

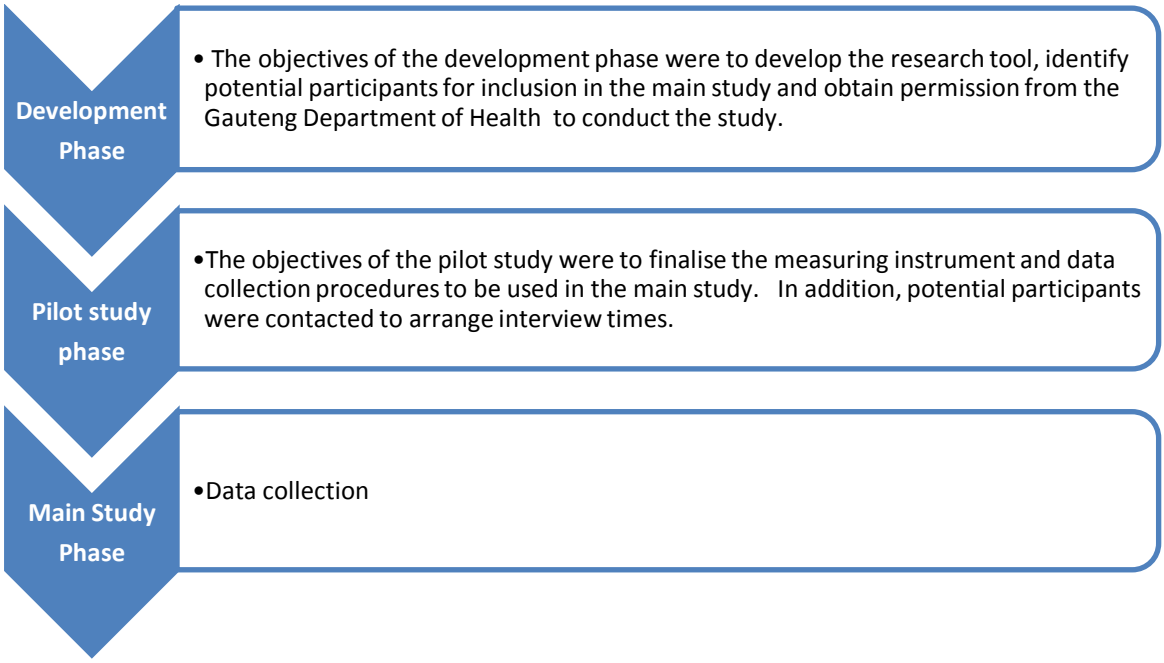


Figure 3.1

Research Phases for the Study

3.4.1 Pilot study

Field-testing an interview (questionnaire) is one of the most useful ways in assessing its suitability (Salkind, 2009). A pilot study was therefore conducted prior to the main study. The pilot study assisted in restructuring the survey format and questions, as recommended by the clinicians (Cresswell, 2003), as well as refining interview methodology.

3.4.1.1 Objectives

The objectives of the pilot study were to:

- Finalise the measuring tool and evaluate its feasibility.
- Estimate the time taken to complete the questionnaire.

- Refine research methodology and determine whether the research tool was able to acquire the information required for the study, in order to ensure validity of the study.
- Evaluate familiarity with, and understanding of, the vocabulary used in the questionnaire (Clark-Carter, 2010).

3.4.1.2 Participants

The pilot study of the structured interview was completed in two separate interviews with two clinicians, trained as audiologists and/or speech-language Pathologists. The two participants met the same selection criteria as for the main study. Both clinicians had clinical experience within the area of paediatric audiology, ABR and ASSR. One participant had less than four years clinical experience post-qualification, while the other participant had 10-15 years clinical experience. Their responses were not included in the final research analysis.

3.4.1.3 Procedures

Both clinicians were interviewed at a time convenient for them and provided verbal informed consent. The administration of the questionnaire was timed. Timing was ceased when the participants discussed possible changes and recommendations to the research tool with the researcher. The same steps as outlined in the main study were followed and the measuring instrument completed with each participant.

3.4.1.4 Results and Recommendations

The pilot study assisted with refining the research measurement instrument. Overall, the questionnaire was found to be a valid research tool. After completion,

modifications to the research instrument and administration methodology were made. The questionnaire was modified with regards to:

- *Additional questions:* Both pilot participants recommended additional questions to further probe certain areas. After considering the research aims and the questions recommended, some additional questions were added to the measurement instrument.

- *Time estimation:* After the pilot study was completed, the estimated time for completion of each interview was increased from the original estimate of a maximum of 30 minutes, to a new time estimate of a maximum of 40-45 minutes. For the main study, the maximum time required varied, depending on which questions were applicable to each participant. The time commitment was amended on the consent form before undertaking the study and participants were informed of the time commitment when confirming an interview date telephonically.

- *Structure of the questionnaire:* Certain questions were modified, as well as the sequence of questions adjusted, to create a better structure to the measurement instrument. In addition, it was suggested that cue cards should be utilised for questions with longer closed-response options to assist interviewees with their response. Overall, the vocabulary used in the questionnaire appeared to be well understood by participants in the pilot study.

3.4.1.5 Summary

A pilot study of the measurement instrument was completed with two clinicians before the research was undertaken. The pilot study was completed to evaluate the estimated time for completion, methodology, validity and required restructuring of the measurement instrument. Modifications to the questionnaire were made as suggested and required, in order to meet research aims.

3.5 Participant selection

3.5.1 Sampling strategy

A non-probability, purposive sampling strategy was utilised for this study. With non-probability sampling, the probability of selecting a participant from a population is unknown (Salkind, 2009). Participants were purposively-selected to recruit as many participants meeting the participant criteria as possible (Cresswell, 2003). For this study, this sampling method had the benefit of convenience, but generalisability of results may suffer due to the researcher only investigating the current clinical practice of clinicians within the Gauteng Province (Salkind, 2009). The sampling method used was appropriate for this study, as due to the potentially small sample size, this sampling method allowed the researcher to recruit as many participants who met participant criteria as possible.

3.5.2 Criteria for Participant Selection

Participants were required to fulfil the following requirements:

a. Audiologist or dual-qualified speech-language therapist and audiologist working in the field of paediatric audiology.

As the research explored the current audiological clinical practice of audiologists with regards to paediatric HA fitting, participants were required to currently be working as a paediatric audiologist in order to describe their current clinical practice.

b. Employed within the private or public health sector in the Gauteng Province. Due to logistical constraints, the study was contained to the Gauteng Province as data was collected via face-to-face interviews. .

The largest proportion (22.4%) of the South African population lives in the Gauteng Province (SSA, 2011). Gauteng also had the largest number of speech therapists and audiologists employed in the public health sector in 2010. During 2010, of the total 396 speech therapists and audiologists working in the public health sector nationally, 28% (*n*=112) were employed in this province (See Figure 3.2) (HRH, 2011). No information was available on employment within the private health sector.

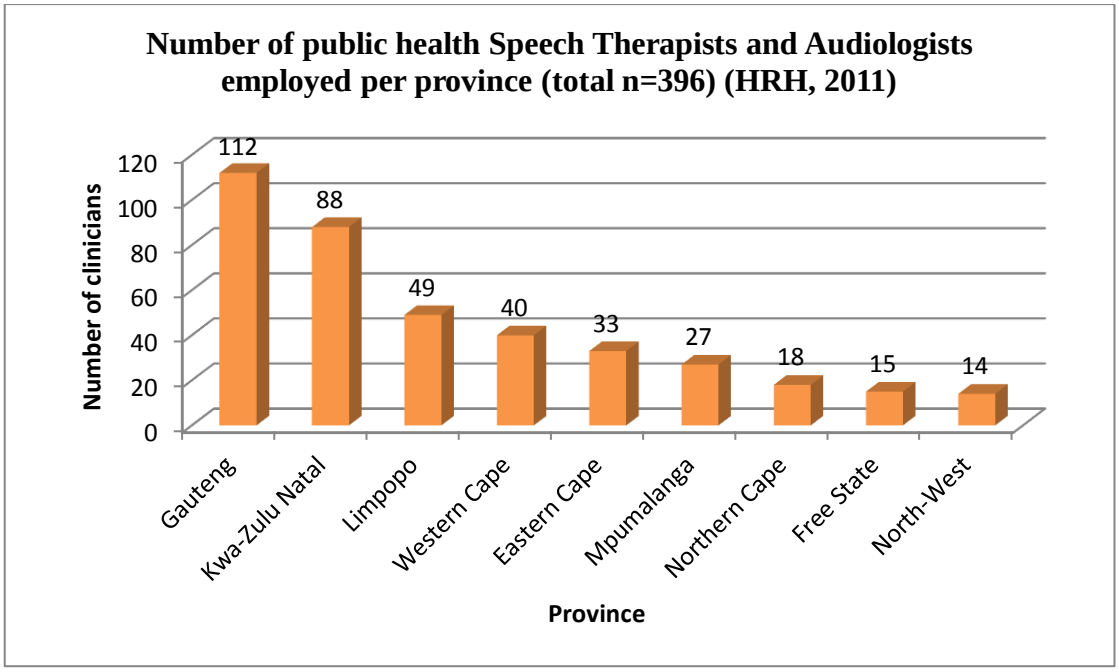


Figure 3.2

Number of Public Speech-Language Therapists and Audiologists per Province-2010 (HRH, 2011)

The inclusion of participants from both the private and public health sector allowed the researcher to determine potential differences in clinical practice between private and public departments.

c. Competent in English.

   As the questionnaire was developed in English, participants were required to be competent in English to ensure that interview questions were fully understood.

d. Working in an audiology department that:

   - performs ABR and/or ASSR testing; and/or

   - uses ABR and/or ASSR results to complete paediatric HA fitting.

This allowed the researcher to explore the aims of the study as it relates to the use of ABR/ASSR for audiological assessment of children, as well as the application of correction values to ABR/ASSR results, in order to estimate behavioural thresholds for paediatric HA fitting.

3.5.3 Participant description

The study included a total of 34 participants who were recruited from 18 audiology departments. It was important to recruit as many participants as possible in order to extract meaningful conclusions from research (Rudestam & Newton, 2001). A survey prior to the study, found a potential of 23 audiology departments, comprising ten practices within the private sector (SAAA members booklet, 2009-2010) and 13 departments within the public sector, in Gauteng. The sample utilised for the final study therefore appears to be representative of audiology departments in the Gauteng Province, when comparing the final sample size to the survey of potential participants.

Seventy-nine percent (*n*=27) of participants were employed within the public health sector and 21% (*n*=7) within the private health sector. When considering that the private health care system covers medical care for only 16% of the South African population through medical aid schemes (Lloyd et al., 2010), one may consider the break-down of participants in the public versus public health care systems as representative of the population receiving private versus public health care.

A total of 34 interviews were conducted: 27 within the public health sector and seven within the private health sector. It was acceptable for more than one

participant per department to participate in the study. Interviewing more than one clinician at each department, allowed the researcher to explore the feasibility of, and adherence to departmental protocols and guidelines. Only one participant per private department was interviewed, as in most cases, private audiology departments in Gauteng are smaller, with fewer clinicians (often only one) working in each department.

The majority of participants 82% (*n*=28) included in the study were dual qualified as both speech-language pathologists and audiologists, while 18% (*n*=6) of participants were qualified as audiologists only. While most were practising as both speech-language pathologists and audiologists (*n*=25; 74%), some dual-qualified therapists were practicing only as audiologists (*n*=9; 26%). Eighty-eight percent (*n*=30) of participants were working with children from birth to 18 years of age. Only 3% (*n*=1) of participants were not seeing infants aged from birth to six months of age, while 9% (*n*=3) participants were not seeing children of high school age.

The majority of the total number of participants, 68% (*n*=23) had four years or less experience, post-qualification. Fifty-seven percent (*n*=4) of the private practice participants had ten years or more experience, while only 7% (*n*=2) of the total public sector participants had ten or more years clinical experience (See Figure 3.3).

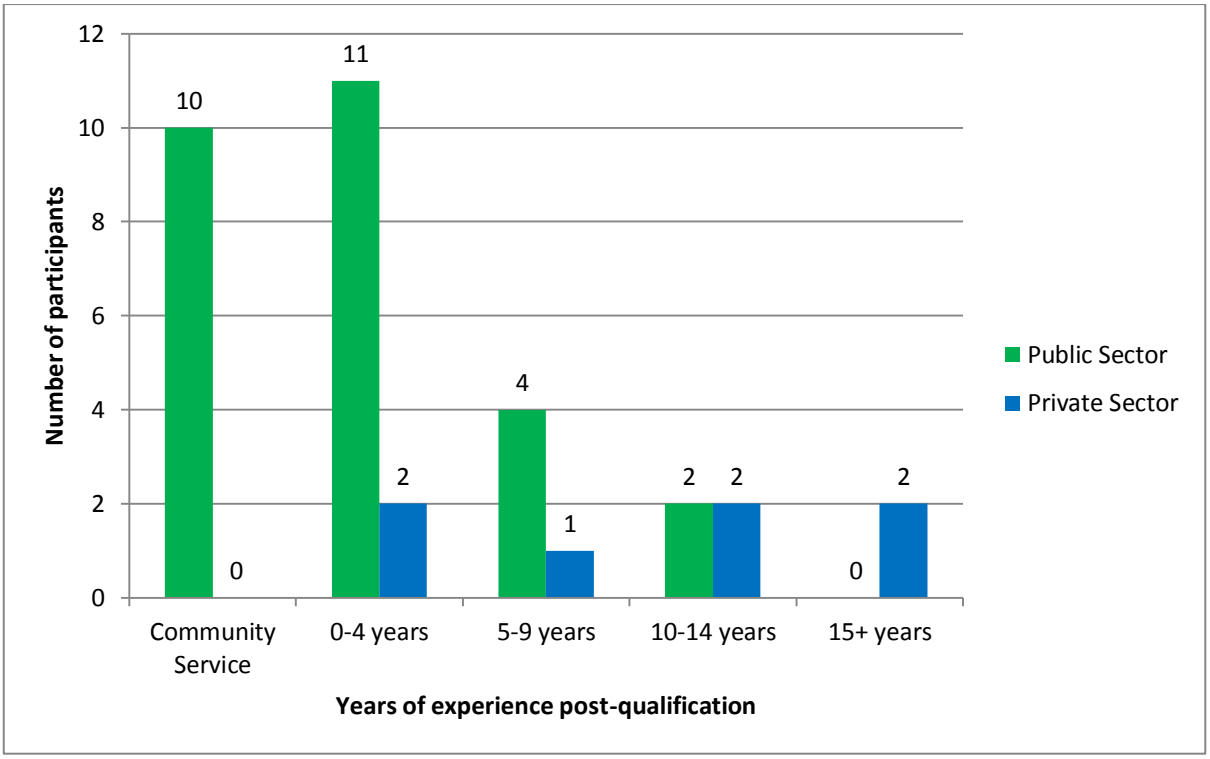


Figure 3.3

Participants Years of Work Experience Post-qualification (N=34)

Community service is a compulsory year of service in the public health care system which newly trained clinicians have to complete before being able to practice independently in South Africa. No community service clinicians were therefore interviewed from private sector departments. Challenges to audiology services in South Africa include that professionals are unequally distributed between the public and private sectors due to international and national lucrative positions and opportunities (Swanepoel, 2006). The limited number of professionals with more than four years of post-qualification experience, may be due to professionals emigrating to other countries, leaving the profession altogether, and/or many professionals working within other private practice areas potentially yielding a higher income e.g. adult HA fitting.

Table 3.18 summarises details of where the interviews were conducted. Data includes: public versus private participants and departments; initial HA fittings completed per month and ASSR/ABR assessments completed per month.

Table 3.18

Participant Demographic Summary

	Private	*Public*	*Private*	*Public*	*Private*	*Public*	*Private*	*Public*	*Private*	*Public*
	n		*Mean*		*median*		*range*		*SD*	
Participants interviewed (*N*=34)	7	27	--	--	--	--	--	--	--	--
Departments visited (*N*=18)	7	11	--	--	--	--	--	--	--	--
Initial HA fittings/month	7	23	1.41	1.61	1	1	0.33 to 2.5	0.167 to 4.5	0.92	1.31
ABR/ASSR assessments/month	7	10	2.43	5.15	2.5	4.5	1 to 4	2 to 12	1.24	2.93

With regard to initial HA fittings per month, 88% (*n*=30) of participants were completing paediatric HA fittings. The remainder of the participants, 12% (*n*=4) were not currently completing paediatric HA fitting currently, but were completing ABR/ASSR testing and referring to another staff member at same department for HA fitting. The 30 participants completing paediatric HA fitting were found to undertake an average of 1.57 initial paediatric HA fittings per month (median = 1; *SD* = 1.22) (seen in subsequent table 4.23).

Seventeen participants from 11 departments reported completing ABR/ASSR testing, 59% (*n*=10) public sector participants, and 41% (*n*=7) private sector participants. The average for the number of children seen per month was 4.03 (range = 4 to12; Median = 4; *SD* = 2.7) (seen in subsequent table 4.23). More ABR/ASSR assessments were being completed in the public sector compared to the private sector.

3.6 Measures

A structured interview with predominantly close-ended questions was employed to achieve the aims of the study (see appendix E). "Structured or closed-ended questions have a clear and apparent focus and call for an explicit answer" (Salkind, 2009, p. 195). Although conducting face-to-face interviews may introduce bias due to the researcher being present (Cresswell, 2003), the structured questionnaire was developed to assist in reducing bias. A structured questionnaire also has the benefit of a standard format, assisting with uniformity in the way

questions are asked, reducing the effect on participant responses, due to the standardised way in which a question is asked (Clark-Carter, 2010)

There are various advantages to administrating a questionnaire via interview as discussed by Maxwell & Satake (2006). One of the advantages is that face-to-face interviews allow for greater control regarding when questionnaires are completed. It further appears less inconvenient to complete. Although completing face-to-face interviews may be more time-consuming, costly and able to reach fewer numbers of participants, it is beneficial that participants are required to answer the question as it is asked and are not able to consult colleagues prior to answering the question. This improves the reliability of responses. Participants are also able to discuss and elaborate their response if required.

A structured interview with a survey research tool was utilised in preference to a postal or online questionnaire, to facilitate the inclusion of as many participants as possible meeting participant criteria. The potential sample size was already small, and a self-administered questionnaire may have resulted in fewer participants, due to the potential perceived inconvenience in completing and returning a self-administered questionnaire (Maxwell & Satake, 2006). It was important to utilise a research methodology able to recruit as many participants as possible, so that meaningful conclusions could be drawn from the research (Rudestam & Newton, 2001).

The measure was self-developed by examining current evidence-based practice and research. Questions were designed to probe the main aim and sub-aims of the study. Details regarding the questionnaire content are described in table 3.19.

