Real-Ear Measurements: Moving Evidence into Practice

A study submitted in partial fulfilment of the requirements for the degree of Master of Science of the University of Hertfordshire

Wendy Martin B.A. (Hons)

University of Hertfordshire

Hatfield

Hertfordshire

May 2017

Acknowledgements

I would like to thank the following people without whom this research would not have been possible:

Lorraine Glover, Paediatric Audiologist who undertook the project with me and generously gave of her time for data collection and for experiencing the learning process with me.

Tracy James for her guidance, supervision, encouragement and advice.

Paediatric Audiology Clinic, Ulster Hospital, for their cooperation and for allowing me to complete the project in the Paediatric Audiology Clinic.

All the children and their families for agreeing to take part in this study.

The audiologists who gave of their time, advice, submitted questionnaires and who agreed to be interviewed.

Rosie, Ellie and Joe for encouraging me, keeping me going through the late nights and putting up with my need to work all the time.

Keith for pushing me on and for doing so much in the background.

Contents

Word count (excluding references, tables, figures and preliminary pages): 13188

List of tables

List of figures

Abstract

The implementation of newborn hearing screening (NBHS) has resulted in earlier diagnosis, earlier access to amplification and earlier intervention for children with hearing loss. It is expected that this will mediate the risks of hearing loss for a child's development. However, studies show that the language outcomes for children who have been identified by NBHS and who wear hearing aids are variable. The audibility provided by hearing aids has been associated with positive language development. It is known that the audibility provided by hearing aids may be underestimated unless individual real-ear measurements (REMs) are carried out during verification. There is a mismatch between the evidence that supports appropriate hearing aid fittings using REMs and the practice in Audiology clinics.

A case study approach was used in this study to investigate the proximity of hearing aid fittings with and without REMs to prescriptive targets for eight children in one Paediatric Audiology clinic. Speech perception outcomes were evaluated for hearing aid fittings without REMs and for hearing aid fittings after REMs were performed.

Survey and interview data was collected from audiologists in the Health Trusts in the region to investigate current clinical practice when fitting hearing aids to infants and young children.

It was found that all fittings without REMs were under-amplified at all input levels. REM-adjustments improved the match to prescriptive targets at all input levels. A general trend of improvements in speech perception scores was found after REM-adjustments of hearing aids.

This study confirmed that REMs for verification enable a closer match to prescriptive targets to be achieved which would support providing optimal audibility for individual children and therefore support language development. This study also investigated implementation of REMs and found that making information available is not enough for implementation. A proactive and targeted effort is required for knowledge to be used. The strategies to implement best-practice can be developed once the barriers in a particular context are better understood. This study contributes to the research on implementation of guidelines by investigating the process of implementation in one case study.

1. Introduction

The widespread implementation of newborn hearing screening has led to the demand for paediatric audiologists who can provide effective services for infants. Children with congenital hearing loss are at risk for delayed speech and language and associated risks for cognition, literacy, academic achievement and social development. Hearing loss interacts with other factors such as family involvement, consistency of amplification use, quality of fitting of amplification, quality of intervention and characteristics of the environment and all contribute to a child's development (Moeller et al, 2007).

The assumption that early intervention and earlier access to hearing aids provides better outcomes requires further examination (Koehlinger et al, 2013). It is important to examine how the quality of hearing aid fit moderates the advantages of early identification.

The quality of hearing aid fittings can be measured by individual verification using real-ear measures (REMs). REMs are the preferred method of verification for infants and young children and are recommended by paediatric hearing aid fitting guidelines (American Academy of Audiology (AAA) 2013; British Society of Audiology (BSA) 2008; Modernising Children's Hearing Aid Services (MCHAS) 2005). However, providing information, for example, in the form of guidelines, is the 'lowest rung of a complex ladder of how to implement a new intervention' (Ratner 2006: 263). Investigating the implementation of evidence-based practice in a case study will help in identifying the barriers and solutions to adherence to guidelines.

1.2 Evidence-Based Practice

Evidence-based practice has its origins in medicine. It attempts to close the gap between research and practice, reduce practice variation and therefore improve patient care (Moodie 2012). Sackett et al (1996: 71) defined evidence-based medicine as 'the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients'. It advocates that individual clinical expertise along with the best available evidence should determine and apply current best practice.

Evidence-based practice and paediatric audiology are inextricably linked due to the rapid expansion of technology and interventions available (Gravel 2004). Audiologists can no longer rely on the information and skills learned in initial formal training. Professionals must become more frequent consumers of the evidence supporting clinical practices (Cox 2005). As far back as 1998, Bess called for audiologists to deemphasize unsystematic clinical experience as the basis for clinical decision making. This study aims to collect evidence on the impact of implementing REMs on hearing aid fittings for a small group of children in order to inform practice in an audiology clinic.

2. Literature review

Much research has been carried out on the ways to achieve the best possible outcomes for individual children with hearing loss and their families. Despite the rapid expansion of technology and information, there are sound foundations on which current audiological practice is based. Some of these are discussed below.

2.1 Early Intervention

Early diagnosis should lead to early access to hearing technology and to early intervention. It is expected that this will result in better communication development and subsequently in long term positive consequences for academic and social outcomes (World Health Organisation 2009). Most researchers would agree that early diagnosis alone is unlikely to translate into long term benefit (Wake et al, 2005). Research is therefore trying to establish the most significant factors for the development of language once a child has been identified at a younger age than ever before.

2.1.1 Does current evidence support early intervention with amplification?

Children are receptive to developing specific skills at certain times of development and so delayed auditory development leads to delayed language skills. Concerns about age related plasticity have driven early detection and early intervention (Flexer 2011; Harrison 2011).

Several studies provide evidence that early-identified infants with hearing impairment achieve improved outcomes in speech and language compared to later-identified infants (Ching 2015; Sininger et al, 2010; Moeller 2000; Yoshinago-Itano et al, 1998).

Some caution should be exercised when considering these studies. The Yoshinago-Itano et al (1998) study used parent reporting and a cohort of children already enrolled in a specialist intervention programme. The use of motivated families may have introduced bias to the reported benefit. Other studies (Fitzpatrick et al, 2007; Kennedy et al, 2006; Wake et al, 2005) found limited or no benefit in language performance for early-identified children. This may have been due to delays between confirmation of hearing loss and provision of amplification which weakened the effect of early detection on outcomes. Hearing aid fitting details were not included.

The US Preventative Services Task Force (2001) identified weaknesses in the design of studies which found benefit from early identification. Therefore, the evidence base that guides the management of these children needs to be strengthened (Moeller et al, 2007). Children wearing hearing aids have variable outcomes (Stiles et al, 2012) even when identified and fitted with hearing aids early. Studies often do not include details of how hearing aids have been fitted or of aided audibility. Rather they concentrate on the 'when' of receiving amplification.