Table 3.19

Description of Self-constructed Questionnaire

Section	***No. of questions***	***Type of questions***	***Information obtained***	***Rationale***
Identifying information	3	Open & closed ended	Participant workplace, date and public vs. private department.	Obtain identifying information regarding participant workplace in accordance with the research aims.
Qualification, current role and work experience	3	Closed ended	Qualification, current role and clinical experience.	Clinical practice, training and work experience may affect a participant's confidence in paediatric HA fitting and audiological assessment. ABR has the capability of providing fairly accurate threshold estimation, but the challenge lies with the audiologist's completion and interpretation of ABR measures (Stapells, 2000b).
Current Clinical Practice	17	Open and closed ended	Current clinical practice, departmental equipment and protocols, and paediatric client demographics.	Age of paediatric clients, equipment available and departmental protocols may affect clinical practice. Strauss' (2006) survey of EHDI services, provided by South African clinicians, found only 35% of respondents had a set protocol for EHDI for infants and children. A comprehensive test battery should be used in audiometric assessment of infants (Gravel, 2000) and children.
Those completing ABR and/or ASSR	10	Open and closed ended	Clinical pathway, clinical practice, departmental protocols and training.	Departmental protocol, clinical pathways and training may affect clinical practice. Appropriate training and experience with all aspects of paediatric audiology is vital, including tone-evoked ABR (Stapells, 2000b).
Calibration	1	Open, with short answers.	Manufacturer calibration standards used and equipment used by participants.	Calibration standards used will affect audiological results and practice. Calibration is important to ensure that audiological results are accurate and regulations met. It is also vital that current relevant calibration standards are used for all equipment (Wilber & Burkard, 2009).
ABR-clinical practice	9	Open and closed ended	Current ABR clinical practice.	Current clinical practice may affect how HAs are fitted based on ABR results. In order to obtain frequency-specific threshold estimates for accurate HA fitting, clinicians should be using TB ABR (Stapells, 2000b).
HA fitting based on ABR/ASSR results	15	Open and closed ended	Current clinical practice of HA fitting based on ABR/ASSR results, including whether correction values are applied to estimate behavioural thresholds for HA fitting and what these are.	Appropriate correction factors should be applied to ABR (Bagatto, 2008) and ASSR (Stevens et al., 2007) results to estimate behavioural thresholds for HA fitting. The correction values used may affect the effectiveness and safety of paediatric HA fitting. HA fitting should provide maximum audibility without any discomfort (Boothroyd, 2000).
Audiologists undertaking HA fitting but not completing ABR/ASSR testing themselves	3	Closed ended	Whether adequate information regarding ABR and ASSR results is received for HA fitting.	Guide recommendations regarding what additional information may be assist audiologists with HA fitting. The goal of a comprehensive audiological evaluation is to determine the type, degree of shape of a HL (Gravel, 2000). It is essential that the audiologist undertaking the HA fitting has complete details of this evaluation to ensure the effectiveness of the fitting.

3.7 Reliability and Validity

3.7.1 Validity

"Validity indicates that a measure in fact measures what it purports to measure." (Rudestam & Newton, 2001, p. 82). Both internal and external validity were considered.

3.7.1.1 External validity

External validity, which is the generalisability of findings (Clark-Carter, 2010) was considered by the researcher. Generalisation and inferences about clinical practice within the whole of South Africa cannot be assumed (Cresswell, 2003), as only clinicians working within the Gauteng Province were included in the study.

3.7.1.2 Internal Validity

a. Face validity

Face validity is the subjective perception by participants of the researcher or the measure (Clark-Carter, 2010). Clark-Carter (2010) discusses face validity and how a participant's view of the measure may affect their responses. He therefore emphasises the importance of finding a balance between providing an adequate amount of information regarding the study to participants, and ensuring that not too much information is provided, as too little or too much information may affect their responses. The researcher therefore provided the participants with the information as outlined in the consent form (appendix A), but instead of stating one of the aims as being 'To determine what correction values clinicians are applying to ABR and/or ASSR results', the researcher kept the description general in terms of the aim involving examining how clinicians are utilising ABR and ASSR

results for HA fitting to children. If the researcher ensured face validity to the extent of directly asking 'I want to know what correction values you are providing', it may have had a significant influence on participants' responses, as they would understand that correction values should be provided, and therefore would answer in a manner which may not accurately reflect how they were utilising ABR and/or ASSR results for HA fitting. The researcher also explained, before the study, that there were no correct or incorrect responses and that responses were participant-specific and based on their views, training and clinical practice.

b. Content validity

Content validity is the ability of the research tool to explore the whole range of areas necessary to research the area chosen, and one can assist in ensuring content validity by consulting experts in the field (Clark-Carter, 2010). In order to assist with content validity, the researcher consulted current literature and experienced professionals in the field while developing the research tool, as well as conducting a pilot study prior to the main study. The pilot study assisted in finalising the content of the research tool.

3.7.2 Reliability

Reliability involves addressing the consistency of measures (Holt & Walker, 2009; Rudestam & Newton, 2001). In an attempt to minimise the Hawthorne effect, the researcher made it clear to participants that there were no correct or incorrect answers to the questions (Maxwell & Satake, 2006). Conducting an interview questionnaire assists with response reliability, as participants are required to provide responses during the interview rather than consult another source before responding, which may occur with self-administered

questionnaires (Maxwell & Satake, 2006). Interviews were not recorded, but participants were provided opportunity to discuss or elaborate their responses to questions.

3.8 Ethical Considerations

Ethics involves upholding the concepts of acceptable behaviour (Holt & Walker, 2009). The World Medical Association (WMA) (2008) declaration of Helsinki ethical principles were upheld during the development and execution of this study.

Specific ethical considerations relating to this study considered the following:

- Ethical Committee permission:

  The researcher obtained ethical clearance from the University of the Witwatersrand's Research Ethics Committee prior to the research study (Protocol number: *M10647*). (Appendix B).

- Gauteng Health Department Permission:

  Written permission was granted by the Gauteng Department of Health prior to commencing the study (Appendix C).

- Informed consent:

  "Informed consent is fundamentally tied to the idea that respect for autonomy requires that people must have the information necessary to make reasonable choices. To deny people adequate information is to deny their rights as autonomous agents and to the respect that is due to them as people" (Strohm Kitchener, 2000, p. 56). Informed consent helps to uphold the principles of beneficence, non-maleficence, and fidelity

(Strohm Kitchener, 2000). All participants in the study were informed of the nature of the study and their right to withdraw from the study at any time, without negative consequences. They were further assured of confidentiality. Each participant signed an informed consent form, providing proof of his/her willingness to participate in the study. Only those that met the inclusion criteria and signed the informed consent form were included in the study. The informed consent form utilised can be found in Appendix A.

- Confidentiality:

  Participants were assured of confidentiality. Confidentiality was maintained by the use of participant numbers on questionnaires rather than names (Appendix E).

- Non-maleficence:

  Although no direct harm came to participants during the study, the researcher considered the time involved for each participant to participate in the study. After the pilot study, it was estimated that the maximum time for completion of each interview would be 40-45 minutes. This varied, depending on which questions were applicable to each participant. Certain questionnaire items were not relevant for every participant (See Appendix E). Before arranging interview dates, departments were informed of the potential maximum time commitment.

- Amendment to study title and aims:

  After data had been collected and analysed, it became evident that the study's title and aims needed to be amended to better reflect the data obtained from this study. As per the WMA Helsinki ethical principles (2008), information regarding these changes was sent to the University of the Witwatersrand's Research Ethics Committee for

approval. Approval for these changes, by the ethics committee can be seen in appendix D.

3.9 Data collection

Data was collected over a two-week period, utilising the self-developed questionnaire administered via individual personal interviews. The researcher undertook the administration of each interview in the same manner. Although more than one clinician was interviewed at some departments, the researcher asked each interviewee all the survey questions, as applicable. Cue cards were utilised for questions with longer closed response options, to assist the interviewee with their response. These cue cards were enlarged, exact copies of certain questions from the questionnaire (Appendix E) for easier reading. Questions were clarified by the interviewer, if required, before participants answered questions.

3.10 Data analysis

Data was documented on the measuring instrument. A pre-designed column marked "For official use only" was placed on the right-hand side of all measurement instruments for encoding the raw data. Encoding was completed by the researcher according to data definitions. All data was computerised for statistical analysis with Windows Excel and SigmaXL 6.11 software packages. Results were analysed utilising a variety of statistical procedures, as listed in table 3.20 and displayed in tables and figures in the results section of this report.

Table 3.20

Statistical Analysis Completed

Statistical procedures	***Rationale & application to the study***
Descriptive statistics • Measures of central tendency e.g. median and average • Measures of variability e.g. range and standard deviation (*SD)*	This type of data was useful for initial analysis of results (Salkind, 2009; Holt & Walker, 2009). Descriptive analysis allowed the researcher to look at frequency patterns (Rudestam & Newton, 2001) and assisted in organising and summarising information (Gravetter & Forzano, 2003).
Descriptive Statistics • Correlation: Pearson correlation co-efficient values	Correlation data analysis allows the description of the degree of relationship between two variables (Gravetter & Forzano, 2003), for example: experience level and correction values for ABR/ASSR results utilised.
Hypothesis Statistics • Test of mean differences: One-sample *t*-test	Hypothesis testing allowed the researcher to determine whether there was a statistically significant difference between participant clinical practice and recommended guidelines (Gravetter & Forzano, 2003), e.g. comparing participants' ABR/ASSR correction values to recommended guidelines.

3.11 Summary

This chapter described the methodology of the research. It included the aim of the research, description of the research design and phases. A description of the pilot study that indicated problem areas and recommendations followed. The main study was discussed with respect to participant selection criteria and description, as well as the measuring instrument. Finally, data collection, reliability, validity, ethical considerations and data analysis were discussed.

Chapter 4: Results and Discussion

4.1 Introduction

The main aim of the study was to describe the current South African audiological clinical practice for paediatric HA fitting, with specific reference to ABR and ASSR measures. The results obtained during the study will be presented and discussed in this chapter, in relation to the sub-aims of the study, namely: the presence of paediatric HA fitting and ABR/ASSR assessment protocols; availability of clinical audiological equipment; audiological measures utilised for paediatric HA fitting to South African children; as well as examining how audiologists utilise ABR and ASSR measures for paediatric HA fitting, by identifying the correction values applied to results to derive estimated behavioural thresholds.

4.2 Protocols

This section focuses on the first two sub-aims, namely the presence or absence of paediatric HA fitting and ABR/ASSR assessment protocols. Protocols based on evidence-based practice assist in achieving care for patients with proven quality and effectiveness (Moodie et al., 2011) as well as assisting with continuity of care with staff turn-over.

Table 4.21 depicts participants' responses regarding the presence of ABR/ASSR and/or HA fitting protocols at their department.

Table 4.21

Presence of ABR/ASSR and HA Fitting Protocols

	% (n)			
	Per Participant		*Per department*	
Protocol	*HA fitting (N=34)*	*ABR/ASSR (N=17)*	*HA fitting (N=18)*	*ABR/ASSR (N=11)*
Yes	44 (15)	47 (8)	28 (5)	27 (3)
No	47 (16)	53 (9)	50 (9)	64 (7)
Unsure	9 (3)	--	--	--
Varied Response	--	--	22 (4)	9 (1)

Of the 34 participants in this study, only 44% (*n*=15) reported having a paediatric HA fitting protocol. It was of concern that 9% (*n*=3) of participants were unsure whether their department had a HA fitting protocol or not. Although 44% of the participants reported having a paediatric HA fitting protocol, when comparing the response to this question across participants at the same department, not all responded with the same answer. Seven public sector departments had more than one participant. Participants at 43% (*n*=3) of the seven public sector departments replied with the same response, i.e. as to whether the department had a paediatric HA fitting protocol, whereas 57% (*n*=4) responded with different responses to this question.

Seventeen participants from 11 departments reported completing ABR/ASSR testing. Only 47% (*n*=8) of these participants reported having an ABR/ASSR assessment protocol. When examining responses per department, 64% (*n*=7) of departments reported *not* having a protocol. Only 27% (*n*=3) of departments reported having a protocol: one private and two public sector departments. At one department (9%), (public sector), responses regarding the presence of a protocol varied.

Private sector departments only had one or two clinicians completing ABR and/or ASSR testing at the department and so participants commented that they did not find it necessary to have a protocol, as both clinicians knew what was expected of one another during assessment.

Participants were asked for copies of their ABR/ASSR assessment protocol, if available. Of those obtained, main details appeared to be procedural with limited direct reference to current evidence-based practice, or comprehensive reference lists.

The lack of use of protocols by departments is concerning, as it makes meeting the needs of patients and families, development of services, consistent clinical practice, as well as adherance to current evidence-based practice challenging. The approach to paediatric HA fitting should be different from adult HA fitting due to various factors, including smaller ear canals and different listening needs. As an infant's ear canal is smaller, higher SPLs will be produced in the ear canal, compared to an adult (BCEP, 2008; Moodie & Moodie, 2004). The listening needs of a child also differ to those of an adult. For children, the goal of amplification is to promote oral speech and language development. However, for adults an acquired HL is post-lingual and language, cognitive and world knowledge can be utilised to facilitate understanding of acoustic information (Stelmachowicz & Hoover, 2009). For equivalent speech recognition ability, young children require greater SPLs compared to adults (Stelmachowicz, Hoover, Lewis, Kortekaas & Pittman, 2000).

Participants' varied responses regarding the presence of protocols within the same department shows uncertainty regarding resources available, as well as the potentially limited use of and adherance to by all staff members to such protocols. There is a shortage of human

resources in the public health sector in compared to the private health sector in South Africa (Padarath et al., 2003). Consistent staffing and continuity of care may be affected by the high staff turn-over in the public sector, partially due to community service clinician turn-over each year. Limited human resources results in reduced capacity for audiological screening and evaluation (Theunissen & Swanepoel, 2008) and may also influence clinicians changing jobs or roles due to challenging work conditions. The lack of staff and high staff turn-over within the public health care sector makes awareness of, and adherance to protocols, more challenging.

Protocols within all areas of paediatric audiology should be utilised, including ABR and ASSR assessment, as well as HA fitting. Regardless of whether these protocols are combined or separate, it is vital to ensure that protocols are as focused as possible, and encompass all relevant areas to ensure clinical practice is evidence-based. An evidence-based approach assists in putting research into clinical practice, improves patient care and promotes standardisation of care (Moodie et al., 2011).

4.3 Equipment

This section focuses on the third sub-aim, namely the availability of clinical audiological equipment to clinicians for assessing and managing children with hearing difficulties.

Participants were asked what audiological equipment their department had available. To assist with answering this question, a list of common equipment was presented, as well as allowing participants to comment on other equipment not listed. Results were analysed in

terms of equipment available per department. Table 4.22 displays the responses to this question, represented as percentage and number of departments with equipment available.

Table 4.22

Equipment Available at Private and Public Sector Audiology Departments (N=18)

	% (n) of Departments											
	Available			*Not available*			*Unsure*			*Varied responses*		
Equipment	*Private*	*Public*	*Total*	*Private*	*Public*	*Total*	*Private*	*Public*	*Total*	*Private*	*Public*	*Total*
ASSR	57 (4)	36 (4)	44 (8)	43 (3)	64 (7)	56 (10)	--	--	--	--	--	--
Diagnostic ABR	100 (7)	36 (4)	61 (11)	--	64 (7)	39 (7)	--	--	--	--	--	--
Diagnostic Audiometer	100 (7)	100 (11)	100 (18)	--	--	--	--	--	--	--	--	--
Diagnostic OAE's	100 (7)	18 (2)	50 (9)	--	55 (6)	33 (6)	--	--	--	--	27 (3)	17 (3)
ECochG (1specified)	14 (1)	--	6 (1)	--	--	--	--	--	--	--	--	--
Noisemakers	57 (4)	82 (9)	72 (13)	43 (3)	9 (1)	22 (4)	--	--	--	--	9 (1)	6 (1)
Otoscope	100 (7)	100 (11)	100 (18)	--	--	--	--	--	--	--	--	--
Screening ABR	43 (3)	55 (6)	50 (9)	57 (4)	36 (4)	44 (8)	--	--	--	--	9 (1)	6 (1)
Screening Audiometer	57 (4)	45.5 (5)	50 (9)	43 (3)	36.5 (4)	39 (7)	--	--	--	--	18 (2)	11 (2)
Screening OAE	100 (7)	100 (11)	100 (18)	--	--	--	--	--	--	--	--	--
Sound-Treated Booth	100 (7)	100 (11)	100 (18)	--	--	--	--	--	--	--	--	--
Sound Level Meter	29 (2)	--	11 (2)	71 (5)	82 (9)	78 (14)	--	--	--	--	18 (2)	11 (2)
HF & LF Tympanometry	57 (4)	36.5 (4)	44 (8)	43 (3)	45.5 (5)	44 (8)	--	9 (1)	6 (1)	--	9 (1)	6 (1)
LF Tympanometry only	43 (3)	55 (6)	50 (9)	57 (4)	36 (4)	44 (8)	--	--	--	--	9 (1)	6 (1)
REMs	43 (3)	36 (4)	39 (7)	57 (4)	64 (7)	61 (11)	--	--	--	--	--	--
VRA	86 (6)	73 (8)	78 (14)	14 (1)	27 (3)	22 (4)	--	--	--	--	--	--
VNG (1 specified)	14 (1)	--	6 (1)	--	--	--	--	--	--	--	--	--

Notes: HF= High Frequency; LF= Low Frequency; VRA= Visual Reinforcement Audiometry; VNG=Videonystagmography
REMS= Real Ear Measures

As seen in table 4.22, for certain items of equipment, some public health sector participants, from the same department, gave varied responses regarding the availability of equipment in their department. Varied responses regarding the presence of equipment per public sector audiology department, were for diagnostic OAEs (27%, *n*=3); noisemakers (9%, *n*=1); screening ABR (9%, *n*=1); screening audiometers (18%, *n*=2); sound level meters (18%, *n*=2); as well as high and low frequency probe tone tympanometry (9%, *n*=1).

All departments (*N*=18) reported having access to sound-treated booths, diagnostic audiometers, screening OAEs and otoscopes. A large percentage, 78% (*n*=14) reported having access to VRA equipment. Only 44% (*n*=8) of departments had access to ASSR, whilst slightly more departments (61%, *n*=11), had access to diagnostic ABR equipment. All private sector departments (*n*=7), reported having access to diagnostic OAE equipment, while only 18% (*n*=2) of public sector departments reported having access to such equipment. Seventy-two percent (*n*=13) of departments had access to noisemakers, 82% (*n*=9) in public sector departments and 57% (*n*=4) in private sector departments. With regard to other screening equipment, 50% (*n*=9) of departments reported having access to both screening ABR and screening audiometers. Only two audiology departments (11%), which were within the private sector, reported having access to sound level meters. One private sector department specified having access to ECochG and VNG equipment.

There was limited availability of REM equipment for verification of HA fitting, as only 39%, (*n*=7) of departments reported having access to such equipment. This was for both

private and public audiology departments. Availability of REM equipment was similar for both private (43%, *n*=3) and public (36%, *n*=4) sector departments.

All departments (*N*=18) reported having access to some form of tympanometry. Fifty percent (*n*=9) of departments reported having access to low frequency tympanometry, while 44% (*n*=8) of departments reported having access to high frequency probe tone tympanometry. Participants at the remaining department (6%, *n*=1), in the public sector, provided varied responses as to whether their equipment had both high and low frequency probe tones available. Only 57% (*n*=4) of the seven private sector departments reported having high frequency tympanometry, but all reported seeing babies less than six months of age. All but one public sector department 91% (*n*=10), reported seeing infants from birth to six months of age. Despite this, of the 11 public sector departments interviewed, only 36.5% (*n*=4) reported having access to high frequency tympanometry. Participants at one public department had varied responses (9%), whilst one participant at another public sector department (9%) was unsure as to whether the immittance equipment had a high frequency probe tone facility. The public sector audiology department not seeing children from birth to six months of age did not have access to high frequency probe tone tympanometry.

Of particular concern in the current study, is the limited availability of high frequency probe tone tympanometry. It is important to use an appropriate immittance probe tone to accurately determine the middle ear status of a child and appropriate equipment is required for this (Baldwin et al. 2008). Recommended practice is the use of a 1000 Hz (high frequency) probe tone rather than 226Hz (low frequency) probe tone, for immittance assessment of infants less than six months corrected age (Baldwin et al., 2008). Appropriate evaluation of middle ear status is of particular importance in South Africa, where one of the

major health challenges prioritised in the public health care sector is HIV/Aids (Open Society Foundation of South Africa, 2007). Children with HIV/AIDS may have recurrent bacterial infections, neurologic disease or developmental problems (Muma, Lyons, Borucki & Pollard, 1997). Due to recurrent infections, these children may require more frequent monitoring of their middle ear status and hearing. It is therefore important to accurately undertake tympanometry measures utilising the appropriate probe tone. Public sector departments requiring such equipment should motivate for its supply and private sector departments should procure such equipment if seeing children less than six months of age, or refer elsewhere for such testing.