2.2 Audibility and Amplification Prescription Targets

Audibility depends on a child's degree of hearing loss, gender of the speaker (Stelmachowicz et al, 2002), the listening environment and the quality of amplification available to the child. Hearing loss is a complex variable (Tomblin et al, 2015) representing both unaided and aided hearing. Tomblin et al (2015) found that the degree to which hearing aid fit provided improved audibility relative to unaided hearing loss was associated with differential rate of language change over time.

McCreery et al (2015) concluded that there is a positive relationship between aided audibility and receptive language ability. Reductions in aided audibility may inhibit the development of language skills such as vocabulary knowledge (Mcreery et al, 2015) and working memory (Tuller & Delage, 2013). These skills aid listening in complex listening environments where there is noise, reverberation and multiple talkers (the classroom). If there is a positive relationship between vocabulary size and aided audibility as measured by the Speech Intelligibility Index (SII), (Stiles 2014) then this will help in the use of top

down processing when less of the signal is available due to background noise (McCreery et al, 2015). Aided speech audibility will also influence children's ability to learn new words as this is in turn affected by their current vocabulary size (Stelmachowicz et al, 2004).

If audibility influences language acquisition, then the primary goal of amplification to young children is to restore audibility of the speech signal to facilitate development of communication and language learning (McCreery & Stelmachowicz, 2011; Stiles 2014) and to cater for the specific listening needs of children. Hearing aids provide audibility of the acoustic cues necessary to support the acquisition of speech and language skills (McCreery et al, 2013).

The two prescriptive approaches recommended for paediatric hearing aid fitting take into account these objectives - the Desired Sensation Level Multistage Input/Output Method (DSL m[i/o]) and the National Acoustics Laboratories Nonlinear Algorithm (NAL-NL1).

To actually use a prescriptive approach which aims to maximise audibility for a given hearing loss, prescriptive targets need to be met in an individual's ear canal.

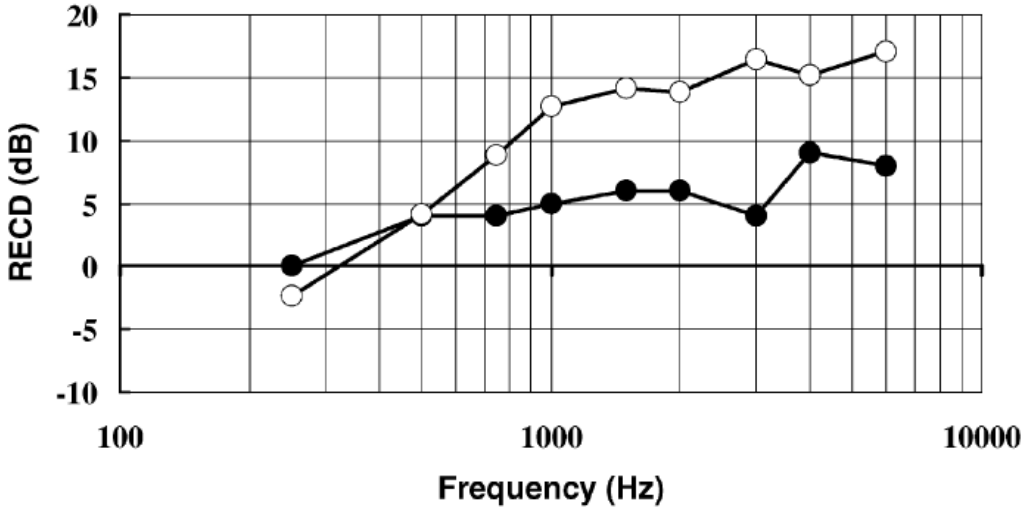
Standardisation of the dB hearing level (HL) scale allows consistent definitions of hearing levels across clinics, stimuli and clinicians. However, 0 dB HL reference is defined relative to the average normal hearing adult population (Bagatto et al, 2005). The HL scale does not accurately reflect audiometric threshold values in the ear canal sound pressure level (SPL) for an individual. This is particularly problematic for children. Therefore, prescriptive approaches must take this into account. Individual measurement of the real-ear component is recommended to accurately define hearing thresholds for hearing aid fitting (Bagatto & Scollie, in Seewald & Tharpe, 2011).

2.2.1 Verification

For children with hearing loss, the development of listening strategies depends in part on the quality of the listening experience they receive. Factors affecting listening include audibility provided by a child's amplification (McCreery et al, 2015; Moodie 2009,). Verifying audibility by an appropriate measurement tool such as REMs helps to ensure benefit from amplification (Palmer 2010; Aarts & Caffee, 2005).

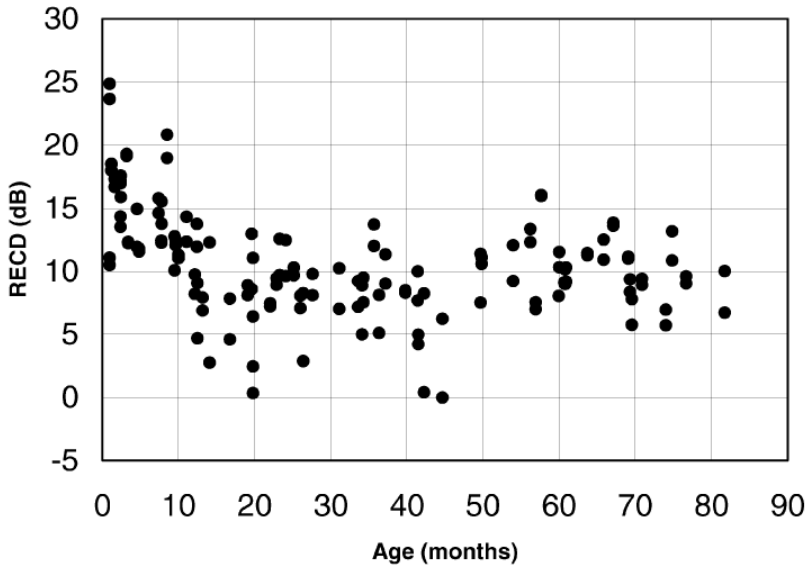
The acoustics of the external ear differ significantly between adults and infants (Figure 2.1).

Figure 2.1: A typical real-ear to coupler difference (RECD) from an infant (open circle) and an adult (filled circle). From Munro (2004)



Individual ear canal fittings have been found to vary by as much as 36 dB in adults (Valente et al, 1994). There is also a large range of individual variability within and across age groups in children (Bagatto et al, 2002) as shown in Figure 2.2.