The varied responses given by some public sector participants regarding the availability of equipment suggests a lack of awareness of resources available. This may possibly be due to high staff turn-over and lack of carry-over, including information regarding availability of equipment. Certain public sector departments reported that equipment was not functioning and that their hospital employer had not provided funding for the timeous repair of equipment. The lack of functioning, well-maintained audiological equipment may affect a clinician's ability to undertake appropriate evidence-based audiological practices.

4.4 Audiological measures used for HA fitting

This section focuses on the fourth sub-aim, namely: audiological measures utilised for paediatric HA fitting to South African children. The various aspects examined include the number of electrophysiological assessments and HA fittings completed; minimum audiological information required for HA fitting; biological calibration of ABR and ASSR;

sequence of and type of TB ABR testing completed; acceptable levels suggesting normal hearing; as well as HA verification.

4.4.1 Number of electrophysiological assessments and HA fittings completed

The number of initial HA fittings and ABR/ASSR testing completed by participants, as well as HA waiting times, are shown in table 4.23.

Table 4.23

Number of HA Fittings and ABR/ASSR Assessments per Month per Participant, and HA Waiting Times

	Department	*n*	*Range*	*Mean*	*Median*	*SD*
No. of HAs fitted (per month)	Private	7	0.33 - 2.5	1.41	1	0.92
	Public	23	0.167 - 4.5	1.61	1	1.31
	Total (*N*)	30	0.167 - 4.5	1.57	1	1.22
No. of ABR/ASSR assessment (per month)	Private	7	1- 4	2.43	2.5	1.24
	Public	10	2 – 12	5.15	4.5	2.93
	Total (*N*)	17	4 – 12	4.03	4	2.70
HA waiting time (in months)	Private	7	None- when available from the manufacturer.			
	Public	27	0.5 – 12	3.46	2.5	3.22

Eighty-eight percent (*n*=30) of participants reported currently conducting HA fittings. On average, 1.57 (*SD* = 1.22) initial paediatric HA fittings were conducted per month. When comparing the private and public sector, the number of initial HA fittings completed per month, were similar.

HAs were reportedly fitted as soon as possible for children seen in private practice. The only factors reported as causing delays were waiting for medical aid clearance, ear moulds and HA deliveries. In the public sector, the waiting time for initial HA fitting was much longer (Mean= 3.46 months; *SD* = 3.22 months). Only 22% (*n*=6) of the public sector participants (*N*=27) indicated that they had a waiting time for fitting of one month or less. One public health sector participant (3.7 %) stated that they currently had a stock of HAs available and so could fit them as soon as possible. This participant's response was included in the analysis of average waiting times for HAs as zero months. The reasons offered for the long waiting time included lack of available budget, as well as the varied availability of donated HAs. Many of the participants stated that priority was given to children for allocation of HAs. The goal of EHDI is to identify a paediatric HL as soon as possible and provide appropriate intervention for this, as children identified early (less than six months of age) have improved language ability compared to later-identified children (Yoshinago-Itano et al., 1998). To this end, it is recommended that HAs are fitted within one month of confirming a paediatric HL (JCIH, 2007). The waiting times found in this study, for paediatric HA fitting in the public health sector, are therefore far longer than recommended.

Seventeen participants from 11 departments reported completing ABR/ASSR testing, 59% (*n*=10) were public sector participants and 41% (*n*=7) private sector participants. The average number of children seen for ABR and /or ASSR testing was 4.03 per month (range = 4 – 12; *SD* = 2.70). More ABR/ASSR assessments were being completed in the public sector per month (Mean = 5.15; *SD* = 2.93) when compared to the private sector (Mean = 2.43; *SD* = 1.24).

4.4.2 Minimum audiological information required for HA fitting

A battery of audiological tests should be utilised when assessing a child's hearing in order to initiate appropriate audiological management (Gravel, 2000). Cross-checking between audiological measures, in order to confirm results, is of vital importance as "No one test or tester is infallible and mistakes made with children can have devastating implications" (Jerger & Hayes, 2006, p. 80). Participants were therefore asked what they required as the minimum amount of audiological information prior to HA fitting for children from birth to six years of age. The question was divided into three age groups; birth to six/seven months of age, six to 36 months of age, and 36 months to six years of age (See Appendix E). The results for each of these age groups is presented and discussed.

4.4.2.1 Birth to six/seven months

Table 4.24 displays participants' responses as to what they required as the minimum audiological information prior to HA fitting for infants from birth to six/seven months of age. Two participants did not answer this question as they were not fitting HAs to children within this age group. The responses of 32 participants will be reported (private sector: $n = 7$; public sector: $n = 25$).

Table 4.24

Minimal Audiological Information Required Before HA Fitting for Infants birth to 6/7 Months of Age - % (n)

		% (n)											
		Yes			*No*			*Case-dependent*			*Unsure*		
Test		*Private*	*Public*	*Total*	*Private*	*Public*	*Total*	*Private*	*Public*	*Total*	*Private*	*Public*	*Total*
Case History		100 (7)	100 (25)	100 (32)	--	--	--	--	--	--	--	--	--
Otoscopy		86 (6)	100 (25)	97 (31)	--	--	--	14 (1)	--	3 (1)	--	--	--
ASSR		28.5 (2)	60 (15)	53 (17)	28.5 (2)	24 (6)	25 (8)	43 (3)	16 (4)	22 (7)	--	--	--
BC ABR		14 (1)	16 (4)	16 (5)	--	40 (10)	31 (10)	86 (6)	44 (11)	53 (17)	--	--	--
Click ABR		100* (7)	88 (22)	91 (29)	--	4 (1)	3 (1)	--	4 (1)	3 (1)	--	4 (1)	3 (1)
Cochlear microphonic		29 (2)	28 (7)	28 (9)	57 (4)	56 (14)	56 (18)	14 (1)	16 (4)	16 (5)	--	--	--
TB ABR		71 (5)	96 (24)	91 (29)	14.5 (1)	--	3 (1)	14.5 (1)	-	3 (1)	--	4 (1)	3 (1)
DPOAE		86 (6)	80 (20)	81 (26)	--	16 (4)	13 (4)	14 (1)	4 (1)	6 (2)	--	--	--
TEOAE (one public sector data missing)		14.5 (1)	21 (5)	19.5 (6)	71 (5)	58 (14)	61 (19)	14.5 (1)	21 (5)	19.5 (6)	--	--	--
High frequency	Tympanometry	57 (4)	76 (19)	72 (23)	14 (1)	16 (4)	15.5 (5)	29 (2)	8 (2)	12.5 (4)	--	--	--
	Acoustic Reflexes	29 (2)	48 (12)	44 (14)	57 (4)	44 (11)	47 (15)	14 (1)	8 (2)	9 (3)	--	--	--
Low frequency	Tympanometry	29 (2)	40 (10)	38 (12)	43 (3)	60 (15)	56 (18)	29 (2)	--	6 (2)	--	--	--
	Acoustic Reflexes	29 (2)	44 (11)	41 (13)	57 (4)	56 (14)	56 (18)	14 (1)	--	3 (1)	--	--	--
Other: Screening OAE		--	*n*=1 specified	*n*=1 specified	--	--	--	--	--	--	--	--	--
Other: Diagnostic VRA		--	*n*=1 specified	*n*=1 specified	--	--	--	--	--	--	--	--	--
Other: Noisemakers		--	*n*=1 specified	*n*=1 specified	--	--	--	--	--	--	--	--	--

Note: Two participants are not included in this question, as they are not currently fitting this age group (*N*=32). Private: (*n*=7) & Public: (*n*=25)
*One participant specified neurological click ABR

All participants (*N* = 32) stated that they required a case history and all but one private sector participant reported that they would conduct an otoscopic examination as a good base for their assessment.

With regards to electrophysiological measures, 53% (*n* = 17) of the participants reported that they required ASSR thresholds. Twenty two percent (*n = 7)* of all participants stated that the completion of ASSR was case-dependent, whilst the remaining 25% (*n* = 8) indicated that they did not require ASSR thresholds for HA fitting. The percentage of public sector participants (60%, *n* = 15) who required these results were much higher than private sector participants (28.5%, *n* =2).

Similar results were obtained for click ABR across the private and public sector participants. Ninety-one percent (*n*=29) of participants required click ABR measures, as well as TB ABR. Slightly more public sector participants required TB ABR (96%, *n*=24) compared to private sector participants (71%, n=5). The one public sector participant not requiring TB ABR stated that he/she was unsure whether they required this measure or not. Only one private sector participant (14.5%) stated that they did not require TB ABR, while the remaining private sector participant (14.5%) stated that requiring TB ABR for this age group would be case-dependent. With regards to BC ABR testing, 16% (*n*=5) of participants required this measure, while 31% (*n*=10) did not require this measure, and for 53% (*n*=17) this measure was case-dependent. No private sector participants stated this measure was not required, and the majority stated that it was case-dependent (86%, *n*=6). This is in contrast to public health participants where 40% (*n*=10) did not require this measure, and only 44% (*n*=11) felt BC ABR was case-dependent.

Included in the question was whether TEOAE, DPOAEs and/or CM measures were required for this age group, prior to HA fitting. Twenty-eight percent (*n*=9) of participants required CM measures, while 56% (*n*=18) stated this measure was not required, and 16% (*n*=5) felt this measure was case-dependent. Similar responses were reported by both private and public health sector participants. The majority of private and public sector participants stated that requiring DPOAEs was required or case-dependent, with 81% (*n*=26) requiring DPOAE's, while 13% (*n*=4) did not require this measure and 6% (*n*=2) felt requiring DPOAE's would be case-dependent. Only 16% (*n*=4) of the public sector participants did not require DPOAEs, while 4% (*n*=1) of public participants and 14% (*n*=1) of private participants felt requiring DPOAEs was case-dependent. Fewer participants required TEOAEs. For private sector participants, only one participant required TEOAEs (14.5%) while 71% (*n*=5) did not require TEOAEs and the remaining participant (14.5%) felt requiring TEOAEs would be case-dependent. In the public sector, 21% (*n*=5) of participants required TEOAEs, while 58% (*n*=14) did not require TEOAEs and 21% (*n*=5) felt requiring TEOAEs would be case-dependent.

With regards to tympanometry, only 72% (*n*=23) of participants indicated that they required high frequency tympanometry measures, while 15.5% (*n*=5) did not require this measure, and 12.5% (*n*=4) felt high frequency tympanometry would be case-dependent. Thirty-eight percent (*n*=12) of participants required low frequency tympanometry, while 56% (*n*=18) did not require low frequency tympanometry. Six percent (*n*=2) of participants felt low frequency tympanometry would be case-dependent. Of the nine participants stating that they did not require high frequency tympanometry, or felt it was case dependent, seven participants did not have high frequency tympanometry available at their department and

two participants were unsure whether the equipment at their department had the option of high frequency tympanometry.

For acoustic reflexes, 29% (*n*=2) of private sector participants required high frequency probe tone acoustic reflex measures, while 57% (*n*=4) did not require this measure and 14% (*n*=1) felt high frequency acoustic reflexes was case-dependent. For public sector participants, 48% (*n*=12) required high frequency acoustic reflexes, 44% (*n*=11) did not require this measure and 8% (*n*=2) felt this measure was case-dependent. Similar results were obtained for low frequency acoustic reflexes. Forty-one percent (*n*=13) of participants required these measures, while 56% (*n*=18) did not require low frequency acoustic reflexes and 3% (*n*=1) felt this measure would be case-dependent prior to HA fitting.

One participant specified requiring screening OAEs prior to HA fitting for babies less than six months, while another participant also required noisemaker and diagnostic VRA results.

Participants who reported having access to high frequency immittance equipment were asked at what age they stop completing high frequency tympanometry. The range, mean, median and *SD* are presented in Table 4.25. Also shown are the results of the one-sample *t*-test completed comparing participants responses to the recommended practice of completing high frequency tympanometry until age six months (Baldwin et al., 2008). The statistical analysis revealed a significant difference (Mean = 8.944; $t = 2.564$; $p = 0.0201$) between the age participants ceased completing high frequency tympanometry and the recommended guidelines, suggesting that participants clinical practice overall, does not adhere to recommended guidelines.

Table 4.25

Age at Which Participants Stop Completing High Frequency Tympanometry

		Months		***One-sample t-test values***		
Participants (*n*)	Reported age range	Mean	Median	*t*-value	*p*-value	*SD*
18	6 to 24	8.944	6.75	2.564	0.0201*	4.872

* *p*-value significant at the p<0.05 level
Note: Participant responses compared to the recommended age of birth to 6 months of age for completing high frequency tympanometry (Baldwin et. al., 2008)

This result may have been influenced by the equipment available at each department and/or a lack of understanding of the appropriate use of such measurements. Children with HL in South Africa are identified at later ages compared to local and international recommendations and are usually identified over six months of age (van der Spuy & Pottas, 2008; Stra uss, 2006). This may lead to a clinician's lack of experience with and knowledge of the appropriate use of high frequency immittance testing in this age group. One participant commented, that due to not seeing many children less than six months of age, it was hard to justify the purchase of such equipment.

Frequency-specific audiological information for accurate HA fitting is vital. It was therefore promising that a large percentage of participants required TB ABR measures prior to HA fitting. There was a large difference between public and private sector participants regarding whether ASSR thresholds and TB ABR testing was required. More participants in the public sector stated they required both of these measures. Private sector departments required TB ABR testing less often than public sector departments, which may possibly be due to time constraints in small private practices, and clinicians attempting to optimise clinical and money-earning potential. The large percentage of public sector departments requiring ASSR as minimal audiological information prior to HA fitting may indicate an

over-reliance on ASSR as a clinical tool, as a significant percentage stated that they required both ASSR and ABR prior to fitting, whereas stating that it would be case-dependent may have been more appropriate. All (but one public sector participant) required TB ABR, suggesting that useful, frequency specific information for HA fitting would be available. The completion of ABR and ASSR in all cases may not be necessary or realistic due to time constraints. This would depend upon the state of the infant's sleep state and whether they slept soundly or not, as well as sedation facilities available to the department. A fairly large percentage of public participants required ASSR, when one takes into account that ASSR thresholds cannot accurately estimate behavioural thresholds for ANSD (Rance & Briggs, 2002; Rance et al., 2005), or provide information regarding the site of lesion of a HL i.e. neural vs. sensory loss (Hall, 2004).

If air conduction ABR thresholds are raised, then BC ABR testing should be completed to assist in determining the type of HL (Stevens et al., 2007). It was therefore concerning that nearly half of public sector participants stated that they did not require BC ABR, where it may have been more appropriate to state that it would be case-dependent. The high percentage of public sector participants not requiring this measure may result in the type of HL not being inappropriately identified. Therefore, inappropriate audiological management may possibly be initiated. This result in public sector departments may be due to high staff turn-over and less clinical experience, as seen by the participant experience levels in the methodology section. Participants with the most clinical experience were working within private practice, with a large percentage of public sector department participants having less than four years' experience.

It was encouraging that nearly all participants stated that they required some form of diagnostic cochlear outer hair cell function assessment in the form of either OAEs or CM. OAEs (Stevens & Parker, 2009) and CM (Ruth, 1994) are a test of cochlear function. Both these measures provide valuable information in the diagnosis of ANSD, where OAEs and/or CM are present (suggesting normal cochlear outer hair cell function), but ABR is absent or abnormal (Berlin, 1999; Simmons, 2008; Mason, 2004). The non-inclusion of a measure to determine the cochlear function could potentially lead to the misdiagnosis of the exact nature of a potential hearing problem. All three of the participants stating they did not require diagnostic cochlear hair cell function assessment, only had screening OAE equipment available and no diagnostic OAE facilities. This may have influenced their responses, although one participant had diagnostic ABR facilities available, allowing for CM assessment.

Unfortunately, not all participants required high frequency tympanometry measures, which may lead to the incorrect evaluation of middle ear status, as a high frequency probe tone is recommended for use in immittance testing of this age group (Baldwin et al., 2008)

It is concerning that one participant required diagnostic VRA and noisemaker information as a minimum prior to HA fitting for an infant less than six months of age. This was despite the fact that electrophysiological measures (e.g. ABR and ASSR) are recommended for confirmation of HL for infants less than six months of age (Diefendorf, 2009), due to developing neck and truck control. A good developmental age to start behavioural testing such as VRA is at six months of age (Diefendorf, 2009).

4.4.2.2 Six/seven months to 6 years

The results of the minimum audiological information required by participants prior to HA fitting for infants from 6/7 to 36 months of age are presented in Table 4.26, and in Table 4.27, for those children from 36 months to six years of age. One participant did not answer this question as she/he was not fitting children within this age group. The responses of 33 participants will be reported (private sector: n = 7; public sector: n = 26).

For the age group 6/7 to 36 months of age, all participants (N=33) required case history, otoscopic examination and tympanometry.

With regards to ASSR, 39.5% (n=13) of all participants required this measure prior to HA fitting. Whilst 24% (n=8), did not require ASSR; 36.5% (n=12) of participants felt ASSR results would be case-dependent.

For click ABR a similar percentage of private vs. public sector participants required this measure. Overall, 76% (n=25) required this measure, while 6% (n=2) did not require click ABR and 15% (n=5) felt requiring click ABR prior to HA fitting would be case-dependent. One public sector participant (4%) was unsure whether they required click ABR measures. For TB ABR, 76% (n=25) required this measure, while no participants did not require this measure, and 21% (n=7) felt TB ABR would be case-dependent. One public sector participant (4%) was unsure whether they would require TB ABR measures. Only 15% (n=5) of participants required BC ABR, while 30% (n=10) did not, and 55% (n=18) felt TB ABR would be case-dependent.

With regards to CM measures, 19% (*n*=6) required these, while 44% (*n*=14) did not and 37% (*n*=12) felt CM measures would be case-dependent.

OAEs were also included in this question. Similar responses were obtained for TEOAE measures between private and public sector participants. Overall, 24% (*n*=8) required TEOAEs, while 58% (*n*=19) did not and 18% (*n*=6) felt requiring TEOAEs was case-dependent. More participants required DPOAEs compared to TEOAEs. Eighty-two percent (*n*=27) required DPOAEs and 12% (*n*=4) did not, while 6% (*n*=2) felt requiring DPOAEs was case-dependent.

Fifty-seven percent (*n*=4) and 73% (*n*=19) of private vs. public sector participants respectively, required acoustic reflexes before HA fitting. The question was not further defined in terms of diagnostic vs. screening acoustic reflexes.

With regards to behavioural audiological assessment prior to HA fitting, the majority, 94% (*n*=31) of the participants, required behavioural audiological measures. The remaining two participants (6%) felt requiring behavioural audiological results would be case-dependent. Twenty-seven percent (*n*=9) required noisemaker information. All private sector participants stated that they did not require audiological information from noisemakers prior to HA fitting, whereas in the public sector only 50% (*n*=13) did not require noisemaker information. Thirty-five percent (*n*=9) of public sector participants stated they definitely required noisemaker information, and 15% (*n*=4) stated it would be case-dependent.

Table 4.26

Minimal Audiological Information Required Before HA Fitting for Children 6/7 to 36 Months of age - % (n)

								% (n)				
	Yes			*No*			*Case-Dependent*			*Unsure*		
Test	*Private*	*Public*	*Total*	*Private*	*Public*	*Total*	*Private*	*Public*	*Total*	*Private*	*Public*	*Total*
Case History	100 (7)	100 (26)	100 (33)	--	--	--	--	--	--	--	--	--
Otoscopy	100 (7)	100 (26)	100 (33)	--	--	--	--	--	--	--	--	--
ASSR	14 (1)	46 (12)	39.5 (13)	29 (2)	23 (6)	24 (8)	57 (4)	31 (8)	36.5 (12)	--	--	--
BC ABR	29 (2)	12 (3)	15 (5)	--	38 (10)	30 (10)	71 (5)	50 (13)	55 (18)	--	--	--
Click ABR	71* (5)	77 (20)	76 (25)	14.5 (1)	4 (1)	6 (2)	14.5 (1)	15 (4)	15 (5)	--	4 (1)	3 (1)
Cochlear microphonic**	33 (2)	15 (4)	19 (6)	50 (3)	42.5 (11)	44 (14)	17 (1)	42.5 (11)	37 (12)	--	--	--
Tone Burst ABR	57 (4)	81 (21)	76 (25)	--	--	--	43 (3)	15 (4)	21 (7)	--	4 (1)	3 (1)
DPOAE	86 (6)	80.5 (21)	82 (27)	14 (1)	11.5 (3)	12 (4)	--	8 (2)	6 (2)	--	--	--
TEOAE	29 (2)	23 (6)	24 (8)	57 (4)	58 (15)	58 (19)	14 (1)	19 (5)	18 (6)	--	--	--
Tympanometry	100 (7)	100 (26)	100 (33)	--	--	--	--	--	--	--	--	--
Acoustic Reflexes	57 (4)	73 (19)	70 (23)	43 (3)	23 (6)	27 (9)	--	4 (1)	3 (1)	--	--	--
Behavioural Assessment	100 (7)	92 (24)	94 (31)	--	--	--	--	8 (2)	6 (2)	--	--	--
Response to Noisemakers	--	35 (9)	27 (9)	100 (7)	50 (13)	61 (20)	--	15 (4)	12 (4)	--	--	--

*One participant specified neurological click ABR
** Data missing/not recorded for one private participant

Table 4.27

Minimal Audiological Information Required Before HA Fitting for Children 36 Months to 6 Years of Age - % (n)

	% (n)											
	Yes			No			Case-Dependent			Unsure		
Test	Private	Public	Total	Private	Public	Total	Private	Public	Total	Private	Public	Total
Case History	100 (7)	100 (26)	100 (33)	--	--	--	--	--	--	--	--	--
Otoscopic examination	100 (7)	100 (26)	100 (33)	--	--	--	--	--	--	--	--	--
ASSR	--	27 (7)	21 (7)	43 (3)	31 (8)	33.5 (11)	57 (4)	42 (11)	45.5 (15)	-	-	-
BC ABR	-	7.5 (2)	6 (2)	14 (1)	34.5 (9)	30 (10)	86 (6)	58 (15)	64 (21)	-	-	-
Click ABR	14 (1)	38 (10)	33.5 (11)	29 (2)	12 (3)	15 (5)	57 (4)	46 (12)	48.5 (16)	-	4 (1)	3 (1)
Cochlear microphonic	--	8 (2)	6 (2)	71 (5)	46 (12)	52 (17)	29 (2)	46 (12)	42 (14)	--	--	--
Tone Burst ABR	14.5 (1)	42 (11)	36.5 (12)	14.5 (1)	12 (3)	12 (4)	71 (5)	42 (11)	48.5 (16)	-	4 (1)	3 (1)
Distortion Product OAE	71 (5)	73 (19)	73 (24)	14.5 (1)	15 (4)	15 (5)	14.5 (1)	12 (3)	12 (4)	--	--	--
Transient Evoked OAE	29 (2)	19 (5)	21 (7)	57 (4)	58 (15)	58 (19)	14 (1)	23 (6)	21 (7)	--	--	--
Tympanometry	100 (7)	100 (26)	100 (33)	--	--	--	--	--	--	--	--	--
Acoustic Reflexes	71 (5)	73 (19)	73 (24)	29 (2)	19 (5)	21 (7)	-	8 (2)	6 (2)	--	--	--
Behavioural Assessment	100 (7)	100 (26)	100 (33)	--	--	--	--	--	--	--	--	--
Response to Noisemakers	-	23 (6)	18 (6)	100 (7)	58 (15)	67 (22)	-	19 (5)	15 (5)	--	--	--
Other: Speech Audiometry	-	8 (2)	2 specified	--	--	--	--	4 (1)	1 specified	--	--	--
Other: Site of Lesion Testing	-	4 (1)	1 specified	--	--	--	--	--	--	--	--	--

For the 36 month to six year age group all participants required case history, otoscopy, tympanometry and behavioural audiological information as a minimum prior to HA fitting.

For this age group, more public sector participants required ASSR results prior to fitting than those clinicians in private practice (See Table 4.27). Of the public sector participants, 27% (*n*=7) required ASSR prior to HA fitting, while 31% (n=8) did not require ASSR, and 42% (*n*=11) stated that obtaining ASSR would be case-dependent. None of the private sector participants required ASSR result prior to fitting and 57% (*n*=4) of private sector participants stated that obtaining ASSR would be case-dependent.

Of the public sector participants, 38% (*n*=10) required audiological click ABR and 42% (*n*=11) TB ABR, whereas of the private sector participants, only 14% (*n*=1) and 14.5% (*n*=1) of participants required click and TB ABR respectively, prior to HA fitting in this age group. Few participants, 6% (*n*=2) required BC ABR, while 30% (*n*=10) did not require BC ABR, and 64% (*n*=21) felt BC ABR would be case-dependent.

Only 6% (*n*=2) of participants required CM information. Both participants were from the public sector. Fifty-two percent (*n*=17) did not require CM information, while 42% (*n*=14) felt CM information would be case-dependent.

Regarding the younger age groups, more participants required DPOAEs compared to TEOAEs. For DPOAEs, responses between private and public sector participants were similar. Overall, seventy-three percent (*n*=24) required DPOAEs, while 15% (*n*=5) did not

and 12% (*n*=4) felt DPOAE information was case-dependent. With regards to TEOAEs, 21% (*n*=7) required these measures, while 58% (*n*=19) did not and 21% (*n*=7) felt requiring TEOAEs would be case-dependent.

Many participants, 73% (*n*=24) required acoustic reflexes, while 21% (*n*=7) did not and the remaining 6% (*n*=2) felt requiring TEOAEs would be case-dependent.

With regards to information from noisemakers, 23% (*n*=6) of public sector participants required noisemakers for this older age group prior to HA fitting, while 19% (*n*=5) stated noisemaker information would be case-dependent. No private sector participants required noisemaker information.

Two public sector participants (8%) specified requiring speech audiometry, while one public participant (4%) stated that requiring this measure would be case-dependent. Site of lesion testing was also specified by one public participant (4%) as being required for this older age group prior to HA fitting.

For the six to 36 month age group, the number of participants requiring acoustic reflexes may be considered to be a large percentage, when taking into account this as minimal audiological information required prior to HA fitting. Acoustic reflexes may not be able to be obtained if the baby or child does not sit for long enough, especially if diagnostic reflexes are preferred. Ipsilateral screening reflexes may be more realistic as a cross check of results. With such a large percentage, one may query the awareness of how having acoustic reflexes may change a patient's clinical management.

For the six to 36 month age group, with regards to BC ABR, it may have been more appropriate for all participants to state that requiring this measure was case-dependent. A little over a third of public sector participants stated that this measure was not required, and as discussed for infants from birth to 6/7 months of age, this may show a lack of understanding of the use of BC ABR in the public sector, and may lead to inappropriate diagnosis of the type of HL, as well as appropriate management thereof.

4.4.2.3 Behavioural measures and validation with electrophysiological measures

Participants were asked at what age they start completing behavioural testing. Results are shown in table 4.28. The age at which participants start completing behavioural testing was found to be statistically significantly different to the recommended age of five to seven months (Madell, 2008). One-sample *t*-test data comparing participants' responses to a recommended start age of six-months is shown in table 4.28 (Mean = 13.85; $t = 4.205$; $p = 0.0002$). Participant responses were also compared to five-month, as well as seven-month start ages for behavioural audiological assessment, and one sample *t*-tests found that participants' responses were also statistically significantly different to these recommended start ages for behavioural testing.

Table 4.28

Age at which Participants Start Completing Behavioural Testing

		Months		***One-sample t-test values***		
Participants (*n*)	Reported age range	*Mean*	Median	*t*-value	*p*-value	*SD*
30	4.5 to 42	13.85	9	4.205	*0.0002	10.23

* *p*-value significant at the p<0.05 level
Note: Participant responses compared to the recommended age of 5-7 months to start completing behavioural assessment (Madell, 2008). Values above are for 6 months of age.

Participants were asked at what age they stop validating behavioural results with electrophysiological measures. Many participants responded that they would not validate behavioural results with electrophysiological measures if behavioural measures were felt to be reliable. The remaining 44% (*n*=15) of participants responded with an age at which they stopped validating behavioural measures with electrophysiological testing. The average age was 58.8 months (range = 24 months to 10 years; *SD* =23.26 months).

There appeared to be an over-reliance on electrophysiological measures for paediatric audiological assessment. Behavioural audiological assessment provides important audiological information regarding hearing across the frequency range for HA fitting. From five to six months of age, behavioural testing can be included as part of the audiological test battery (Madell, 2008), in the form of VRA from five months of age, and play audiometry from 25 months of age (Hodgson, 1994). The majority of participants stated that they required behavioural audiological results for the 6/7 to 36 month age group, and all participants required behavioural audiological results for the 36 month to six year age group, prior to HA fitting. Despite this, for the majority of participants, their confidence in, and the appropriate use of behavioural testing is questioned. When asked at what age they start completing behavioural testing, participants responses were found to be statistically significantly different to recommended guidelines. Although just over half of participants

stated that they would not validate behavioural results with electrophysiological measures if behavioural measures were felt to be reliable, the remaining participants' responses resulted in average and median age values that appeared high. Even if one considers the JCIH (2007) recommendation that at least one ABR is completed for children younger than 36 months of age, the median age reported by participants is considerably higher than this. Within the South African context, when staff and clinical resources are limited, it is unlikely that all children under the age of three years will have an ABR completed, unless there are insufficient behavioural and other objective measures available, or there is a suspicion of ANSD.

Other findings from the study suggested an over-reliance on electrophysiological measures and lack of confidence in behavioural measures. For the 6/7 to 36 month age group, a significantly larger percentage of participants in the public sector required ASSR and TB ABR thresholds, when compared to private sector participants. Nearly half of public sector participants required ASSR. Two public sector participants also stated that requiring behavioural thresholds was only case-dependent. As with the 6/7 to 36 month age group, for the 36 month to six year age group, more public than private sector participants required ASSR results prior to HA fitting. Just over a quarter of public sector participants required ASSR results prior to HA fitting in this older age group, again suggesting an over- reliance on electrophysiological measure. Many participants did state that obtaining ASSR would be case-dependent, which would be more appropriate. The apparent over-reliance on electrophysiological measures was also suggested by many public sector participants in the 36 month to six year age group requiring click and TB ABR, as a minimum prior to HA fitting in this age group. Although all participants stated that they required behavioural measures, it would appear that clinicians, particularly in the public sector, do not feel assured

in the reliability of these results, and perhaps do not have confidence in their behavioural testing ability.

Another indication suggesting that not all participants had confidence in their behavioural assessment skills was that some public department participants stated that they required information from audiological assessment with noisemakers as part of their minimum audiological information, prior to HA fitting. Noisemakers should not be used as tools to assess hearing, but can assess how a patient responds to what they have heard, as well as training appropriate responses to acoustic stimuli (Young, 1994). For the 6/7 to 36 month age group, just over a third of public sector participants stated that they definitely required noisemaker information and nearly a quarter of public department participants required noisemakers for the 36 month to six year age group. As no public departments reported having a sound-level meter, it is unlikely that noisemaker measurements would be controlled, and sound levels verified. This result is therefore concerning, as this clinical practice may lead to inappropriate diagnosis and management. It may also indicate a lack of skill in behavioural paediatric testing and/or equipment.

These results suggest that many clinicians do not appear to have confidence in the behavioural results they are obtaining and are over-reliant on electrophysiological measures for paediatric audiological assessment. This may be due to insufficient training; lack of understanding of procedures and their benefits and pitfalls; adequate equipment, including appropriate sizing and set-up of sound-treated booths; busy, stressful clinics; and high staff turn-over. Many may also be working in isolation, making conditions challenging for optimal behavioural assessment when two clinicians are required, as well as not having senior clinical staff to mentor their clinical skill development.

One participant commented that many of the children they work with have additional needs, and therefore require electrophysiological testing for audiological results. South Africa is a developing country and therefore many children may experience co-morbid conditions including HIV/Aids and associated health problems. It was reported that in 2006, 30.2 % of pregnant women were HIV-positive (Open Society Foundation for South Africa; 2007). This may have an influence on potential peri- and postnatal complications and co-morbid conditions that children may experience. HIV/Aids creates an additional burden on under-resourced health care systems (McPherson, 2008). These children may also have additional needs, making behavioural audiological assessment more challenging. This increased burden may also impact on audiology facilities, which are not properly equipped to meet the demands.

4.4.3 ABR and ASSR measures

This section focuses on the fourth sub-aim, namely the audiological measures utilised for paediatric HA fitting.

4.4.3.1 Calibration

Participants were asked for a copy of their ABR and ASSR calibration certificate. On inspection of the calibration certificates provided, the only calibration standards mentioned were the South African Bureau of Standards (SABS) 10154-1: 2004 and 10154-2: 2004 for the calibration of pure-tone audiometers Part 1: Air conduction and Part 2: Bone conduction respectively (SABS, 30th August 2011, personal correspondence). It is unclear whether all manufacturers in South Africa are using the recommended international ISO 389-6 (2007) standards to calibrate ABR systems.

Participants were asked if they had performed a biological calibration on their ABR equipment. Only 21.5% (*n*=3) of participants reported completing some form of biological calibration, while 71.5% (*n*=10) of participants had not completed a biological calibration, and one participant (7%) was unsure whether a biological calibration had been completed on the equipment they were utilising.

An understanding of calibration standards used for calibrating audiological equipment will ensure that accurate estimates of hearing thresholds are obtained. It is therefore essential that audiologists obtain this information before using equipment. Standardisation of calibration across clinics will be possible with clinics and manufacturers implementing the ISO 389-6 ABR calibration standards (2007) (Lightfoot et al., 2007).

4.4.3.2 Types of ABR measures

The results of the types of ABR measures utilised are presented in Table 4.29, whilst the frequency of completion of such measures is shown in table 4.30. Only 14 participants reported conducting ABR assessments.

The most commonly used air conduction ABR measures were reported as being neurological click and 1000 Hz tone burst (100% of the participants), audiological click and 500 Hz tone burst (93%, *n*=13), followed by 2000 Hz and 4000 Hz tone bursts, which were both reported as being used by 79% (*n*=11) of participants.

For BC ABR, most participants 93% (*n*=13) reported completing this measure if required. Of these participants, various BC measures were reported as being completed. The

majority (92%; *n*=12) reported completing click BC measures, whilst 77% (*n*=10) completed 500 Hz; 69% (*n*=9) 1000 Hz; 31% (*n*=4) 2000 and 4000 Hz; and 8% (*n*=1) 6000 Hz. Thirty-one percent (*n*=4) of participants reported that completing 2000 and 4000 Hz was case-dependent, while one participant (8%) reported completing 1000 Hz if possible, and 7% (*n*=1) 2000 and 4000 Hz if possible.

Upon further exploration (as per Table 4.30), when asked if TB ABR was completed 'always' or 'sometimes', it can be seen that 50% (*n* = 7) of the time, air conduction TB ABR was 'always' completed. Reasons for completing TB ABR included: if a low frequency loss was suspected; if there was a discrepancy between ABR and ASSR results; wanting to obtain hearing thresholds for HA fitting; and to validate ASSR results. Two participants commented that they would continue with ASSR testing if a neurological click was abnormal.

Table 4.29

ABR Measurements Being Completed (N=14)

	% (n)								
	Click		*Tone Bursts*						
	Audiological Click	*Neurological Click*	*250 Hz*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*	*6000 Hz*	*8000 Hz*
Yes	93 (13)	100 (14)	7 (1)	93 (13)	100 (14)	79 (11)	79 (11)		
No	7 (1)					14 (2)	14 (2)		
Mostly				7 (1)					
If Possible						7 (1)	7 (1)	7 (1)	
Sometimes									7 (1)

Table 4.30

Frequency of Completion of Tone-burst and BC ABR Measures

	% (n)					
	Always	*Sometimes*	*Yes*	*No*	*If Required*	*Unknown*
Completion of TB ABR (*N*=14)	50 (7)	50 (7)				
Completion of BC ABR (*N*=14)				7 (1)	93 (13)	
BC ABR measures completed (*N*=13)	*Click*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*	*6000 Hz*
Yes	92 (12)	77 (10)	69 (9)	31 (4)	31 (4)	8 (1)
No	8 (1)	23 (3)	23 (3)	31 (4)	31 (4)	
Case-Dependent	0	0	0	31 (4)	31 (4)	
If possible	0	0	8 (1)	7 (1)	7 (1)	

The ABR frequencies tested by participants in this current study are in contrast with the guideline developed by Stevens et al. (2007). This guideline recommends that TB ABR be completed at 4000 Hz or 2000 Hz if click ABR results are elevated, or if click ABR was not completed. The updated guideline (Stevens et al.2011) recommends that testing start with 4000 Hz tone burst testing unless ANSD is suspected, followed by 1000 Hz, 2000 Hz and lastly 500 Hz. Not starting TB ABR testing with the recommended 4000 Hz has the potential of wasted clinical time. The results of the current study are, however, similar to the findings of Moodley et al. (2010) and Theunissen and Swanepoel (2008), who found that click ABR was used most frequently by South African audiologists. The findings of the current study for the most frequently used tone burst frequency when conducting TB ABR, is similar to results of Moodley et al. (2010) where it was found that all ABR results on record (*N*=15), included 500 Hz tone bursts and 53% (*n*=8) of record included 1000 Hz TB ABR measures.

BC ABR is recommended if air conduction thresholds are raised in order to determine the presence of a conductive component of the HL (Stevens et al., 2007; Stevens et al., 2011). The results of the current study indicate that if required, most participants will conduct BC ABR testing. This is in contrast with the findings reported in previous studies (Theunissen & Swanepoel, 2008; Moodley et al., 2010).

4.4.3.3 Order of completion: tone burst ABR measures

Participants were required to indicate the order in which they completed TB ABR. Results are presented in Table 4.31. The most commonly reported order was 500 Hz first and 2000 Hz second. Both 1000 Hz and 4000 Hz were reported by participants as being

completed third. Interestingly, 500 Hz was also reported as the most commonly reported tone burst reported as being completed last.

Table 4.31

The Most Commonly Reported order of TB ABR Completion

				% (n)			
Order of Completion	*250 Hz*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*	*6000 Hz*	*8000 Hz*
1st		57 (8)	28.5 (4)	7 (1)	7 (1)		
2nd		7 (1)	28.5 (4)	50 (7)	14.25 (2)		
3rd			43 (6)	7 (1)	43 (6)		
4th		36 (5)		22 (3)	21.5 (3)	7 (1)	
5th	7 (1)			7 (1)			7 (1)
not completed				7 (1)	14.25 (2)		

The results of the current study are in contrast to the recommended guidelines (Stevens et al. 2007; Stevens et al., 2011). In 2007, it was recommend that if click ABR thresholds are mildly to moderately raised, then 4000 Hz should be recorded, followed by a low frequency TB ABR, preferably 1000 Hz (Stevens et al. 2007). This was revised in 2011, with the recommendation that tone burst testing be completed in the following order: 4000 Hz, 1000 Hz, 2000 Hz and lastly, 500 Hz (Stevens et al, 2011).