Figure 2.2: RECD values at 4000 Hz shows variation among individuals. From Munro (2004)



This affects the level of sound delivered to the ear canal by the hearing aid. As a child's ear grows, the HL required to generate a given SPL will increase. It is inaccurate to assume that across ears, a given HL signal will result in the same ear canal SPL (Munro 2004). Using the real-ear as the reference point eliminates variations across individuals due to differences in ear canal dimensions.

Existing paediatric guidelines (AAA 2013; MCHAS 2005) recommend verification for individual children to adjust the hearing aids so that prescriptive targets for electroacoustic performance are achieved. At the time of writing, a new REMs protocol by the BSA is out for consultation. Best practice guidelines will support the efforts of families, caregivers and early interventionists to promote a child's learning and development and facilitate the developmental advantages of auditory learning from early intervention. Probe-microphone measures of speech signals at multiple intensity levels provide the most accurate assessment of hearing aid gain characteristics. When REMs are not practical, real-ear-to-coupler-difference (RECD) measures are an acceptable alternative (Child Amplification Laboratory 2010). Applying the RECD allows the audiologist to predict the performance of the hearing aid in the real-ear by making

measurements in a controlled test box environment. It allows accurate measurement for very young children who will not tolerate a probe-microphone for a period of time and has been found to be accurate to within +/-2dB when compared to real-ear measurement (Bagatto & Moodie, 2007).

There is a range of evidence that using manufacturers' initial fit and on screen simulations of hearing aids consistently fails to approximate prescribed responses verified with individual REMs (Aazh & Moore, 2007; Aarts & Caffee, 2005; Hawkins & Cook, 2003). Hawkins & Cook (2003) used data collected as part of routine clinical practice for adult patients fitted with new hearing aids and found that manufacturer gain values tended to overestimate the amount of actual gain in the hearing aid.

Seewald et al (2008) found substantial variation generated among manufacturer-specific prescriptive algorithms using average RECD values for a 6 month old infant and 9 audiograms ranging from mild to profound to programme the hearing aids.

The overestimation of simulated values may impact user satisfaction and benefit. Aarts & Caffee (2005) suggest that reliance on software predictions of real-ear hearing aid performance may account for low satisfaction rates reported by hearing aid users. Kochkin (2011) concluded that using real-ear verification increased patient satisfaction so that fewer return visits were needed to achieve a satisfactory fit. Reliance on predicted gain values may parallel the plateau in perceived value benefit and hearing aid performance in noise in recent years (James 2014).

Taylor (2015) concludes that following a best practice protocol is more important than the level of technology dispensed. Hearing aids with basic technology fitted using a standardised approach including REMs are more likely to result in better outcome results than premium products using a minimalist protocol because manufacturers cannot account for individual ear variability (Leavitt & Flexer, 2012).

2.2.2 Baseline

Abrams et al (2012) used a verified prescriptive approach and an initial fit approach to compare self-perceived benefit. Hearing aids were adjusted on adult patients in both approaches on request of the patient. Making adjustments from

the verified prescriptive approach produced better user outcomes than if the manufacturer's initial fit algorithm was used as the starting point for adjustments (measured by Abbreviated Profile of Hearing Aid Benefit - APHAB).

Children cannot comment on perceived benefit or quality of sound, so the clinician and family may examine functional outcomes. However, interpreting functional outcomes for a child is not useful unless you know about the quality of the hearing aid fitting. If functional outcomes are poor, is this due to a poor match to prescriptive targets or is there an additional speech and language problem? (Bagatto 2012). Working from a verified baseline may help to distinguish those children who have a language impairment in addition to their hearing loss as opposed to a hearing aid fitting which does not meet intended targets.

2.3 Individual Variability

Children with mild to severe hearing loss who wear hearing aids have been under studied (Roush 2015) and there is a good deal of variability in outcomes for children with hearing loss. Vohr et al (2011) found that children with all degrees of hearing loss benefit from early intervention but wide individual differences remain.

Some children with hearing loss achieve spoken language comparable to that of their peers (Koehlinger et al, 2013; Tuller & Delage, 2013). However, others do not. Factors contributing to more positive outcomes may include less severe hearing loss (Ching & Dillon, 2013; Sininger et al, 2010), early intervention (Yoshinago-Itano et al, 1998), access to audible speech (Stiles et al, 2012), quantity and quality of speech in the home (Fitzpatrick et al, 2011) and level of maternal education and socio-economic status (Ching 2016).

Collectively, factors interact to result in inconsistent access to the speech signal.

Tomblin et al (2015) suggest that previous studies may have assumed good aided audibility and good hearing aid use and therefore these variables were not considered as contributing to outcomes. However, paediatric hearing aid fittings in clinical populations may be significantly more variable and populations of children wearing hearing aids may have a wider range of auditory experience than expected and therefore related outcomes (McCreery et al, 2013).

Stiles et al (2012) investigated the variability in language learning outcomes of children wearing hearing aids. Age at intervention and degree of hearing loss accounted for some of the variability in language outcome. However, individual differences did not correlate consistently with degree of hearing loss. The pure tone audiogram does not represent the aided listening condition, and audibility as defined by the SII may be a more reliable predictor of language development in children with hearing loss wearing hearing aids. The authors suggest that goodness of hearing aid fit should be considered as an independent variable when investigating language outcomes. Depending on the configuration of hearing loss, characteristics of the amplification system and how well the system is fitted, two children with the same pure tone average (PTA) may have different SIIs, different auditory experiences and therefore, different trajectories of language development (Stiles et al, 2012).

There is a need for studies which include hearing aid fitting details to help guide the development of outcome evaluation of early amplification (Koehlinger et al, 2013; Bagatto 2012; Stiles et al, 2012; Sininger et al, 2010). Knowledge of hearing aid fitting details helps to interpret outcomes of amplification, especially with a population of early-identified children. The quality of hearing aid fitting should be included in studies on the impact of early intervention.

2.4 Growth in Technology

The field of audiology is experiencing a rapid expansion of information and new technology.

Children learning language require access to high frequency sounds (Stelmachowicz et al, 2002). There is a growing trend to use frequency lowering technologies (Jones & Launer, 2010). Outcomes appear encouraging (Wolfe et al, 2010; Glista et al, 2009). However, studies have not been carried out on populations of children fitted with frequency lowering in a range of real world clinics where optimal fittings may not be measured or achieved (McCreery et al, 2013). Dillon (2012) asserts it is difficult to know if frequency lowering has been optimised for an individual. Decreased frequency resolution means the listener may be able to hear the amplified sounds but may not be able to resolve the shape of the compressed spectrum (Ching et al, 2013). It is important for the audiologist to understand how input consistency affects learning. Despite

continued advancement in hearing aid technology, there is still a need to determine what is actually occurring in the patient's ear (Pumford & Sinclair, 2001).

2.5 Mismatch between Evidence and Practice

The parameters associated with a child's amplification affect the quality of the listening experiences they receive (Moeller & Tomblin, 2015; Stiles et al, 2012) and therefore affect language development. Evidence indicates that appropriate hearing aid fittings are important and necessary for children's auditory, language and social development (AAA 2013; MCHAS 2005).

The first fit response of a hearing aid may not match the prescribed gain and output levels of hearing aids (Abrams & McArdle, 2006). We have the knowledge to guide the assessment, selection and fitting, verification and evaluation of hearing aids. We have prescriptive algorithms based on best-evidence. However, a review of literature reflects a mismatch between evidence and implementation of guidelines in audiology (Mueller & Picou, 2010; Bamford et al, 2001; Bess 1998; Tharpe 1998).

Studies have found that children's hearing aid fittings are often inadequate (McCreery et al, 2013; Strauss & Van Dijk, 2008) and that real-ear measurement to verify hearing aid performance is not routine clinical practice (Seewald et al, 2008; Mueller 2006; Seewald & Scollie, 2003). Bretz (2006) found that as hearing aid processing strategies have become more complex and specific to the manufacturer, that audiologists are showing an increased reliance on manufacturers' simulated values and recommended settings. This fitting strategy can create a fitting that provides less audibility for speech than the clinician intended (Seewald & Scollie, 2003).

It has been found elsewhere in health care that the transfer of research findings into practice is unpredictable (Eccles et al, 2009). Pope (2003) states that while evidence-based practice frequently appears in policy documents and medical journals, studies continue to suggest that the findings of scientific research do not influence every day practice. In the UK, the National Institute for Health and Clinical Excellence synthesizes evidence and produces guidelines for use within the National Health Service. Evaluation of implementation has shown that practice lags behind expectations (Harrison et al, 2009). Evidence is only helpful

to professionals and clients if health service providers seek it out, understand it and apply it. This creates a potential break in the chain from research to practice (Ratner 2006).

2.6 Practice Equity

Evidence-based practice seeks to improve equity of care. This requires consistency of procedures and compliance with evidence-based protocols (Hyde 2004). Clinicians differ, but there is an obligation to identify practice that meets standards of benefit (Kent 2006). Otherwise, the benefits of early identification of hearing loss could be lost.

Evidence-based practice is seen as an integral part of clinical practice today. However, the literature reveals a tension between evidence-based practice and every day practice. Evidence-based practice advocates using a hierarchy of evidence with randomised controlled trials (RCTs) at the top and experiences and intuition at the bottom (Rolfe & Gardner, 2006). However, it is difficult to produce RCTs in a paediatric population due to the ethical difficulties of withholding treatment. The low incidence rate of permanent childhood hearing impairment makes it difficult to reach a sufficient sample size for RCTs. Many best practices will never be evaluated using the highest level of evidence-based studies because of ethical considerations. A control group used in before and after designs would not be used in the paediatric population due to difficulties of withholding treatment. Pope (2003) suggests that due to the restrictive nature of RCTs, evidence-based practice has helped to create and sustain the idea that evidence and practice are opposed.

The literature can also be confusing in its conclusions on how to weight sources of evidence and the parallel use of clinical experience (Rolfe & Gardner, 2006). Rycroft-Malone et al (2004) concluded that agreed standards for determining whether research evidence is appropriate and useful for a particular patient/context and how it can be used have yet to be developed.

Using an evidence hierarchy alongside clinical expertise cannot be separated from the provider's personal clinical judgement and opinion. Opinion can be affected by personal experience, selective use of evidence, predetermined bias, motivation, memory, belief there is only one way to do something, professional norms (Moodie 2012), confidence in skills and the context worked in. Personal

experiences affect how we make decisions (Limb 2011). However, reliance on opinion gained from experience means you cannot use explicit, formally specified knowledge to defend work practices (Pope 2003). Hyde (2004) argues that this is a matter of ethics and that the onus is on providers of care to maximize their consistency of practice. Evaluation is necessary to reduce variation in practice, however, it is not possible to evaluate practice without following defined guidelines.

2.7 Clinical Practice Guidelines (CPGs)

CPGs are produced by professionals and their organisations working together to review relevant evidence and literature and to produce guidelines that clinicians can use as tools to inform evidence-based practice. They can reduce practice variation, promote effective treatment and discourage ineffective treatment (Moodie 2012). Audiology has guidelines specifically for paediatric services (AAA 2013; BSA 2008; MCHAS 2005). However, the challenge remains to ensure that guidelines are implemented in practice.

Guidelines alone often do not change practice behaviour (Moodie 2012; Roberts et al, 2012). They may not be implemented even though they make sense and meet a specific need (Moodie 2012; Harrison et al, 2009). The development of guidelines may only be the first step in a complex process to ensure that practice is based on evidence. Making information available is not enough to implement an intervention (Greenhalgh 2010; Ratner 2006; Rycroft- Malone et al, 2004) because an interaction of other variables will influence practice, i.e. capability, opportunity and motivation (Michie et al, 2011). Human factors have a large role to play as well as the context that people are working in (Greenhalgh 2010).

2.8 Implementation Research

Implementation research seeks to study strategies and interventions that affect change in individuals and the complex organisations in which they work (Eccles et al, 2009). Considerable money is spent on clinical research and yet relatively little attention has been paid to ensure that findings are implemented into routine clinical practice. Mueller (2003) stated that there is a current trend to develop test protocols that are evidence-based, but before any new guidelines are developed, research should investigate adherence issues to existing guidelines. There is a need to determine how knowledge (guidelines) is going to be implemented in practice (Moodie 2011).

The intended strategy of implementation research is to identify barriers to practice change and then to implement strategies that account for identified barriers. Barriers can be specific to practitioners themselves or specific to the context they work in (Michie et al, 2011; Chisolm & Abrams, 2010; Greenhalgh 2010).

2.8.1 Common Barriers

Clinical expertise is essential to evidence-based practice (Palmer 2007) and can be a significant barrier. Implementation into practice often takes learning a new skill. This takes time and is affected by motivation and opportunity. National Deaf Children's Society (NDCS) guidance for paediatric audiology (2016) recommends that all paediatric audiologists are trained at postgraduate level e.g. MSc. in order to ensure appropriate skills.