4.4.3.4 Acceptable dBnHL values suggesting normal hearing

Participants were asked what they felt acceptable ABR thresholds for discharge were. Table 4.32 provides a summary of the means, medians, *SD*, ranges, as well as the one-sample *t*-test values comparing participants' responses to the generally-accepted 30 dBeHL level (Stevens et al., 2007 & Stevens et al., 2011). Correction values from the Stevens et al. (2007) guideline were used to derive the acceptable dBnHL values for each ABR measure when analysing participants' responses.

It is evident from the findings that for infants under three months of age, the mean acceptable thresholds for discharge reported by participants for click ABR was 26.79 dBnHL. The mean acceptable TB ABR threshold reported by participants was 35.36 dBnHL for 500 Hz; 32.32 dBnHL for 1000 Hz; 31.15 dBnHL for 2000 Hz and 30.39 dBnHL for 4000 Hz.

With regard to children over three months of age, results differed slightly for click and 500 Hz TB ABR only. The mean acceptable threshold for discharge reported by participants for click ABR was 27.14 dBnHL. For 500 Hz, the mean reported acceptable TB ABR threshold was 35.71 dBnHL. For 1000 Hz, 2000 Hz and 4000 Hz TB ABR, reported acceptable ABR thresholds for discharge were the same as for infants less than three months of age.

One-sample *t*-tests were employed to determine whether there was a statistically significant difference between participant responses and the recommended guidelines. Compared to the Stevens et al (2007) recommendations, for infants under three months corrected age, a statistically significant difference was found at the 5% confidence level for TB ABR at 500 Hz ($p = 0.0002$), 1000 Hz ($p = 0.0002$) and 4000 Hz ($p = 0.045$). For infants older than three months, statistically significant differences were found for click ABR ($p = 0.0003$), and TB ABR at 500 Hz ($p = 0.0000$), 1000 Hz ($p = 0.0000$), and 2000 Hz ($p = 0.0013$). This indicates that the audiologists who participated in this study are completing ABR testing at unnecessarily low test levels for children with normal hearing. Only one participant suggested different levels as acceptable for children under versus over three months of age. This was only for TB ABR 500 Hz and click ABR, where the participant reported that they would accept dBnHL thresholds that were 5dB greater than acceptable thresholds for discharge, compared to infants less than three months of age.

Compared to the BCEP (2008) recommendations for children over three-months corrected age, a statistically significant difference was found at the 5% confidence level for TB ABR 4000 Hz ($p = 0.0445$).

Table 4.32

Acceptable ABR Thresholds for Discharge (dBnHL), as Responded by Participants

		Participant acceptable dBnHL thresholds for discharge per stimulus type and t-test values				
Age				*Tone Burst ABR*		
		Click (n=14)	*500 Hz (n=14)*	*1000 Hz (n=14)*	*2000 Hz (n=13)*	*4000 Hz (n=13)*
Under 3 months	Mean (dB)	26.786	35.357	32.321	31.154	30.385
	Median (dB)	30	32.5	30	30	30
	SD (dB)	6.235	7.129	5.757	7.679	8.651
	Range (dB)	10-35	25-50	20-50	15-50	10-50
	Comparison to Stevens et. al. (2007) recommended level for discharge (30dBeHL)					
	t	1.071	-5.061	-4.991	-1.806	2.244
	p-value (2-sided)	0.303	0.0002*	0.0002*	0.096	0.045*
Over 3 months	Mean (dB)	27.143	35.714	32.321	31.154	30.385
	Median (dB)	30	35	30	30	30
	SD (dB)	5.953	6.963	5.757	7.680	8.651
	Range (dB)	10-35	25-50	20-50	15-50	10-50
	Comparison to Stevens et. al. (2007) recommended level for discharge (30dBeHL)					
	t	-4.938	-7.676	-8.241	-4.153	-1.924
	p-value (2-sided)	0.0003*	0.0000*	0.0000*	0.0013*	0.0784
	Comparison to BCEP (2008) recommended levels for discharge					
	t	n/a	0.383808	-1.741	0.541736	2.244
	p-value (2-sided)	n/a	0.7073	0.1053	0.5979	0.0445*

Note: *p*-value significant at the p<0.05 level

* *p*-values indicating a significant difference between participants acceptable levels for discharge and recommended levels

When compared to Stevens et al.'s (2007) recommended levels, for most stimuli participants' reported acceptable levels for discharge were significantly different from recommended values. Only one participant suggested different levels for children under versus over three months of age. It is important to consider different correction values and minimal discharge levels for infants less than three months, as infants have smaller ear canal size compared to adults, which is why the Stevens et al. (2007) recommend different correction values for babies under versus over three months of age. The subsequent Stevens et al. (2011) guideline also has different correction values for different ages.

When compared to the BCEP (2008) guideline, participants' reported acceptable levels for discharge were similar to recommendations, except for the 4000 Hz TB ABR stimulus. At this stimulus, participants' responses were higher than the BCEP (2008) recommended level, which may possibly lead to missing a mild HL at this frequency. This is in contrast to the Steven's et al. (2007) guideline, where participants' responses were at unnecessarily low testing levels.

4.4.3.5 Satisfaction with ABR/ASSR results received

Sixteen of the participants in the current study were not conducting ABR and/or ASSR testing, but received results from another department to assist them with HA fitting. Only 50% (*n*=8) of these participants reported that they felt the results were sufficient for HA fitting. A total of 24 reasons were provided as to why results received were felt to be insufficient. One participant (4%) found that the results received were limited, as only click ABR results were received, 25% (*n*=6) reported receiving a report only describing the HL, without a print-out of results; another 25% (*n*=6) did not receive BC results, and 25% (*n*=6) stated that there was no indication as to whether correction values had been applied or not.

Twenty-one percent (*n*=5) of participants provided other varied reasons. These included not receiving guidance regarding management (*n*=1), communication of results being inconsistent and sometimes not receiving full results (*n*=1), only receiving a description of results and not exact thresholds (*n*=2), as well as not receiving CM results (*n*=1), unless specifically requested.

The lack of standardised documentation of results may possibly lead to confusion during HA fitting and, therefore, non-optimal paediatric amplification. The BCEP (2008) recommends that ABR reports sent to external sources include the numerical ABR data, and an interpretation and summary of the results. They further recommend that results include at least two of the following: dBnHL values, dBeHL values and correction values. A report documented in this manner promotes transparency of the results and would result in less confusion during HA fitting.

4.4.4 Verification

Thirty-two participants answered the question regarding completion of REMs, as two of the participants were not conducting paediatric HA fittings. The results are presented in Table 4.33.

Table 4.33

Completion of Real-ear-measures per Participant

	Completion of real ear measures % (n)		
	Private (n=7)	*Public (n=25)*	*Total (N=32)*
Yes	29 (2)	8 (2)	12 (4)
No	57 (4)	72 (18)	69 (22)
Sometimes	14 (1)	20 (5)	19 (6)

Interestingly, only 12% (*n*=4) of all participants reported using REMs to verify *all* paediatric HA fittings, whilst 19% (*n*=6) reported that they sometimes completed REMs. The majority of participants, (69%; *n*=22) reported that they do not complete any REMs to verify paediatric HA fittings. A larger percentage of private sector participants reported completing REMs than did public sector participants.

Participants (*N* = 10) who reported routinely completing REMs, were probed on which REMs were completed (See Figure 4.4). Thirty percent (*n*=3) of these participants indicated that they used real-ear-insertion-gain (REIG), whilst 20% (*n*=2) of participants relied on the HA company to assist with completing the REMs at the fitting, but did not know which REM was used. Another 20% (*n*=2) completed a variety of REIG, REAR, and RECDs and simulated real ear measures (S-REMs). One participant (10%) reported completing RECDs and S-REMs, while another (10%) used a combination of REAR, and RECDs and S-REMs. The remaining participant (10%) used REIG and REAR.

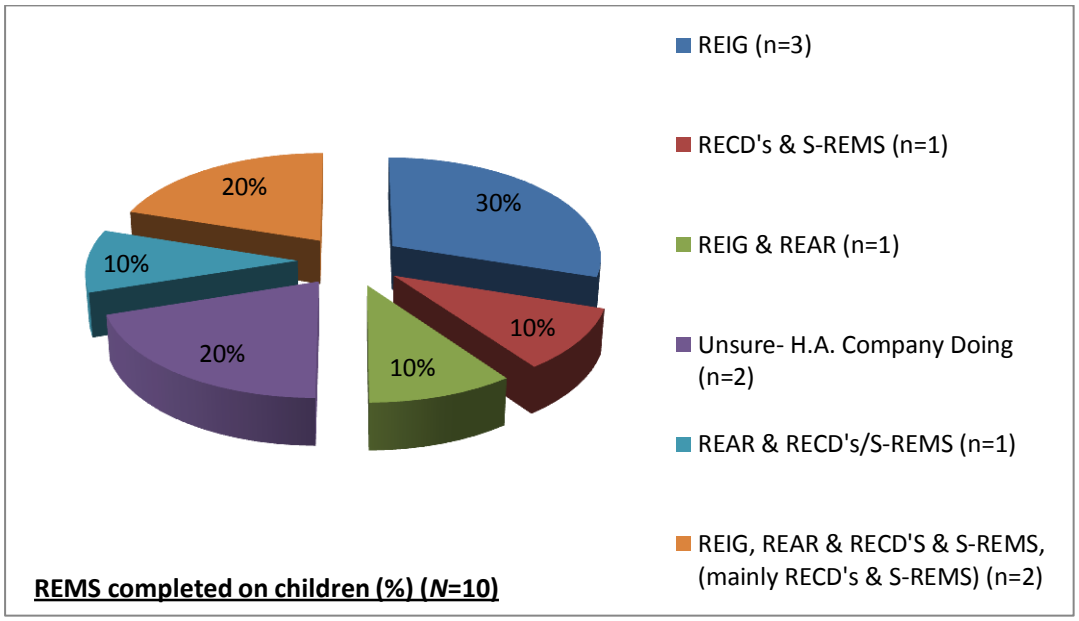


Figure 4.4

REMS Completed During Paediatric HA Fitting (N=10)

The 22 participants not completing REMs were probed on why REMs were not completed or only completed sometimes. The majority of these participants (82%; *n*=18) reported the main reason as being lack of equipment. Only 43% (*n*=3) of the private sector and 36% (*n*=4) of the public sector departments had access to REM equipment. Other reasons provided included malfunctioning equipment; unfamiliarity with the equipment; infrequent fittings not justifying the cost of the equipment, and REMs being too time consuming or unreliable. In addition, it was reported that REMs were only completed if the child was making insufficient progress, or if they were older than six years. Some participants also reported that they rely on other measures such as aided testing, parental report and checklists.

It is of great concern that the majority of participants do not routinely complete REMs to verify paediatric HA fittings. Objective verification ensures that target gain, compression ratio and threshold, as well as output levels, are met and therefore ensure optimal HA fitting (Beauchaine, 2001).

4.5 Correction values applied for HA fitting

The results obtained regarding how audiologists utilise ABR and ASSR measures for paediatric HA fitting, by identifying the correction values applied to results to derive estimated behavioural thresholds, will be presented and discussed in this section.

Once testing has been completed, it is essential to apply appropriate correction values to ABR (Bagatto, 2008; Cunningham, 2008) and ASSR results (Stevens et al., 2007 & Stevens et al., 2011), in order to estimate behavioural thresholds for subsequent HA fitting.

Corrections values applied to ABR and ASSR thresholds for the estimation of behavioural thresholds should consider transducer corrections and offset values (Stevens et al., 2011). The first factor, *transducer corrections*, allows for differences between stimuli presented through BC, insert earphones and headphones transducers, whilst the second factor, *offset values*, accounts for differences between ABR and/or ASSR thresholds and behavioural thresholds (Stevens et al., 2011).

Participants were asked two questions to determine participants' knowledge on the application of correction values to ABR and ASSR results to estimate behavioural hearing levels. The first question directly probed the correction values used and source of these values, whilst in the second question, participants were provided with a set of ABR and ASSR results. They were required to calculate the hearing levels they would use for HA fittings based on these results. This allowed the researcher to evaluate participants' adherence to the correction values provided.

4.5.1 Origin of correction values used

When probed on what the correction values participants applied were based on, a variety of responses were obtained (See Table 4.34). In a number of instances, participants responded with more than one source, with a total of 27 sources reported.

Table 4.34

Origin of Correction Values used to Estimate Behavioural Thresholds

What correction values were based on	***% (n)***
Other - Various sources	33 (9)
Departmental protocol, manufacturer's guidelines & recommended correction values	29.5 (8)
Manufacturer's guidelines	14.5 (4)
Recommended correction values & other	7 (2)
Own clinical research, manufacturer's guidelines & recommended correction values	4 (1)
Correction values as recommended by……..(specified author)	4 (1)
Various: own research, protocol, manufacturer's guidelines & recommended correction values	4 (1)
Own clinical research & departmental protocol	4 (1)

The majority of participants reported using a variety of sources for correction values, including: colleague consultation; relationships with patients and parents report; undergraduate training; and clinical experience (33%, *n = 9).* The combination of departmental protocols, manufacturer's guidelines and recommended correction values then followed (29.5%, *n*=8). Manufacturer's guidelines were used as a source by 14.5% (n=4) of participants.

Participants gave varied sources as the origin of the correction values they utilised. Three specific authors mentioned included Bagatto (2008), L. Hood & J.W. Hall, with no specific reference of year given for the last two authors.

Overall there did not appear to be a consensus as to what correction values should be used. The sources used by participants did not appear to be systematic or have a strong evidence-base. Strong evidence bases include randomised control trials, systematic reviews and meta-analyses of randomised control trials (Cox, 2005). Clinicians should therefore not rely solely on colleague's views regarding appropriate correction values, as expert opinion

and case reports (which can be subject to bias), are the lowest in the hierarchy of evidence bases (Cox, 2005).

4.5.2 Correction values for ABR

Participants were asked if they applied correction values to ABR results. A total of 33 participants answered this question. Over half of these participants, 55% (n=18) stated that they applied correction values to dBnHL values obtained by ABR testing. Thirty percent (*n*=10) were not applying any correction values, whilst 12% (*n*=4) were unsure whether or not correction values had been applied during ABR assessment completed by their colleagues at the same department, or what these correction values might be. One participant (3%) was unsure as whether to apply correction values to all ABR results or not.

The participants (*n* = 19) stating that they were applying correction values, as well as the participant who was unsure whether or not to apply correction values to all results, were asked at what stage correction values for ABR were applied. Fifty-eight percent of participants stated that it was completed during the assessment and documented on printed results, while 37% stated that whoever fitted the HAs applied the correction values. One participant (5%) responded that it varied as to when correction values were applied to the ABR results.

Participants were asked what correction values they were applying to ABR results for various transducers. Table 4.35 summaries the participant data collected regarding ABR correction values applied, when participants were asked the direct question regarding correction values used.

Table 4.35

Summary of Participant Data Collected for ABR Correction Values (Direct Question) (N=34)

	% (n)					
	Headphones		*Insert phones*		*Bone conduction*	
Participant Category	*Click*	*TB ABR*	*Click*	*TB ABR*	*Click*	*TB ABR*
Correction value data available	47 (16)	53 (18)	73 (25)	79 (27)	65 (22)	68 (23)
Not currently fitting	3 (1)	3 (1)	3 (1)	3 (1)	3 (1)	3 (1)
Not using/do have transducer	26 (9)	26 (9)	--	--	--	--
Missing data	3 (1)	--	3 (1)	--	3 (1)	3 (1)
Unsure	18 (6)	15 (5)	18 (6)	15 (5)	26 (9)	23 (8)
Rely on ABR/ASSR report	3 (1)	3 (1)	3 (1)	3 (1)	3 (1)	3 (1)

Table 4.36 shows results for insert phones and headphones, while Table 4.37 displays results for the BC transducer. Participants responding that they would not apply any correction values were included in this data as a 0dB correction value. Correction values provided by participants were therefore compared to recommended correction values of -15, -10, -5 and 0dB correction values, for 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz respectively (BCEP, 2008); as well as Stevens et al. (2007) recommended correction values of -5, -20, -15, -10 and -5dB correction values for click, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz respectively. The Stevens et al. (2007) recommendations were used for comparison of participants reported correction values, in preference to the updated Stevens et al. (2011) recommendations. This is due to this study being developed considering the (2007) guideline and data collected prior to the (2011) guideline being released.

Not all participants provided the researcher with correction values for all transducers - this was mainly due to 26% (*n*=9) not utilising headphones. Many participants were also unsure what correction values they would apply, despite being given the

opportunity during the interview to look up correction values if required. Of these participants, 18% (*n*=6) were unsure for click ABR, and 15% (*n*=5) were unsure for tone burst stimuli (both insert phones and headphones). The greatest uncertainty was seen for the BC transducer, where 26% (*n*=9) of participants for click ABR and 23% (*n*=8) of participants for tone burst stimuli, were unsure as to what correction values to apply.

Thirty-one participants answered the question regarding whether they would apply different correction values for infants less than three months of age. Only 10% (*n*=3) of these participants responded that they would apply different correction values for this age group. These participants stated that they may be more conservative with the fitting, but were unclear on the exact levels they would use. One participant stated that they would input the HL as +-20dB less than the actual hearing levels, while another would input +-15dB less. The remaining participant stated that he/she would fit more conservatively for this age group if he/she was concerned about the results. Another six participants stated that their colleagues applied correction values at assessment, but that they were unsure what these correction values were for various ages.

Table 4.36

Air Conduction ABR Correction Values Applied and Comparison to the BCEP, (2008) & Stevens et al., (2007) (> 3 months C.A.) Guidelines

		Correction value per stimulus type and t-test values						
Transducer Type	*Data category*	*Click (n=16)*	*500 Hz (n=18)*	*1kHz(n=18)*	*2kHz (n=18)*	*4kHz (n=18)*	*6kHz***	*8kHz***
Headphones	Mean (dB)	-0.625	-3.75	-3.194	-2.639	-2.639	--	--
	Median (dB)	0	0	0	0	0	--	--
	SD (dB)	9.421	12.013	11.042	10.378	10.378	--	--
	Range (dB)	-20 to 20	-25 to 20	-20 to 20	-20 to 20	-20 to 20	--	--
	Comparison to Stevens et. al. (2007) recommended correction values							
	ɬAMP(over-under-correct)(n)	13:3:0	14:2:2	14:3:1	13:3:2	12:5:1	--	--
	t	1.858	5.739	4.536	3.009	0.965	--	--
	p-value (2-sided)	0.083	0.000*	0.0003*	0.008*	0.3479	--	--
	Comparison to BCEP, (2008) recommended correction values							
	ɬAMP(over-under-correct)(n)	--	14:3:1	13:4:1	12:5:1	2:6:10	--	--
	t	--	3.973	2.615	0.965	-1.079	--	--
	p-value (2-sided)	--	0.001*	0.0181*	0.348	0.296	--	--
Insert phones		Click (*n*=25)	500 Hz (*n*=27)	1kHz (*n*=27)	2kHz (*n*=27)	4kHz (*n*=27)	6kHz (*n*=3)	8kHz (*n*=2)
	Mean (dB)	-5.1	-11.111	-9.444	-8.148	-7.778	-15	-12.5
	Median (dB)	0	-10	-10	-10	-10	-15	-12.5
	SD (dB)	8.084	12.487	10.569	9.796	9.716	5	3.536
	Range (dB)	-20 to 15	-35 to 15	-25 to 15	-25 to 15	-25 to 15	-20 to -10	-15 to -10
	Comparison to Stevens et. al. (2007) recommended correction values							
	ɬAMP(over-under-correct)(n)	14:10:1	14:6:7	14:9:4	12:9:6	12:14:1	--	--
	t	-0.062	3.699	2.731	0.982	-1.486	--	--
	p-value (2-sided)	0.951	0.001*	0.011*	0.335	0.149	--	--
	Comparison to BCEP, (2008) recommended correction values							
	ɬAMP(over-under-correct)(*n*)	--	14:11:2	12:13:2	12:15:0	1:15:11	--	--
	t	--	1.618	0.273	-1.670	-4.160	--	--
	p-value (2-sided)	--	0.118	0.787	0.1069	0.0003*	--	--

Note: p-value significant at the p<0.05 level

* *p*-values indicating a significant difference between the correction values provided by participants and recommended correction values

** No recommended correction values available for 6kHz and 8kHz in the BCEP (2008) and Stevens et. al. (2007) guidelines

ɬ Amplification provided, i.e. over-amplification : under-amplification : correct amount of amplification.