Lack of time is cited as a major difficulty in much of the literature, regardless of profession (Moodie 2012; Kajermo et al, 2010; Eccles et al, 2009; Zippoli & Kennedy, 2005). Kajermo et al (2010) suggest that time may be a complex barrier. There is often a culture of busyness in healthcare professions where being busy is seen as important, creating a lack of mental time and energy. Therefore, providing resources to create an environment that fosters and values reflection and research may be more effective than just providing more physical time in a working day.

2.8.2 Context

Moving evidence into practice is also dependent on factors at organisational levels (Rycroft-Malone et al, 2004). Eccles et al (2009) argue that our knowledge of how to implement research or guidelines is limited because of the diversity of contexts in which people work. The Barriers Scale (Funk et al, 1991) is unlikely to adequately inform interventions intended to increase use of evidence in practice because of its general nature. Barriers in one setting may not be present in another.

2.8.3 Solutions to Barriers

Specific roles should be identified to ensure success of any new process. Effective teams consist of system leadership (authority to implement and maintain change), technical expertise (skill development) and day to day leadership (maintenance of momentum) (National Health and Medical Research Council 2000).

Collaborative working enhances success. Rycroft-Malone et al (2004) identified multidisciplinary work as increasing chances of successful implementation, i.e. good relationships allow common ways forward to be more easily developed. The flow of information and knowledge can be inhibited by professional boundaries.

It is known from the literature that passive dissemination of information is ineffective no matter how important the issue (Bagatto 2012). Multi-faceted interventions or a combination of methods have been suggested as more effective than single interventions (Bagatto 2012; Grol & Grimshaw, 2003). Models promoting multi-faceted interventions have been suggested e.g. the Behaviour Change Wheel (Michie et al, 2011) and the Knowledge to Action Cycle (Graham et al, 2006). Targeting all three variables that can influence practice, i.e. capability, opportunity and motivation (Michie et al, 2011) may be more successful in supporting change. However, Roberts et al (2012) found no significant changes in audiological practice patterns for a small group involved in a multi-faceted educational event which targeted three variables. Grimshaw et al (2004) in a systematic review found only 10% improvement in adherence to guidelines from using multi-faceted approaches and concluded that there is an imperfect evidence-base for decision makers to work from. Grol and Grimshaw

(2003) also conclude that research so far shows that no approach is superior for all changes in all situations. It may be that individual solutions will always be necessary as research may not generalise to individual organisations.

2.9 Conclusion and Rationale for Research

Implementing change and ensuring guidelines are used is complex and challenging. There is no clear outline of strategies that work for any given situation. However, some commonalities have been identified.

The evidence-base for audiological practice with infants and children supports a consistent and systematic approach to hearing aid fitting in order to maximize audibility of speech. However, there is widespread variation in outcomes for children with hearing loss despite the advent of newborn screening (Tomblin et al, 2015). There is also variation in adherence to a systematic approach. There is a need to further examine the contribution of factors such as quality of hearing aid fit and consistency of hearing aid use to language outcomes in the paediatric population. It is important for the audiologist to understand how input provided by amplification affects learning (Stiles et al, 2012).This may support the motivation for change in clinical practice and an increased use of REMs in fitting hearing aids to children.

Moodie (2011) argues for an increased understanding of audiologists' perceptions of the barriers to the use of evidence in the practice environment and the broader healthcare system in which they work. This is necessary to develop strategies to facilitate practice behaviour change. It is known that producing guidelines (knowledge) is not sufficient. More time should be spent on the critical components for moving the knowledge into practice. This will then further support the goals of early identification and intervention for permanent childhood hearing loss.

2.10 Aims of Study

This study seeks to investigate the use of REMs in one paediatric audiology clinic. Barriers and solutions to the implementation of REMs in the clinic are explored.

Quality Standards (QSs) for Paediatric Audiology have not yet been adopted in Northern Ireland (NI). This has likely had an effect on adherence to best practice guidelines. Aided sound-field measures are most often used for the verification

stage of hearing aid fitting for children. However, aided sound-field measures do not provide information about the gain for speech level inputs and maximum SPLs delivered to the ear in the non-linear aid. There is no standard for the amount of functional gain which is sufficient, other than believing that lower thresholds are better (McCreery 2013; Kuk & Ludvigsen 2003).

The verification method used is a potential factor in quality of hearing aid fitting outcome. This study seeks to investigate the actual proximity to prescriptive targets of the current hearing aid fittings for a group of children and to evaluate the kind of fitting that can be achieved using REMs to verify hearing aid output in this clinical context. Context is important when considering changing practice. Hakkenes and Dodd (2008) argue that effective change only occurs if barriers specific to a particular group or organisation are identified and then strategies to address these barriers in this context are developed. It is hoped that this research will be a first step to gain an increased understanding of the barriers in this local context and that working closely with audiologists will improve communication and working relationships between services. The results of this study will be provided to the local clinic to aid the decision making process in producing guidelines for the fitting of hearing aids to young children in this clinic.

2.11 Research Questions

Four research questions are posed in this study:

1. When carrying out a REM during a routine audiology appointment – what is the proximity of the current (initial) hearing aid fitting to DSL V 5.0 prescription targets? That is, what is the measured difference between target gain and actual gain from the hearing aid across the frequency range and at input levels of 50dB SPL, 65dB SPL and 80dB SPL?
2. What is the proximity of the adjusted hearing aid fitting to DSL V 5.0 prescription targets with individually measured RECDs by the audiologist following BSA guidelines (2008) for verification?
3. Do aids modified as a result of verification using REMs improve speech perception scores in quiet / in noise?
4. What are the barriers to change in practice with reference to REMs for children in a case study of a Paediatric Audiology Clinic?

As part of research question 2, a null hypothesis was proposed:

Frequency does not affect proximity to target in adjusted fitting at 65 dB SPL input level.

3. Methodology

3.1 Study Design

A case study approach was chosen using mixed methods. This approach involves collecting a range of data to focus on a particular unit of analysis. A case study is useful when interested in a wider issue, that is, the implementation of best-practice guidelines in audiology. There is a need for research on both the implementation of and the accuracy of REMs by typical clinicians in typical clinics (Dillon & Keidser, 2003).

Case studies recognise that context is a powerful determinant of causes and effects (Koshy 2010). They can be a step to action in that insights may be interpreted and put to use for development in an institution (Cohen et al, 2000). It is known that dissemination of guidelines alone is not enough to put them into practice (Bagatto 2012). Barriers to implementation of practice cannot be generalised across different organisations. A case study then is useful to systematically look at a specific case, collect data and interpret findings within a specific context. The author and lead audiologist had the opportunity to collaborate and experience the process of implementing REMs in the clinic and to identify the barriers which emerged in this context in order to identify specific strategies for implementation.