Table 4.37

BC ABR Correction Values Applied and Comparison to Stevens et al., (2007) (>3 months corrected age) Guideline

		Correction value per stimulus type and t-test values				
Transducer Type	*Data category*	*Click (n=22)*	*500 Hz (n=23)*	*1kHz(n=23)*	*2kHz (n=23)*	*4kHz (n=23)*
Bone conduction	Mean (dB)	-2.72	-5.109	-4.457	-4.239	-4.022
	Median (dB)	0	0	0	0	0
	SD (dB)	6.497	10.014	8.853	8.375	8.283
	Range (dB)	-12.5 to 15	-25 to 15	-20 to 15	-20 to 15	-20 to 15
	ǂAMP(over-under-correct)(n)	15:6:1	18:2:3	18:3:2	15:4:4	15:7:1
	t	1.641	7.132	5.711	3.299	0.566
	p-value (2-sided)	0.1157	0.000*	0.000*	0.003*	0.0577

Note: *p*-value significant at the $p<0.05$ level

* *p*-values indicating a significant difference between the correction values provided by participants and recommended correction values

ǂ Amplification provided, i.e. over-amplification : under-amplification : correct amount of amplification.

One-sample *t*-tests were employed to determine whether there was a statistically significant difference between participant responses and recommended guidelines (BCEP, 2008; Stevens et al., 2007). The Stevens et al. (2007) correction values for infants over three months of age were utilised for comparison, as participants did not report utilising specifically different correction values for infants less than three months of age (See Tables 4.36 & 4.37).

When compared to the correction values used for post-aural headphones (Stevens et al., 2007), one-sample *t*-test values showed a statistically significant difference between recommended correction values and participants responses for TB ABR at 500 Hz (p = 0.000), 1000 Hz (p = 0.0003) and 2000 Hz (p = 0.008). For insert earphones, statistically significant differences were found for TB ABR at 500 Hz (p = 0.001), and 1000 Hz (p = 0.011). Correction values for the BC transducer were statistically significantly different for TB ABR at 500 Hz (p = 0.000); 1000 Hz (p = 0.000) and 2000 Hz (p = 0.003).

Compared to the BCEP (2008) recommendations, participants' correction values for headphones were statistically significantly different for TB ABR at 500 Hz (p=0.001) and 1000 Hz (p=0.0181) at the 5% confidence level. For insert earphones, participants correction values were statistically different for 4000 Hz (p= 0.0003) TB ABR measures only. These significant differences indicate that the audiologists who participated in this study are not applying appropriate correction values to ABR results.

To investigate the adherence to correction values, participants were also asked what values they would use for HA fitting, based on a set of ABR results shown to them, for a two-year-old child. This question was asked prior to the direct question of what correction values

are applied. Details of participants responding to this question are shown in Table 4.38. Seventy-six percent (*n*=26) and 79% (*n*=27) of participants responded to this question for click ABR and TB ABR respectively. When comparing participants' responses to the two correction value questions, namely: the direct question regarding what correction values were applied, as well as the question asking how one would use a set of ABR results for HA fitting, 4 participants applied different correction values to the two questions.

Table 4.38

Summary of Participant Data Collected for ABR Correction Values (ABR Example Given) (N=34)

	Headphones/Insert phones % (n)	
	Click (N=34)	*Tone Bursts (N=34)*
Participants providing response	76 (26)	79 (27)
Not currently fitting	6 (2)	6 (2)
Usually fit using ASSR	6 (2)	6 (2)
Unsure	12 (4)	9 (3)

The correction values used were extrapolated from the hearing levels that participants reported using for HA fitting for the set of ABR results (See question 41 - Appendix E). These correction values are presented in Table 4.39. For participants who did not apply correction values to the ABR example shown, responses were entered as a 0dB correction value for analysis.

Table 4.39

Correction Values that Would be Used for HA fitting, as Extrapolated From a set of ABR Thresholds for a 2 Year old

		Correction value per stimulus type and t-test values				
Transducer Type	*Data*	Click (*n*=26)	500 Hz (*n*=27)	1kHz (*n*=27)	2kHz (*n*=27)	4kHz (*n*=27)
Air conduction (Headphones/inserts)	Mean (dB)	-5.096	-9.722	-8.148	-6.944	-6.481
	Median (dB)	0	-10	-10	-10	-5
	SD (dB)	9.260	13.070	11.215	10.408	10.197
	Range (dB)	-20 to 20	-35 to 20	-25 to 20	-25 to 20	-25 to 20
	Comparison to Stevens et. al. (2007) recommended correction values					
	AMP(over:under:correct)(n) ǂ	15:11:0	15:5:7	15:8:4	13:8:6	13:13:1
	t	-0.053	4.086	3.175	1.525	-0.755
	p-value (2-sided)	0.958	0.0004*	0.004*	0.139	0.457
	Comparison to BCEP, (2008) recommended correction values					
	AMP(over:under:correct)(n) ǂ	--	15:10:2	13:12:2	13:14:0	2:14:11
	t	--	2.098	0.858	-0.971	-3.303
	p-value (2-sided)	--	0.046*	0.3987	0.341	0.003*

Note: p-value significant at the $p<0.05$ level

* *p*-values indicating a significant difference between the correction values provided by participants and recommended correction values

ǂ Amplification provided, i.e. over-amplification : under-amplification : correct amount of amplification.

One-sample *t*-tests were employed to determine whether there was a statistically significant difference between participant responses and recommended guidelines. The BCEP (2008) and Stevens et al (2007) recommended correction values for children over three months of age were used for comparison. Participants' responses were statistically significantly different (at the 5% confidence level) for TB ABR at 500 Hz (p = 0.0004) and 1000 Hz (p = 0.004), compared to Stevens et al. (2007) recommended values. Compared to the BCEP (2008) recommendations, participants' responses were statistically significantly different for 500 Hz (p = 0.046) and 4000 Hz (p = 0.003). This indicates that the majority of audiologists participating in this study do not apply recommended correction values. Most participants would therefore be under- or over-amplifying, resulting in HA fitting not being optimal.

The correlation between correction values used and experience post qualification (per category of years of experience) were calculated, using Pearson's correlation coefficient (see Table 4.20). No significant relationship was found for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for insert phones, headphones and BC transducers.

Table 4.40

Pearson Correlation Co-efficient Values (Correction Value vs. Experience Category)

Pearson's Correlation Co-efficient Values (r) (correction value vs. experience)					
Transducer Type	*Click*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*
	Direct Question re correction values applied				
Headphones	-0.376	-0.428	-0.438	-0.405	-0.405
Insert Phones	-0.101	-0.436	-0.418	-0.299	-0.265
Bone Conduction	-0.311	-0.230	-0.267	-0.269	-0.283
	ABR Example given to participants				
Air Conduction (Headphones/Inserts)	-0.151	-0.439	-0.431	-0.306	-0.276

Table 4.41 shows the correlation co-efficient values obtained by comparing the correction values applied to the direct question versus the ABR example given. The closer a correlation value is to -1.00 or +1.00, the stronger the correlation. A correlation co-efficient of -1 or +1 indicates a perfect fit, while a value of 0 indicates no correlation between variables (Gravetter & Forzano, 2003). A strong correlation was found for TB ABR utilising headphones. The correlation co-efficient values were *r*= 0.890; *r*= 0.870; *r*= 0.851 and *r*= 0.852 TB ABR values at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz respectively. Similarly, for insert earphones a strong correlation was found for TB ABR values at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, where correlation co-efficient values were *r*= 0.911; *r*= 0.873; *r*= 0.850 and *r*= 0.844 respectively. This indicates that there was no significant difference between participants' responses to the direct correction value question, and correction values applied to the ABR example given, for TB ABR.

A slightly weaker relationship was found for click stimuli, as Pearson correlation co-efficient values were *r*= 0.665 and *r*= 0.705 for headphones and insert earphones respectively. This suggests more variation in participants' responses between correction values provided for the direct question versus the example given, for click stimuli.

Table 4.41

Pearson Correlation Co-efficient Values: Corrections Applied (Direct Question vs. Example)

	Pearson's Correlation Co-efficient Values per stimulus type				
Transducer Type	*Click*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*
Headphones	0.665	0.890	0.870	0.851	0.852
Insert Phones	0.705	0.911	0.873	0.850	0.844

The application of correction values allows for the accurate estimation of a child's HL for HA fitting (Bagatto, 2008). Despite this, only just over half of participants stated that

they were applying correction values to their ABR dBnHL values. The rest of the participants were either unsure what correction values had been applied by their colleagues, or if they would apply correction values themselves. This shows a lack of understanding regarding the application of correction values to estimate behavioural thresholds.

Overall, there appeared to be confusion and lack of consensus regarding the application of correction values to ABR results to estimate behavioural thresholds for HA fitting. The findings indicate that when considering over or under-amplification versus correct amount of amplification provided (for all transducers and stimuli), participants would either be over- or under-amplifying during paediatric HA fitting. The exception was for 4000 Hz using the BCEP (2008) recommended correction value. As the BCEP (2008) correction value for 4 kHz is 0dB, it is likely that this result was, however, greatly influenced by the inclusion of participants not using correction values as a 0dB correction value.

The greater uncertainty regarding correction values for the BC transducer may have been contributed to by additional correction values being recommended for young babies (<12 weeks corrected age). There is uncertainty regarding the correction values for 500 Hz and 1000 Hz BC thresholds for this age group (Stevens et al., 2011). In addition, a lack of experience in using this transducer during ABR assessment may have contributed to this result.

There was also a great variation reported regarding the stage at which correction values were being applied. This variation means that if results are not clearly documented, then no correction, or a double correction, may be incorrectly applied to estimate behavioural thresholds during HA fitting. To avoid such confusion and potentially inaccurate HA fitting,

it is recommended that reports document ABR results in both dBnHL and dBeHL thresholds (Stevens et al., 2011).

The importance of applying different correction values for different aged infants cannot be emphasised enough. As infants and young babies have smaller ear canal volumes than adults, there are louder SPLs in the ear canal when the same level stimulus is passed through a transducer (Green, 2004). Smaller ear canals result in greater sound intensity (Green, 2004). Despite this, only 10% (*n*=3) of participants reported that they would apply different correction values for this age group. These participants were, however, unsure what correction values to apply.

It is therefore evident that many of the infants and young children fitted with HAs by the participants in the current study are not being optimally fitted. Optimal HA fitting is vital in children to ensure oral language development, as well as promoting socio-emotional and cognitive development (Boothroyd, 2000).

4.5.3 Correction values for ASSR

Only 28 participants were using ASSR results for HA fitting. Of these, 64% (*n* =18) responded that they would use the manufacturer's estimated audiogram for fitting. Seven percent (*n*=2) provided varied responses (e.g. HAs were programmed by HA company, or that no test values were provided in reports). Another 7% (*n*=2) of participants were unsure how they would use the results, stating that they might use the manufacturer's estimated audiogram. On further probing they were, however, not aware of what the manufacturer's correction values were. Eleven percent (*n*=3) of participants would use the results 'as is',

without applying any correction values and another 11% (*n*=3) responded that they would use their own correction values.

Only five participants' responses were considered with regards to what correction values they were applying. Two of these participants responded that they applied their own correction values and another three stated that they would use the results 'as is', which the researcher considered as a 0dB correction value (See Table 4.42). As one participant responded that they only used insert earphone results, and not BC or post-aural headphones, no data was entered for these transducers (See Table 4.42). The average correction values applied for post-aural headphones were -1.25 dB (*SD* = 2.5) across stimulus type (250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz). Similarly, for insert phones (*N*=5), participants' responses were the same across stimulus type, with an average of -2 dB (*SD* = 4.472). For the BC transducer, all participants (*N* = 4) provided a 0dB correction value for ASSR results. Further statistical analysis of the correction values provided was not completed due to the small sample size.

Table 4.42

Correction Values Participants Would Apply to ASSR dBnHL Values to Estimate Behavioural Thresholds for HA Fitting

		Stimulus type				
Transducer Type		*250 Hz*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*
Headphones (*N*=4)	Mean (dB)	-1.25	-1.25	-1.25	-1.25	-1.25
	Median (dB)	0	0	0	0	0
	SD (dB)	2.5	2.5	2.5	2.5	2.5
	Range (dB)	-5 to 0	-5 to 0	-5 to 0	-5 to 0	-5 to 0
Insert phones (*N*=5)	Mean (dB)	-2	-2	-2	-2	-2
	Median (dB)	0	0	0	0	0
	SD (dB)	4.472	4.472	4.472	4.472	4.472
	Range (dB)	-10 to 0	-10 to 0	-10 to 0	-10 to 0	-10 to 0

Participants were also shown a set of ASSR results for an 18-month old child and asked what values they would use for HA fitting. The corresponding correction values were extrapolated from their responses (See Table 4.43). The average correction value reported, across stimulus type, was -4.167 dB (range= -17.5 to 5 dB; *SD*= 7.906). Inconsistencies were noted in participant responses when comparing responses given to the two ASSR correction value questions, i.e. i) the direct question regarding what ASSR correction values were being used, and ii) the correction values applied to a set of ASSR results shown for HA fitting. Forty percent (n=2) of the five participants responding to the direct ASSR correction value question, provided different correction values to the ASSR example given. One of the two participants provided different correction values, while the other was unsure how to use the ASSR example given for HA fitting, and gave a 0dB correction value during the direct question.

Table 4.43

Correction Values Participants Would Use for HA fitting Based on ASSR Results Obtained for an 18 Month Old.

		Stimulus type				
Transducer Type	***Data***	*250 Hz*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*
Air Conduction (*N*=9)	Mean	-4.167	-4.167	-4.167	-4.167	-4.167
	Median	0	0	0	0	0
	SD	7.906	7.906	7.906	7.906	7.906
	Range (dB)	-17.5 to 5	-17.5 to 5	-17.5 to 5	-17.5 to 5	-17.5 to 5

Participants were asked if they applied different correction values to ASSR results for infants less than three months of age. Data of only 25 participants was included in analysis, as these participants fitted HAs based on ASSR. Only one participant (4%) reported applying different correction values for infants younger than three months of age, while 68% (n=17)

were not applying different correction values. One participant (4%) reported they would be more conservative during fitting, but had not fitted a baby less than three months of age, while another two participants (8%) were unsure if they would apply different correction values. One participant (4%) used the manufacturer's estimated audiogram, while another (4%) reported that their colleague applied correction values. The remaining two participants (8%) reported that the HA supply company programmed the HAs, but were unaware what correction values the HA company applied.

Participants were asked if they applied different correction values for infants less than three months of age for ASSR measures. Twenty-two participants (65%) answered this question. Of these, two participants (6%) reported that the HA company fitted the HAs and they were unaware what correction values the company used for younger infants. Another two participants (6%) stated that they used the manufacturer's estimated audiogram, while 17% (n=6) reported not using ASSR results for HA fitting. For one participant (3%) the data for this question was not recorded and missing, while the remaining participant (3%) did not report fitting HAs to infants less than three months of age. Of the twenty-two participants answering this question, 82% (*n*=18) responded that they would not apply different correction values, while 9% (*n*=2) stated they were unsure if they would apply different correction values. Another participant 4.5% (*n*=1) stated that he/she would be conservative, but had not, as yet, fitted a child this young. The participant (4.5%) stating that he/she would apply a different correction value, stated that they would apply their own subjective correction value based on the degree and shape of the HL and monitor after the initial HA fitting.

The majority of participants reported using the manufacturer's estimated audiogram for HA fitting. They were, however, unaware of what these correction values were. This

indicated complete trust in the manufacturer's algorithms, without any understanding or knowledge of what correction values the manufacturers were utilising.

In contrast to the recommended guidelines (Stevens et al., 2007), none of the participants suggested using different correction values for varying degrees of HL, which may lead to under- or over-amplification during HA fitting. Another factor that may lead to the over- or under-amplification during HA fitting (based on ASSR results), is the incorrect application of correction values for infants under the age of three months (Stevens et al., 2007). The majority of participants in this study stated that they would not apply different correction values, while the rest stated that they would not apply different correction values for infants less than three months. Overall, there appeared to be a limited understanding of how to utilise ASSR results for paediatric HA fitting.

Additional comments made by participants included that they were not currently seeing, or had not seen, a baby of less than three months of age for HA fitting. This is likely due to the later age of identification of HL in South Africa (Strauss, 2006; van der Spuy & Pottas, 2008). This late identification of HL in South Africa unfortunately leads to a lack of experience for South Africa clinicians with working with young infants.

4.5.4 Why correction values were not applied to ABR/ASSR results

Sixteen participants gave reasons for not applying correction values to their ABR and/or ASSR results (See Figure 4.5). Nearly half of the sixteen participants 44% (n=7) stated that they did not feel it was necessary to apply correction values (25%, n=5), or were unaware that correction values existed (19%, n=3). The remaining participants (56%, n=9), provided various other reasons for not applying correction values. These included: relying

on the report sent by the department completing ABR/ASSR assessment, but being unsure whether results were reported in dBnHL or dBeHL (31%, n=5); own clinical decision making post-HA fitting (12.5%, n=2); and being aware there were correction values, but not being sure what to use or how to use them (12.5%, n=2).