3.1.1 Validity and Reliability

Some difficulties arise from a case study approach. A case study cannot be replicated and it may also be difficult to generalise to other examples. However, Flyvberg (2006) suggests that if knowledge cannot be generalised, this does not mean that it cannot enter into the process of knowledge accumulation. It is important however that the researcher does not present data in ways which suggest it applies in general rather than to a specific set of circumstances (Anderson & Arsenault 2005). This case study is a response to a particular question and therefore it can only provide a partial understanding of the actions and beliefs of participants involved (Willig 2013). Despite these disadvantages, case studies can give explanations that potentially apply to other cases (Willig 2013). The outcomes from this case study may apply in other paediatric audiology clinics.

The validity of the research also depends on the researcher's ability to reflect on and recognise their own bias. It is the responsibility of the researcher using qualitative data to attempt to understand bias so as not to distort data (Ely et al, 2003). The author believes that REMs should be carried out as far as possible in routine paediatric audiology appointments in order to obtain robust verification. This bias may colour conclusions but efforts have been made to recognise this bias and to present all results even if they do not result in the implementation of REMs.

3.2 Ethics

REMS are not outside the normal care in a Paediatric Audiology Clinic and their use meets national quality guidelines for hearing aid fitting. Information and consent forms were provided to both parents and children and who participated in the study. Information letters were sent to audiologists outlining the study and its purpose. Confidentiality and anonymity were assured and maintained.

Ethics approval was sought from University of Hertfordshire.

Copies of documents are included as Appendix A.

3.3 Quantitative data collection

3.3.1 REMS

Quantitative data was collected to measure the difference between target gain and actual gain in the current hearing aid fittings of eight children. Speech perception scores were measured before and after hearing aids were adjusted according to REMs for each child. The children in the study attend the local Paediatric Audiology Clinic and are on the author's educational case load.

Data collection was carried out over a period of four months. Table 3.1 shows criteria for inclusion:

Table 3.1: Criteria for investigation of REMs

Inclusion Criteria	**Exclusion Criteria**
• Bilateral sensorineural hearing loss with amplification for at least one year.	• Children with profound hearing loss. Fitting to targets can be difficult with this group of children. The degree to which speech can be made audible through amplification is strongly dependent on the degree of hearing loss (McCreery et al, 2015). It would be unlikely to see significant differences in the output of hearing aids for this group of children. The emphasis is more on audibility than strict adherence to targets for profound losses (BSA 2008). Children with profound loses are also likely to be implanted.
• Use of spoken language as primary form of communication.	• Children with fluctuating or conductive losses. REMs on ears with conductive loss require careful interpretation because it is difficult to know whether the

	intensity level that is recorded is the same as that being transmitted to the middle ear (BSA 2008).
• Participants are consistent hearing aid wearers as reported by parents/carers and teachers of the deaf.	
• Hearing aids before the study have been fitted using DSLv5.0 selected in manufacturer software and averaged real ear to coupler difference (RECD) according to age, that is, 'click and fit' method.	
• Age range of 5 to 12 year olds.	
• Good fitting earmoulds.	

3.3.1.1 Equipment (REMs)

Make – Siemens

Model – Unity 2

Software – Siemens Probe-mic

3.3.1.2 Procedure

When carrying out REMS, the real-ear aided response (REAR) was used as recommended by BSA (2008). It was decided to use an RECD measurement for a coupler derived REAR.

Prior to testing, otoscopy was carried out to ensure participants' ear canals were sufficiently clear to use the insert probe-tube. Tympanometry was carried out to check middle-ear status. Fitting data for the current fit (initial fit) of each hearing aid was obtained by connecting with the software.

To measure the actual output of the hearing aid in the child's ear, REAR was measured following BSA (2008) recommended procedures. For the RECD

measurement, the coupler measurement was completed first by recording the reference-microphone in the coupler. Next, the REM was carried out by placing the calibrated probe-tube in the child's ear. Accurate placement was achieved by setting the black marker on the probe-tube to guidelines recommended by BSA (2008), that is, 25 mm for children who are 5+ years old and within 5mm of the tympanic membrane (Munro 2004). The probe-tube was then inserted down the ear until the marker was at the tragus. Otoscopy was used again to check placement of the probe-tube along the bottom of the ear canal. The earmould attached to the insert earphone was inserted into the ear and a real-ear unaided response (REUR) measurement was completed to give an additional check for probe-tube placement. Then the second part of the RECD was measured. It was attempted to measure RECDs bilaterally, but where this was not possible, e.g., due to excessive cerumen, the RECD recorded from one ear was also used on the untested ear (Munro 2004).

The hearing aid was attached to the coupler and measured RECD was selected in the software. The hearing aid was unmuted with all usual features left on.

For Phonak hearing aids employing frequency compression, adaptive features including SoundRecover were deactivated in the verification software to allow adjustment of gain (Phonak 2016).

An input of 65 dB SPL modulated speech-shaped noise stimulus (International College of Rehabilitative Audiology, ICRA) was selected and targets matched as closely as possible. Any deviations from the target across frequencies were recorded in dB SPL, first for the current fit (initial) and then for the REM-adjusted fit. This process was repeated for input levels 80 dB SPL and 50 dB SPL and separate adjustments made for each input level.

3.3.2 Evaluation using Speech Perception Tests

3.3.2.1 Equipment

The Parrot Portable Automated Speech System was used to measure speech perception scores. Delivery through the Parrot system allowed for more reliable test-retest conditions and for tests to be delivered by audition only. AB open set word lists were used. Each list consists of 10 monosyllabic words and is balanced for phonemic content. These tests are currently used by teachers of the deaf (TOD) for this group of children. They are scored by phoneme.

Each child was tested in their educational setting in a quiet room during a normal visit by the TOD. Calibration of equipment was carried out at each session using a sound level meter and calibration check stimulus on the Parrot system (calibration tone of 60 dBA at 75 cms).

All tests were delivered via the loudspeaker of the Parrot system at 50dBA and 65dBA at 0-degree azimuth without competing noise. Classroom babble was chosen for the noise conditions of +10dB signal to noise ratio (SNR), +5dB SNR and 0dB SNR.

Before their appointment at the audiology clinic for REM-verification, a baseline speech perception measurement was carried out. A second measure was carried out 4 weeks after REM-adjustment of hearing aid fit.