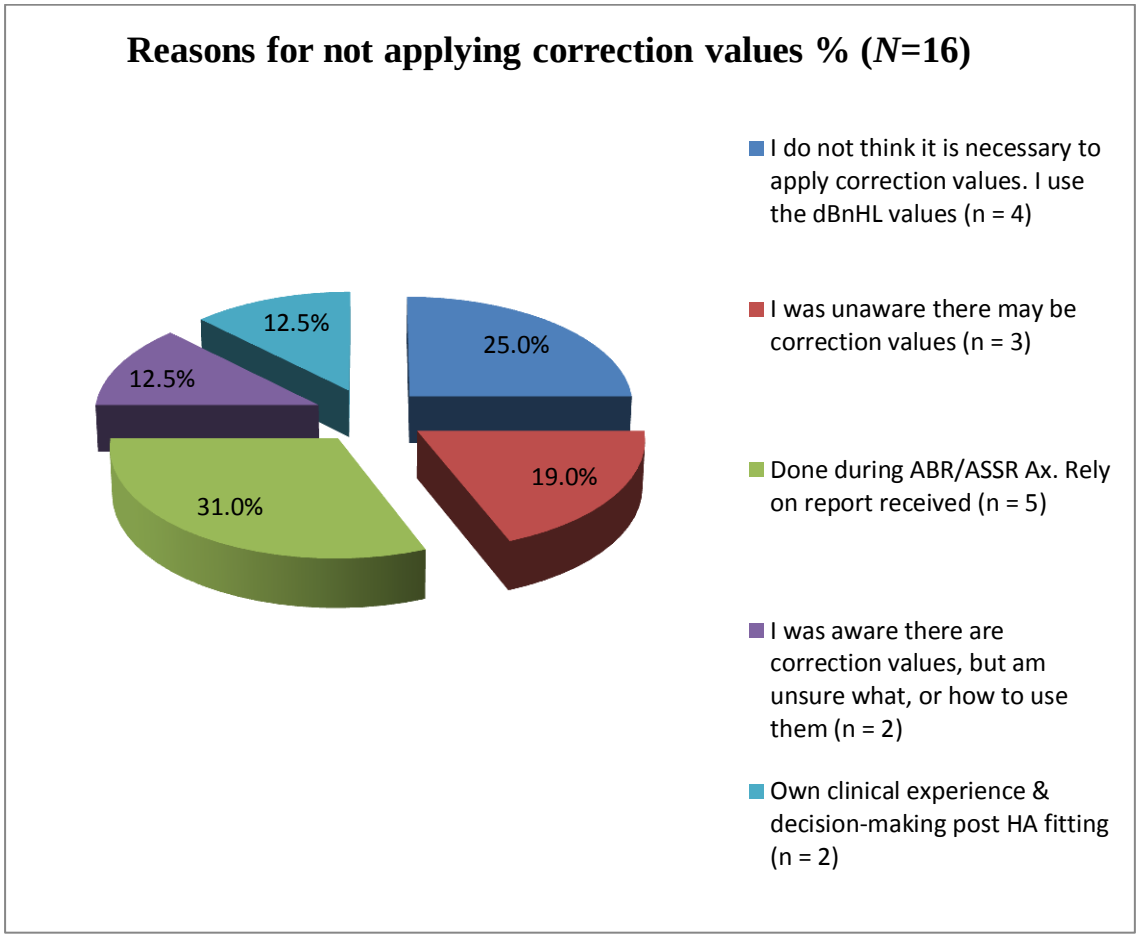


Figure 4.5

Reason for not Applying Correction Values to ABR/ASSR Results (N=16)

Estimation of behavioural thresholds from ABR measures is required for HA fitting, as well as for accurate comparison of later behavioural pure tone audiometry results with ABR measures (Sutton, 2008). Estimation of behavioural thresholds from ASSR results is also important for accurate estimation of behavioural thresholds (Stevens et al., 2007; Stevens et al., 2011). Despite this, for participants partaking in this study, there appeared to be

confusion regarding the importance of applying correction values, as well as who should be applying correction values. Nearly a third of clinicians relied on the report received from the department undertaking ABR/ASSR assessment, but they were unaware of whether results were reported in dBnHL or dBeHL values, and what correction values had been applied. These participants were involved with subsequent HA fitting post ABR/ASSR assessment, and would then be fitting HAs with no knowledge of correction values having been applied, or not having been applied. This will make accurate HA fitting challenging, due to uncertainty regarding whether any correction values had been applied, or should be applied. Two of the participants stating that they did not feel it was necessary to apply correction values, stated that this was due to the majority of the hearing losses they saw being profound hearing losses, and they did not feel it was necessary to apply correction values with this degree of HL. Non-application of correction values in these cases may lead to incorrect diagnosis regarding the degree of HL as well as inaccurate HA fitting.

The comments and responses from sixteen of the participants show a lack of understanding regarding the application of correction values to ABR and /or ASSR results for accurate threshold estimation and subsequent HA fitting. Many appeared unsure as to how to use these results effectively for paediatric HA fitting. There was also the perception that it was not beneficial or necessary to apply correction values to profound hearing losses, despite guidelines recommending correction values be applied, (BCEP, 2008; Stevens et al. 2007 & Stevens et al. 2011).

4.6 Summary

This chapter highlighted the results of the research and were organised, analysed and described as it relates to the aims of the research. Results from this study found that only 44% (*n*=15) of participants reported having a paediatric HA fitting guideline, while only 47% (*n*=8) of participants reported having an ABR/ASSR assessment /guideline. A lack of awareness of protocols available within departments was evident, as participants from the same department responded with different responses regarding whether protocols were available. Similarly, there were varied responses from public sector participants regarding the equipment available at the same department, suggesting a lack of awareness of accessible resources. It was further evident that participants did not always appear to utilise age-appropriate assessment measures and the application of certain audiological measures did not adhere to recommended guidelines. There further appeared to be an over-reliance on electrophysiological measures and lack of confidence in behavioural measures.

There was a lack of understanding regarding the application of correction values to ABR and ASSR measures for paediatric HA fitting. Some participants were not applying correction values to ABR and/or ASSR results, as they did not feel this was necessary or were unaware they should do so. For those participants applying correction values, there was no consensus amongst participants regarding what correction values should be applied. Participants receiving results for HA fitting relied on the reports they received, but many were unaware what correction values had or had not been applied. The majority of clinicians did not appear to be undertaking clinical practice based on a strong evidence-base, which is important in promoting high quality, effective and standardised care (Moodie et al. 2011).

Chapter Five: Conclusions

5.1 Introduction

This chapter will discuss the significance of findings from this study, limitations, as well as recommendations and implications of the study. The methodological and general limitations of this study, as well as findings, will guide the recommendations, which are discussed in relation to clinical, theoretical and research implications.

5.2 Summary of the findings

The main aim of this study was to describe the current South African audiological clinical practice for paediatric HA fitting, with specific reference to the application of ABR and ASSR measures.

5.2.1 Paediatric HA fitting; and ABR and/or ASSR assessment protocols

The use of current, evidence-based practice for paediatric HA fitting is important in ensuring that secondary developmental delays associated with a delay in early intervention for children with HL, are ameliorated. Despite this, it was found in the current study that limited departmental protocols exist within departments for both ABR/ASSR assessment and paediatric HA fitting. The adherence to available protocols is also questioned, as some participants, within the same department, were unaware of existing protocols.

5.2.2 **Availability of audiological equipment**

Overall, there appeared to be a wide variety of equipment available to both the private and public sector departments where participants were interviewed. Public sector departments had less access to certain items of equipment, particularly diagnostic OAE, as well as HAs, for which long waiting times in the public sector existed. Public sector participants experienced particular challenges with the timeous repair of equipment by hospital management. Participants from the public sector were not always aware of equipment and equipment features available to them. Varied responses were provided by participants regarding the availability of certain items of equipment, in particular screening equipment, diagnostic OAEs, high versus low frequency tympanometry, as well as sound level meters. There was a lack of availability of certain items of audiological equipment, including REM equipment for verification of paediatric HA fitting, in both the private and public health sectors. There was limited access to sound level meters and high frequency tympanometry.

5.2.3 **Audiological measures used for paediatric HA fitting**

Results suggested a lack of adherence to recommended guidelines with regards to the appropriate utilisation of audiological measures for various age groups. There appeared to be an over-reliance on electrophysiological measures. Some participants did not appear to have confidence in the behavioural results they were obtaining. A statistically significant difference was found between the age at which participants started completing behavioural testing and recommended guidelines. Contrary to recommended guidelines, not all participants stated that they would use a high frequency probe tone for immittance testing of infants less than six months of age. A statistically significant difference was found between the age that participants were utilising high frequency tympanometry and recommended

guidelines. Participants' responses regarding the most frequently utilised TB ABR measures, as well as the order of TB ABR testing, were in contrast to recommended guidelines, leading to potentially unnecessarily wasted clinical time. With regards to acceptable ABR thresholds suggesting normal hearing thresholds, there was a statistically significant difference between participants' responses and recommended guidelines for most stimuli. This indicates a lack of adherence to recommended guidelines as well as potentially wasted clinical assessment time.

5.2.4 **Application of correction values to ABR and ASSR measures**

There was a lack of consensus regarding the application of correction values to ABR and ASSR results. Correction values utilised by participants often differed statistically significantly to recommended guidelines. There also appeared to be a lack of understanding regarding the use of different correction values for younger infants - relating to their smaller ear canal size.

5.3 Strengths

Strengths of the study included:

- The methods used in this study may be applied to other studies to investigate adherence to clinical paediatric HA fitting and ABR/ASSR assessment guidelines.

- The study provided specific information regarding current audiological clinical practice for paediatric HA fitting in the Gauteng Province, South Africa.

5.4 Limitations

5.4.1 Methodological

The following methodological limitations to this study exist:

- The descriptive research design, utilising a survey research tool, relies on participants honest and transparent responses to questions, but participants may conceal information, or not have knowledge about the questions they are asked. The findings of this study can only describe participants' *reported* clinical practice, which may differ to actual practice in some cases (Gravetter & Forzano, 2003).

- As a purposive sampling method was employed, participants were only recruited from the Gauteng Province. This study can therefore not make inferences about the clinical practice of audiologists throughout South Africa.

- As interviews were not recorded, inter-rater reliability could not be established, thus reliability of results may therefore be affected. Observer error occurs when human error affects how responses are recorded (Gravetter & Forzano, 2003). Observer error was reduced by utilising predominantly closed-ended questions and carefully recording participant responses to questions. If the researcher did not understand a response given by a participant, clarification was requested.

- The majority of participants were employed in public sector audiology departments. Although a limitation of the study, it is representative of the typical distribution of

audiologists' employed in Gauteng. It is further argued that the majority of the South African population only have access to public health care.

5.4.2 General

- The current study did not explore the following:
    - The confidence levels of audiologists with regard to ABR/ASSR assessment and paediatric HA fitting: The confidence in their own skills and ability within these clinical areas may have affected their responses to certain questions such as the correction values utilised.
    - The use of validation methods by participants during the HA fitting process.
    - Audiologists knowledge on the acceptable hearing levels for discharge (i.e. results suggesting normal hearing) for ASSR.
    - The clinical equipment parameters for ABR and ASSR assessment utilised by participants.

5.5 Recommendations

The findings from this study provide several recommendations and implications for paediatric audiology in South Africa in order to promote development of this area in this country. Recommendations based on this research are discussed in relation to possible research topics, guidelines and continued professional development, as well as clinical practice, equipment and policy implementation needs.

5.5.1 Research topics

The results revealed interesting trends. Preliminary answers and many more questions were raised that can be answered by conducting research in the following areas:

- The development, implementation, feasibility and effectiveness of national, evidence-based guidelines for both paediatric ABR/ASSR assessment and HA fitting.

- To determine clinicians' confidence in their own clinical skills for ABR/ASSR assessment and paediatric HA fitting. This could be compared to internationally-recommended clinical practice guidelines, to determine whether clinical confidence in these areas affects clinical practice in South Africa.

- To determine the level of experience that South African audiologists have with working infants less than six months of age, and how this relates to their clinical practice.

- To determine the effectiveness of South African audiologists' clinical skills in the behavioural assessment of infants and young children's hearing.

- To describe the use of validation methods utilised by clinicians during the paediatric HA fitting process.

- To describe the acceptable levels of discharge (i.e. results suggesting normal hearing) for ASSR, utilised by clinicians and how these compare to recommended guidelines.

- To describe the clinical equipment parameters utilised by South African clinicians for paediatric ABR and ASSR assessment, and how these compare to recommended guidelines.

- To describe clinical practice with regards to the interpretation and classification of high frequency tympanometry by South African audiologists.

5.5.2 Guidelines

Development of South African national, evidence-based guidelines:

In South Africa, there are currently no nationally-agreed guidelines or standards for paediatric HA fitting or ABR/ASSR assessment. Based on findings from the current study, it is recommended that the national guidelines should, in addition to other relevant aspects, include the following:

ABR and ASSR assessment protocol:

Separate guidelines should be developed for adult and paediatric patients, as the clinical application and test parameters vary between the two age groups. It is proposed that these guidelines include:

- Recommended manufacturer and biological calibration guidelines.

- Recommended recording parameters for ABR and ASSR.

- The order in which ABR testing should be completed to ensure that a holistic view of a child's HL is obtained across the frequency range.

- Recommended acceptable levels for ABR and ASSR testing, suggesting satisfactory hearing sensitivity.

- Information on when correction values should be applied to ABR and ASSR results. To assist with this, a standard reporting form should be included in the paediatric ABR and ASSR guideline with sections to include dBnHL, dBeHL values and reference correction values utilised. This would facilitate the standardisation in reporting, and in ensuring that correction values are correctly utilised.

- A section stating how ABR and ASSR results should be used for fitting HAs to children.

HA fitting protocol:

- Levels of service delivery and the minimum equipment required to promote standard levels of care.

- Recommendations on time frames between diagnosis and initial HA fitting. This will assist public sector departments, with long HA waiting times, to motivate for increased budgets or quicker HA order processing times.

- The utilisation of ABR and ASSR correction values to estimate behavioural thresholds for paediatric HA fitting.

Once final guidelines have been released, departments should develop their own internal guidelines by referring to national guidelines, as well as providing clinic-specific

procedures (if appropriate). This will assist with standardisation of care and sustainability of services.

In the interim, it is recommended that departments develop their own guidelines based on evidence-based practice. All team members within a department should be aware of guidelines available to them.

5.5.3 Continued professional development

This study has shown that within certain areas, the knowledge of South African clinicians regarding current, recommended paediatric audiology practice appears to be lacking. With the tremendous advancements within the field of paediatric audiology (Bess & Gravel, 2006), it is a clinician's ethical and professional responsibility to continually improve their knowledge and skills in all the clinical areas in which they practice. Continued professional development is vital in ensuring that clinicians maintain acceptable standards of practice (Battle, 2007).

5.6 Implications

5.6.1 Clinical Practice

Findings from this study have a number of important implications for future clinical practice in paediatric audiology in South Africa.

- It is the responsibility of clinicians to continually improve their knowledge and skills in working with infants and young children. This will ensure evidence-based clinical practice in the areas of behavioural audiological assessment, high-frequency

tympanometry, ABR and ASSR test parameters, the application of correction values for HA fitting and verification of HAs with REMs.

- The streamlining of clinical service requires that all team members should be aware of the available guidelines, resources and equipment.

- In order to promote clinical transparency, reports on the ABR and/or ASSR assessments for HA fitting should be as comprehensive as possible. It is recommended that it should include a print-out of results, a clear indication of the correction values that were used, and what values should be used for HA fitting. Documented results after assessment should include both dBnHL and dBeHL values (BCEP, 2008). It is the responsibility of clinicians utilising these results for HA fitting to critically evaluate the results and make their own evidence-based clinical judgement to ensure effective and appropriate amplification.

5.6.1.1 Equipment

It is imperative that clinicians have access to audiological equipment that is relevant for use in the paediatric population, is well-maintained and timeously repaired. HAs should also be readily available to ensure that if a paediatric HL is identified, the fitting takes places within a month after diagnosis (JCIH, 2007). Adequate funding for the procurement and maintenance of equipment and HAs should be a priority, as without fully functioning equipment and available HAs, audiologists cannot effectively perform their role and meet the needs of children with HL.

5.6.1.2 Policy

- *Universal newborn hearing screening & EHDI*

Universal hearing screening may be viewed as a costly endeavour, but one which will assist many children in becoming functioning members of society and eventual tax payers (Yoshinago-Itano & Gravel, 2001). It is therefore imperative that the HPCSA's 2007 Position Statement on EHDI is implemented in South Africa. For this to be a viable project, it should be supported by the National Department of Health, with dedicated funding for human and equipment resources, and effectively monitored to ensure sustainability.

5.7 Summary

This chapter summarised the findings of the research. By means of a critical evaluation of the research, combined with a discussion of the study's strengths and weaknesses, the validity of the study is established. The research, theoretical, and clinical implications of the research were pointed out.

Given the dearth of information regarding the South African audiological clinical practice in terms of the use of ABR and ASSR measures for paediatric HA fitting, this study has provided the groundwork for future more in-depth research. This may include replication, refinement and expansion of the current study in various ways that would allow for generalisation of results beyond this specific population.

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Appendices

Appendix A: Informed consent letter



SPEECH PATHOLOGY AND AUDIOLOGY

School of Human & Community Development

Faculty of Humanities



University of the Witwatersrand
Private Bag 3, W ITS, 2050
Tel: (011) 717 4577; Fax: (011) 717 4572

THE APPLICATION OF ELECTROPHYSIOLOGICAL MEASURES FOR FITTING HAS TO SOUTH AFRICAN CHILDREN

Dear Audiologist,

My name is Leanne Grimshaw; I am an Audiology Masters student from the University of the Witwatersrand. As part of the requirements for my studies I am required to complete a research dissertation. The aim of this study is to examine how South African clinicians are utilising ABR(ABR) and Auditory Steady State Response (ASSR) results for paediatric HA fitting. I wish to invite you to participate in this study. You may withdraw from the study at any stage without negative consequences.

Due to newborn hearing screening programmes, children with HL are being identified at earlier ages. This has resulted in more children being assessed using electrophysiological measures to identify a HL and subsequently fit HAs. For my Audiology Masters study, I wish to further investigate the:

- Use of ABR and ASSR measures for paediatric HA fitting.
- Current equipment calibration standards used by manufacturers and hospitals for ABR equipment.

It is envisaged that this study will assist in developing national guidelines for paediatric HA fitting, based on electrophysiological measures. This will have the following benefits:

- Assist with the comparison of results across Audiology departments.
- Ensure that HA fittings are as accurate as possible, based on current research, thereby ensuring that patients are given the best access to audition, as is feasible.

There are no known risks associated with your participation in this research. You will be required to agree to be interviewed by myself. Your participation will require a maximum of 40-45 minutes, depending on which questions are applicable, at a time convenient to yourself. I understand that your time is valuable, and will try and take up as little of it as possible.

Participation is entirely voluntary and you will not be forced to participate in this study without giving your full consent. Anonymity will be guaranteed and no identifying information will be used in the research report. Every effort will be made to guarantee confidentiality and all personal information will be only be reviewed by the research team (researcher and academic supervisor). Personal information will be safely stored and no other parties will have access to this. At any stage during the interview, you are welcome to ask questions to clarify questions which are not clear, and you may withdraw from the study at any stage should you wish, without any negative consequences.

You are welcome to contact me at any stage, on 072 341 2063 or green_pepperz@yahoo.co.uk, with any queries. You may alternatively contact the administrator of the Medical Ethics Committee at the University of the Witwatersrand, Anisa Keshav on 011 717 1234 or e-mail: anisa.keshav@wits.ac.za or the chairperson, Prof. Cleaton-Jones on 011 717 2301 for additional enquiries.

Kind Regards,

Leanne Grimshaw
M.A. Audiology Student

Dr. Karin Joubert
Supervisor
(011) 717 4561

By signing this consent form, I understand that I give consent to participate in the study and for information from the study to be used for research analysis, possible publication and training purposes.

Participant Name:_____ Date:_____

Participant Signature:_____

Researcher signature: _____ Date: _____

Appendix B: University ethics committee research permission

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Miss Leanne Grimshaw

CLEARANCE CERTIFICATE	**M10647**
PROJECT	The Application of Electrophysiological Measures ofr Fitting Hearing Aids to South African Children
INVESTIGATORS	Miss Leanne Grimshaw.
DEPARTMENT	Speech Pathology & Audiology
DATE CONSIDERED	25/06/2010
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 03/08/2010 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Dr K Joubert

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

Appendix C: Gauteng Health Department research permission

CONDITIONS OF APPROVAL OF RESEARCH PROPOSAL

FOR APPROVAL BY DIRECTOR: POLICY, PLANNING AND RESEARCH

GAUTENG PROVINCIAL GOVERNMENT

HEALTH AND SOCIAL DEVELOPMENT
(GDHSD)
POLICY, PLANNING AND RESEARCH (PPR)
Enquiries: Sue le Roux
Tel: +2711 355 3212
Fax: +2711 355 3675
Email: Sue.LeRoux@gauteng.gov.za

CONTACT DETAILS OF THE RESEARCHER	
Date	09 September 2010
Tel number	+27- 11- 717-4577 (Office) , +27- 11- 717-4572 (Fax), +27- 72-341-2063 (Mobile)
Email	geen_pepperz@yahoo.co.uk
Researcher /Principal investigator (PI)	Leanne Grimshaw
Supervisor	Dr Karin Joubert
Institution	Speech Pathology and Audiology, School of Human and Community Development, Faculty of Humanities , University of Witwatersrand
Research title	" The Application of Electrophysiological Measures to fit Hearing Aids to South African Children "

Approval is hereby granted by the Gauteng Department of Health and Social Development for the above research project to be conducted. Approval is limited to compliance with the following terms and conditions:

1. All principles and South African regulations pertaining to ethics of research are observed and adhered to by all involved in the research project. Ethics approval is only acceptable if it has been provided by a South African research ethics committee which is accredited by the National Health Research Ethics Council (NHREC) of South Africa; this is regardless of whether ethics approval has been granted elsewhere.

   Of key importance for all researchers is that they abide by of all research ethics principles and practice relating to human subjects as contained in the Declaration of Helsinki (1964, amended in

This approval is only granted for a research study entitled "'The Application of Electrophysiological Measures to fit Hearing Aids to South African Children" which will be conducted by Leanne Grimshaw under supervision of Dr Karin Joubert

1983) and the constitution of the Republic of South Africa in its entirety. Declaration of Helsinki upholds the following principles when conducting research, respect for:

- Human dignity;
- Autonomy;
- Informed consent;
- Vulnerable persons;
- Confidentiality;
- Lack of harm;
- Maximum benefit;
- and justice

2. The GDHSD is indemnified from any form of liability arising from or as a consequence of the process or outcomes of any research approved by HOD and conducted within the GDHSD domain;
3. Researchers commit to providing the GDHSD with periodic progress and a final report; short term projects are expected to submit progress reports on a more frequent basis and all reports must be submitted to the Director: Policy, Planning and Research of the GDHSD;
4. The Principal Investigator shall promptly inform the above mentioned office of changes of contact details or physical address of the researching individual, organisation or team;
5. The Principal Investigator shall inform the above office and make arrangements to discuss their findings with GDHSD prior to dissemination;
6. The Principal Investigator shall promptly inform the above mentioned office of any adverse situation which may be a health hazard to any of the participants;
7. The Principal Investigator shall request in writing authorization by the HOD via PPR for any intended changes of any form to the original and approved research proposal;
8. If for any reason the research is discontinued, the Principal Investigator must inform the above mentioned office of the reasons for such discontinuation;
9. A formal research report upon completion should be submitted to the Director: Policy, Planning and Research of the GDHSD with recommendations and implications for GDHSD, the Directorate will make this report available for the HOD.

This approval is only granted for a research study entitled "The Application of Electrophysiological Measures to fit Hearing Aids to South African Children" which will be conducted by Leanne Grimshaw under supervision of Dr Karin Joubert

AGREEMENT BETWEEN THE GAUTENG DEPARTMENT OF HEALTH AND SOCIAL DEVELOPMENT (GDHSD) AND THE RESEARCHER

Ms. S le Roux

Director: Policy, Planning and Research

Date: 09/09/2010

Signature:

Name and surname of Principal Researcher
Leanne Grimshaw

Research/Academic Institution University of the Witwatersrand.

Date: 15/9/10

Signature: LGRIMSHAW

3

This approval is only granted for a research study entitled '"The Application of Electrophysiological Measures to fit Hearing Aids to South African Children" which will be conducted by Leanne Grimshaw under supervision of Dr Karin Joubert

Appendix D: University ethics committee - Permission for change of title and aims

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Ms L Teixeira (Grimshaw)

CLEARANCE CERTIFICATE	M10647
PROJECT	The Application of Audiological Measures for Fitting Hearing Aids to South African Children (Revised title)
INVESTIGATORS	Ms L Teixeira (Grimshaw).
DEPARTMENT	Speech Pathology & Audiology
DATE CONSIDERED	25/06/2010
M100DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 01/11/2011 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Dr K Joubert

DECLARATION OF INVESTIGATOR(S)
To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

Appendix E: Questionnaire

UMTHOMBO WOPHUHLISO LOLUNTU
School of Human & Community Development

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

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

		FOR OFFICE USE ONLY
	IDENTIFYING INFORMATION:	
	Participant number:	
	Today's Date:	
	Private Institution	1
	Public Institution	2
	QUALIFICATION, CURRENT ROLE AND WORK EXPERIENCE	
1	Your qualification	
~	Audiologist	1
~	Dual Qualified Speech and Language Therapist and Audiologist	2
2	Please specify your role at the hospital	
~	Audiologist	1
~	Dual Qualified Speech and Language Therapist, and Audiologist	2
3	How many years have you been working	
~	Community Service Clinician	1
~	0-4 years	2
~	5-9 years	3
~	10-15 years	4
~	15 years +	5
	CURRENT CLINICAL PRACTICE	
4	What age are the children you see? (Tick all that are appropriate)	
~	Birth to 6 months	1
~	6 months to 3 years	2
~	3 years – 5.11 years	3
~	Primary School age	4
~	High School age	5
5	On average, how many children do you fit with hearing aids in a month (first fitting)?	
	_____	
6	Does your department have a paediatric hearing aid fitting protocol/guideline (i.e. what assessments/ techniques should be undertaken during hearing aid fitting)?	
~	YES	1
~	NO	2

7 If you answered YES to QUESTION 6 above, please would you mind supplying me with a copy of your protocol/guideline?
(Or allow me to look at the protocol and make notes if you do not wish to supply me with a copy).

_____

_____

8 What is the average waiting time for children for hearing aids, after diagnosis of a hearing loss, at the hospital/clinic?
(If this is variable, please state why).

_____

_____

9 What assessment equipment does your hospital/clinic/practice have (Mark 'Y' for YES and 'N' for NO)?

~ Auditory Steady-State Response (ASSR)	1
~ Diagnostic Auditory Brainstem Response ABR	2
~ Diagnostic Audiometer	3
~ Diagnostic Otoacoustic emissions (OAE)	4
~ Noise-makers	5
~ Otoscope	6
~ Screening Automated Auditory Brainstem Response (AABR)	7
~ Screening Audiometer	8
~ Screening OAE	9
~ Sound-treated Booth	10
~ Sound level meter	11
~ Tympanometry	
o High (1000Hz and 678 Hz) frequency and low (226Hz) frequency probe	12
o Low frequency only (226Hz)	13
~ Visual Reinforcement Audiology (VRA)	14
~ OTHER_____	15

10 Before fitting an infant LESS THAN 6-7 months of age with hearing aids, what are the standard, minimum audiology results you require?
(Whether completed at your hospital/clinic or undertaken elsewhere) (Mark as many as appropriate) (Mark 'Y' for YES and 'N' for NO):

~ ASSR	1
~ Bone conduction ABR	2
~ Case History	3
~ Click ABR	4
~ Cochlear microphonic	5
~ DPOAE's	6
~ High frequency tympanometry	7
~ High Frequency acoustic reflexes	8
~ Low Frequency tympanometry	9
~ Low frequency acoustic reflexes	10
~ Otoscopy	11
~ TEOAE's	12
~ Tone-burst ABR	13
~ OTHER_____	14

11 Before fitting an infant/child FROM 6-7 to 36 months of age with hearing aids, what are the standard, minimum Audiology results you require?
(Whether completed at your hospital/clinic or undertaken elsewhere) (Mark as many as appropriate) (Mark 'Y' for YES and 'N' for NO):

~ Acoustic reflexes	1
~ ASSR	2
~ Behavioural Thresholds	3
~ Bone conduction ABR	4
~ Case History	5
~ Click ABR	6
~ Cochlear microphonic	7
~ DPOAE's	8
~ Otoscopy	9
~ Response to Noise-makers	10
~ TEOAE's	11
~ Tone-burst ABR	12
~ Tympanometry	13
~ OTHER_____	14

12 Before fitting an infant/child FROM 36 months to 6 years of age with hearing aids, what are the standard, minimum Audiology results you require?
(Whether completed at your hospital/clinic or undertaken elsewhere) (Mark as many as appropriate) (Mark 'Y' for YES and 'N' for NO):

~ Acoustic reflexes	1
~ ASSR	2
~ Behavioural Thresholds	3
~ Bone conduction ABR	4
~ Case History	5
~ Click ABR	6
~ Cochlear microphonic	7
~ DPOAE's	8
~ Otoscopy	9
~ Response to Noise-makers	10
~ TEOAE's	11
~ Tone-burst ABR	12
~ Tympanometry	13
~ OTHER_____	14

13 At what age do you start completing behavioural audiometric testing in a typically developing child?

_____

14 If you complete high frequency tympanometry, at what age do you start completing low frequency tympanometry?

_____

15 At what age do you stop validating behavioural results with electrophysiological testing (i.e. ABR and ASSR)?

_____

16 Do you complete Real Ear Measures (REMs) with EVERY paediatric fitting to verify the fitting?

~ NO	1
~ SOMETIMES	2
~ YES	3

17 **If you answered YES or SOMETIMES to QUESTION 16 above, please indicate which measures you are using?**
(Mark as many as appropriate) (Mark 'Y' for YES and 'N' for NO):

- Real ear insertion gain (REIG) 1
- Real Ear Aided Response (REAR) 2
- Real-ear-to-Coupler Differences (RECD's) and simulated REMS 3

18 If NO was answered to QUESTION 16, why not?

- Lack of equipment 1
- Do not see the need for REMS to be completed 2
- I rely on other measures such as _____ 3
- OTHER_____ 4

19 If you answered SOMETIMES to QUESTION 16, please state why.

- Only if there is time 1
- Only if the child is not making as much progress with their hearing aids as expected 2
- Only if requested by another professional or family 3
- I rely on other measures such as _____ 4
- OTHER_____ 5

20 Do you complete electrophysiological testing like ABR and/or ASSR testing for paediatric clients?

- YES 1
- NO (if NO please indicate which is applicable below)
  - o We refer to the appropriate public institution for testing to be completed 2
  - o Another member in the department completes testing 3
  - o We refer to a colleague in another private practice for testing to be completed 4
  - o Other 5

<u>THOSE COMPLETING ABR AND/OR ASSR: IF YOU COMPLETE ABR AND/OR ASSR TESTING, THEN PLEASE ANSWER QUESTIONS 21-31</u>

21 What electrophysiological measures do you complete for children, (in terms of ABR and ASSR testing)?

- ABR only 1
- ASSR only 2
- Combination of ABR and ASSR as appropriate 3

22 Does your department have an ABR/ ASSR testing protocol guideline (i.e. what assessments/techniques should be undertaken during ABR/ASSR testing)?

- YES 1
- NO 2

23 If you answered YES to QUESTION 22 above, please would you mind supplying me with a copy of your protocol? (Or allow me to look at the protocol and make notes if you do not wish to supply me with a copy).

24 Do you feel your undergraduate training equipped you with enough skill and knowledge for ABR testing?

- YES 1
- NO 2

25 Do you feel your undergraduate training equipped you with enough skill and knowledge for ASSR testing?

- YES 1
- NO 2

26 If you answered NO to QUESTION 24 and/or 25 above, why not (Tick as many as appropriate)?

- Not enough theoretical training 1
- Not enough practical training 2
- OTHER_____ 3

Comments_____

_____

27 After ABR and ASSR assessment, do you then see these children for hearing aid fitting?

- YES 1
- MOSTLY 2
- SOMETIMES 3
- NO 4

28 If you answered NO, MOSTLY or SOMETIMES to QUESTION 27 above, why not? (Tick as many as apply).

- Referred back to their local hospital/clinic/private practice for fitting 1
- Another staff member at the same department undertakes the hearing aid fitting 2
- Lack of hearing aids. 3
- Lack of equipment to program the hearing aids. 4
- Lack of training 5
- Limited staff 6
- OTHER_____ 7

29 Approximately how many children do you see for hearing ABR/ASSR assessment a month?

_____

30 If you complete both ABR and ASSR, do you use the same piece of equipment for ABR and ASSR testing?

- YES 1
- NO 2

CALIBRATION

31 Calibration certificate/s for ABR and ASSR.
(Request to see calibration certificates and for a copy if possible)
CALIBRATION STANDARDS:

_____

EQUIPMENT MODEL:

_____

DATE OF CALIBRATION:

_____

NO CALIBRATION CERTIFICATE AVAILABLE_____

ABR CLINICAL PRACTICE: IF YOU COMPLETE ABR TESTING PLEASE COMPLETE QUESTIONS 32 TO 40, as indicated.

32 Which ABR measurements do you complete? (Tick as many as appropriate)

- Click ABR 1
- Neurological ABR 2
- Tone-burst ABR
  - a. 500Hz 3
  - b. 1000Hz 4
  - c. 2000Hz 5
  - d. 4000Hz 6

If you complete tone-burst ABR testing, then please answer questions 33-34.

33 If you complete tone-burst ABR testing, when do you complete this testing?
~ Always 1
~ Sometimes, when_____ 2

34 In which order do you complete tone burst ABR testing?

	500Hz	1000Hz	2000Hz	4000Hz
1st				
2nd				
3rd				
4th				

35 For ABR threshold testing, do you complete bone conduction ABR testing?
~ NO 1
~ IF REQUIRED 2
~ YES 3

If you answered <u>YES</u> OR <u>IF REQUIRED</u> to the question 35 above, please complete question 36.

36 For which measurements do you complete bone conduction testing as standard?
~ Click ABR 1
Tone-burst ABR
~ a. 500Hz 2
~ b. 1000Hz 3
~ c. 2000Hz 4
~ d. 4000Hz 5

37 Have you completed a biological calibration on your ABR equipment (i.e. comparing results obtained using conventional pure tone audiometry to response thresholds using inserts/headphones/ bone conductor through the ABR equipment).
~ YES 1
~ NO 2
~ UNKNOWN 3

38 If you answered YES to QUESTION 37 above, please state whether you found that you need to apply additional correction factors after biological calibration?
~ YES 1
~ NO 2

39 If you answered YES to the QUESTION 38, please state the correction factors you apply? (If required, please look these up, in order to answer the question).

	CLICK	500Hz	1000Hz	2000Hz	4000Hz
AIR CONDUCTION HEADPHONES					
AIR CONDUCTION INSERT PHONES					
BONE CONDUCTION					

40 During ABR testing, what do you accept as a 'normal' response for discharge (dBnHL) (i.e. no need for further follow-up for further diagnostic testing)?

	Click	500Hz	1000Hz	2000Hz	4000Hz
Under 3 months of age					
Over 3 months of age					

Comments:_____

_____

_____

HEARING AID FITTING BASED ON ABR/ASSR RESULTS
FOR ALL TO COMPLETE

41 What threshold values would you use for hearing aid fitting, if you got the following ABR results for a 2 year old child?

ABR:

	CLICK	500Hz	1000Hz	2000Hz	4000Hz
AIR CONDUCTION	50dBnHL	60dBnHL	60dBnHL	55dBnHL	50dBnHL
VALUES WHICH WOULD BE USED FOR FITTING					

Comments:_____

_____

_____

42 What threshold values would you use for hearing aid fitting, if you got the following ASSR results for an 18 month old child?

ASSR:

	250Hz	500Hz	1000Hz	2000Hz	4000Hz
AIR CONDUCTION (NOT Manufacturer's estimated audiogram)	80dBnHL	80dBnHL	85dBnHL	85dBnHL	100dBnHL
VALUES WHICH WOULD BE USED FOR FITTING					

Comments:_____

_____

_____

43 Do you apply any correction factors to your dBnHL **ABR** results in order to obtain estimate behavioural thresholds for hearing aid fitting?

~ YES 1

~ NO 2

If you answered YES to QUESTION 43 ABOVE, please complete QUESTIONS 44 TO 48, as appropriate, otherwise move to question 49.

44 When do you apply correction values to estimate behavioural thresholds?

~ During assessment. The corrected results are documented on the printed results. 1

~ Whoever fits the hearing aids applies correction values for their fitting. 2

~ OTHER_____ 3

45 What correction values do you apply for children OVER 3 months of age? (Please look these up, if required, in order to answer the question).

	CLICK	500Hz	1000Hz	2000Hz	4000Hz
AIR CONDUCTION HEADPHONES					
AIR CONDUCTION INSERT PHONES					
BONE CONDUCTION					

46 Do you apply different correction factors for infants UNDER 3 months of age?

~ YES 1

~ NO 2

47 If you answered YES to QUESTION 40, please specify the correction values used (Please look these up, if required, in order to answer the question).

	CLICK	500Hz	1000Hz	2000Hz	4000Hz
AIR CONDUCTION HEADPHONES					
AIR CONDUCTION INSERT PHONES					
BONE CONDUCTION					

48 Do you apply correction values to **ASSR** results for hearing aid fitting?

~ YES, Manufacturer's estimated audiogram. 1

~ YES, own correction values 2

~ NO, I use the results as obtained during testing 3

If you answered YES (MANUFACTURER'S CORRECTION VALUES) to QUESTION 48 above, please complete QUESTION 49 BELOW.

49 Do you know what the manufacturer correction values are?

- NO 1
- YES. If yes, please list these below. 2

	250Hz	500Hz	1000Hz	2000Hz	4000Hz
AIR CONDUCTION HEADPHONES					
AIR CONDUCTION INSERT PHONES					
BONE CONDUCTION					

If you answered YES (OWN CORRECTION VALUES) to QUESTION 48 above, please complete QUESTIONS 50 TO 53 Otherwise move to question 54.

50 When do you apply correction values to estimate behavioural thresholds?

- During assessment. The corrected results are documented on the printed results. 1
- Whoever fits the hearing aids applies correction values for their fitting. 2
- OTHER_____ 3

51 What ASSR correction values do you apply?

ASSR:

	250Hz	500Hz	1000Hz	2000Hz	4000Hz
AIR CONDUCTION HEADPHONES					
AIR CONDUCTION INSERT PHONES					
BONE CONDUCTION					

52 Do you apply different correction factors for infants UNDER 3 months of age for ASSR?

- YES 1
- NO 2

53 If you answered YES to QUESTION 52, please specify the correction values used.

	250Hz	500Hz	1000Hz	2000Hz	4000Hz
AIR CONDUCTION HEADPHONES					
AIR CONDUCTION INSERT PHONES					
BONE CONDUCTION					

Answer Question 54 or 55., as appropriate

54 If you apply correction factors for ABR and/or ASSR, what do you base your correction factors on?

- ~ Own clinical research 1
- ~ Departmental protocol/guideline 2
- ~ Manufacturer guidelines 3
- ~ Correction values as recommended by _____ 4
- ~ OTHER_____ 5

55 If you do not apply correction values to your ABR and ASSR results, why not? (Tick as many as apply)?

- ~ I do not think it is necessary to apply correction factors. I use the dBnHL values as obtained. 1
- ~ I was unaware there may be correction factors. 2
- ~ OTHER. 3

AUDIOLOGISTS UNDERTAKING HEARING AID FITTING, BUT NOT COMPLETING ABR/ASSR TESTING THEMSELVES

QUESTIONS 56 TO 58 TO BE COMPLETED BY THOSE WHO DO NOT COMPLETE ABR/ASSR BUT USE RESULTS TO FIT HEARING AIDS TO CHILDREN

56 If a hearing loss is identified, do you then receive the results for hearing aid fitting at your centre?

- ~ YES 1
- ~ SOMETIMES 2
  I.e. They are sometimes fitted by the referral centre who completed the ABR/ASSR
- ~ NO 3

57 If you do receive the results to fit yourself, do you feel you receive adequate information for the hearing aid fitting?

- ~ YES 1
- ~ NO 2

58 If you answered NO to QUESTION 50, above, please state why the information is inadequate (tick as many as are appropriate)

- ~ I only get a report and not the actual waveforms and parameters 1
- ~ I only get air conduction click ABR results 2
- ~ I only get ASSR results 3
- ~ I get air conduction ABR and ASSR results but no bone conduction results 4
- ~ I get results, but no indication as to whether correction values have or have not been applied 5
- ~ OTHER_____ 6

59 (ALL) ANY OTHER COMMENTS?

_____
_____
_____
_____
_____

Thank you for you time in completing the interview.