3.3.3 Audiology questionnaire

A questionnaire was used to establish patterns and general views on the wider use of REMs in health trusts. The purpose was to learn:

a. How often REMs are used routinely with children.
b. Initial information on audiologists' perceptions of barriers and facilitators to implementing evidence-based practice with specific reference to REMs.
c. Information on the sources of knowledge which audiologists use to guide management of patients and procedures.

A postal questionnaire was used which can result in a lower response rate and therefore reduce reliability. Strategies to maximise response rate were used, including a stamped addressed envelope, follow up to request returns and a covering letter (Appendix A) to explain the purpose and benefit of the

questionnaire. Care was taken in design of the questionnaire taking into account ease of completion and time required to complete the questionnaire.

A questionnaire may be an effective method of collecting data because it is anonymous. However, there is a risk that respondents may reply in the way they believe is expected (Koshy 2010) rather than stating their real belief. Validity is also affected by those who fail to return questionnaires, that is, would they have given the same distribution of answers as the returnees (Cohen et al, 2000).

Open questions were included in the questionnaire to obtain further information on barriers to practice. This may create some bias in results because such questions may evoke responses only from those with more extreme views (Anderson & Arsenault 2005).

3.3.3.1 Instrument

The first two parts of the questionnaire were based on questions in the Developing Evidence-Based Practice Questionnaire (Gerrish et al, 2007). This questionnaire has previously been demonstrated to have acceptable reliability and validity. It was originally developed for use with the nursing profession but has been adapted for use with audiologists (Moodie 2012). Section 1 includes 21 items that measure sources of knowledge used in practice. Each item is scored on a 5-point Likert scale from 1 (never) to 5 (always). Section 2 includes 11 items to measure variables relating to barriers to changing practice. This was scored on a 4-point Likert scale. The neutral point was removed to force respondents to make a choice in order to assist in identifying barriers in practice. Respondents were asked in an open-item response format to provide any additional information on facilitators and barriers to the provision of evidence-based care in their practice. Respondents were then asked about their approach to verification. A final question sought to investigate audiologists' perceptions concerning the most important factors for improving outcomes for deaf children in this region. The questionnaire is included in Appendix B.

3.4 Qualitative Data Collection

3.4.1 Interviews

Triangulation was achieved by holding semi-structured interviews to gain a deeper understanding of the perceptions and experiences of audiologists in this region. Interviews allow for more in-depth analysis of a case. It is important to discover audiologists' views and the barriers to practice in this particular context in order to fulfil the aims of the study. The interview can aid understanding of the experiences of people in a similar situation (Flick 2008). It is important to acknowledge research bias in order to avoid value judgements and to ensure respect for peoples' intentions when interpreting their practices or statements collected in interview data. This case study should not be judged as a deficit model regarding the use of REMs in the verification process.

A semi-structured interview was used (Appendix B). Questions were considered in light of research outlined in the literature review and questionnaire responses. Five interviews were carried out. The audiologists interviewed were known to the researcher. This interview situation allowed open and frank responses to be made.

3.5 Quantitative data analysis

3.5.1 REMs

Two groups of data were analysed:

1. Recorded deviations from prescriptive targets on the current (initial) fitting of each child's hearing aids.
2. Recorded deviations from prescriptive targets after verification using REMs (RECD)-adjusted fitting.

Obtained fitting data for the initial fitting was compared to DSlv5.0 prescriptive targets. Deviations from prescriptive targets for each input level and across frequencies were entered into Microsoft Excel 2013 ™ and charts generated.

Percentages were calculated for the number of ears found to be above, on or under target for each input signal level across the frequency range for both initial fittings and adjusted fittings.

A root mean square error (RMSE) of fit-to-target was calculated for each child's initial fitting and adjusted fitting. RMSE was used because deviations from target included both positive and negative numbers. RMSE measures the magnitude of a set of numbers and gives a sense of the typical size of the numbers. It provided a single value of deviation from targets for each child. It was calculated by squaring the values, finding the average of the squares and taking the square root of the average.

The RMSE of the fitting to DSLv5.0 prescriptive targets was compared to each child's PTA for both the initial fitting and the adjusted fitting. The relationship between the RMSE and PTA was evaluated using a correlation analysis in Excel.

The deviations from prescriptive target for 65 dB SPL input on the adjusted fitting were entered into Excel. A repeated ANOVA measure was calculated to examine whether frequency was an influence on the ability to match prescriptive targets when adjusting aids using the child's individually measured RECD. A repeated measures ANOVA detects any overall differences between related means. It can be used for differences in mean scores, that is, deviations from targets for each child under 3 or more different conditions, that is, frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz and 6000 Hz.

The match to prescribed target slope in each octave was not analysed.

3.5.2 Speech Perception

Scores for initial fitting speech perception and scores for speech perception after REM-adjustment of hearing aids were entered into Excel. The mean of each child's initial speech perception scores in each condition (50dBA, 65dBA, +10 SNR, +5SNR, 0SNR) was calculated. This was repeated for each child's speech perception scores after REM-adjustment. The means from the initial condition and REM-adjusted condition were used to carry out a one tailed T-Test. A one tailed T-Test can predict if the mean is significantly greater than the original mean value.

3.5.3 Questionnaire

A descriptive analysis was used due to the small numbers involved in the survey. The aim was to provide an overall picture of practice and the perceptions of audiologists in this region.

Scores for each response in questions 3, 4 and 9 (based on Likert scale) were entered into Excel and a mean score with standard deviation calculated. Each item was then ranked in order according to score.

A percentage of responses indicating how hearing aid fittings are verified was calculated.

The content of the open-ended questions were examined for additional information.

3.6 Qualitative data analysis

3.6.1 Interviews

A transcript was made of each interview and initial notes made in response to the text. Emergent themes were identified. The analysis aim was to encourage more in-depth reflection on experiences and attitudes.

4. Results

4.1 Quantitative analysis

4.1.1 REMs

Fitting results were obtained from 16 ears.

4.1.1.1 Relative output levels

Figures 4.1 to 4.12 show hearing aid outputs for initial fittings and adjusted fittings across frequencies relative to each input level (50, 65 and 80 dB SPL) for 16 ears. MCHAS guidelines (2005) recommend a tolerance to the prescription of ±5 dB at frequencies 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz and ±8 dB at 3000 Hz and 4000 Hz. A ±5 dB tolerance range for all frequencies was used for ease of calculation. Each scatter plot figure has a corresponding figure to show the percentage match to prescriptive targets.

Percentages were calculated for the number of ears with output levels above, on and under prescriptive targets for each signal input across the frequency range. A tolerance range of ±5 dB was defined as being on target.

Figure 4.1: Relative output levels (difference between the measured outputs and the DSLv5.0 target values) for an input signal of 50 dB SPL for initial fits. The 0 value (blue line) represents prescriptive targets.

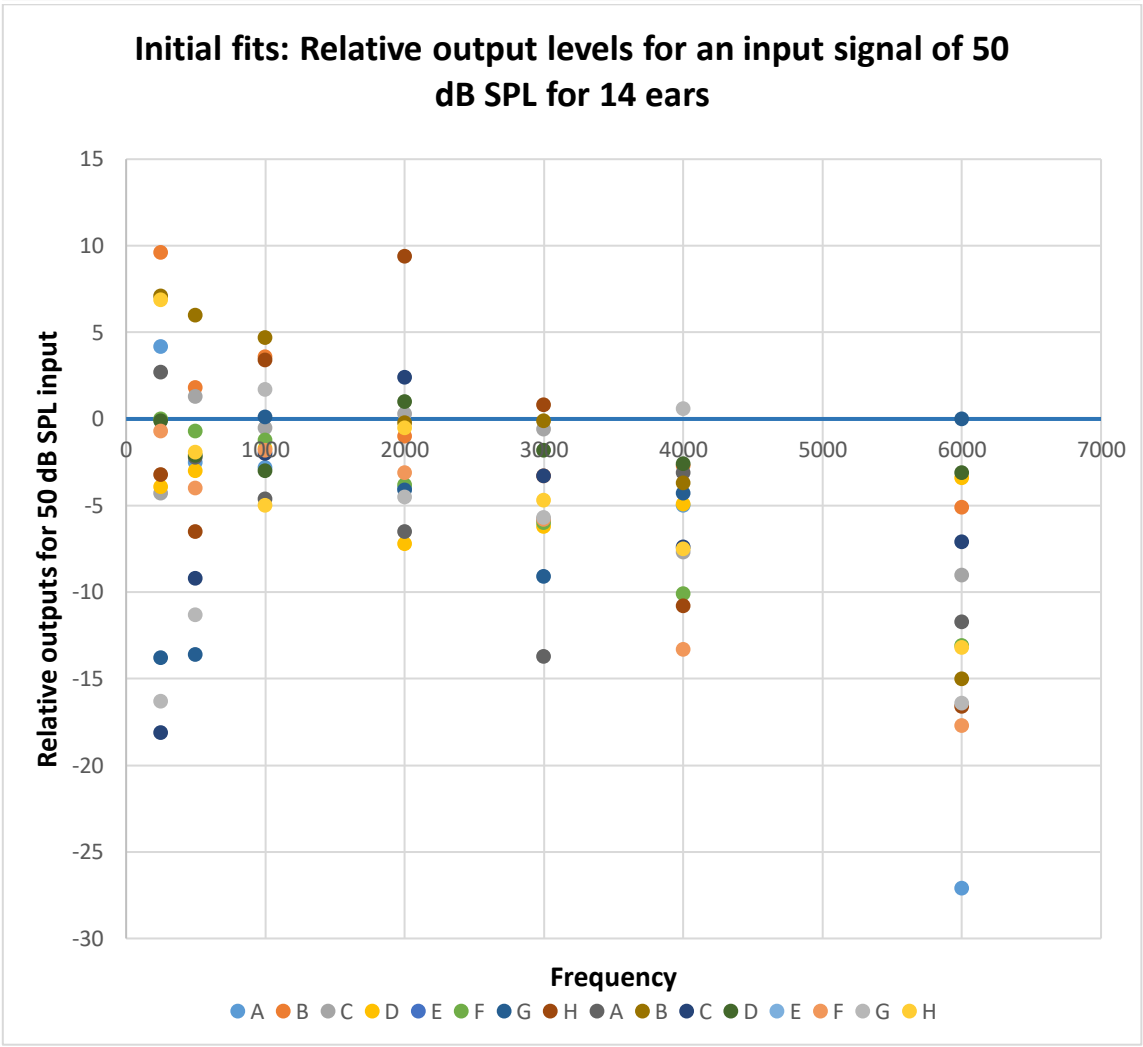
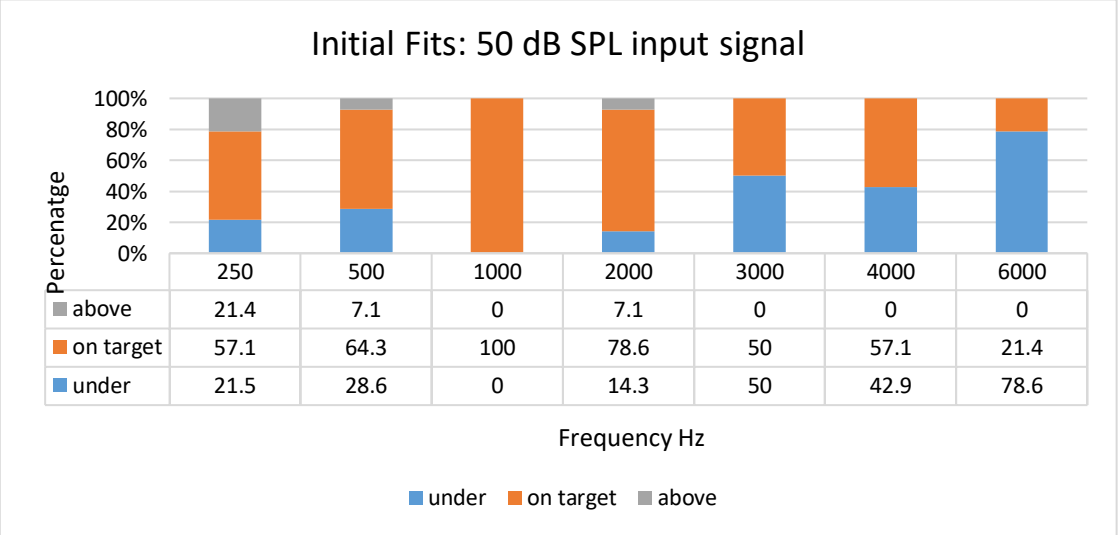


Figure 4.2: Distribution of relative output levels (differences between measured outputs and DSLv5.0 target values) according to three categories (above, on, under target) across frequencies for 14 ears (initial fits): 50 dB SPL input



	250	500	1000	2000	3000	4000	6000
above	21.4	7.1	0	7.1	0	0	0
on target	57.1	64.3	100	78.6	50	57.1	21.4
under	21.5	28.6	0	14.3	50	42.9	78.6

Figure 4.3: Relative output levels (difference between the measured outputs and the DSLv5.0 target values) for an input signal of 50 dB SPL for 14 ears (adjusted fits). The 0 value (blue line) represents prescriptive targets.

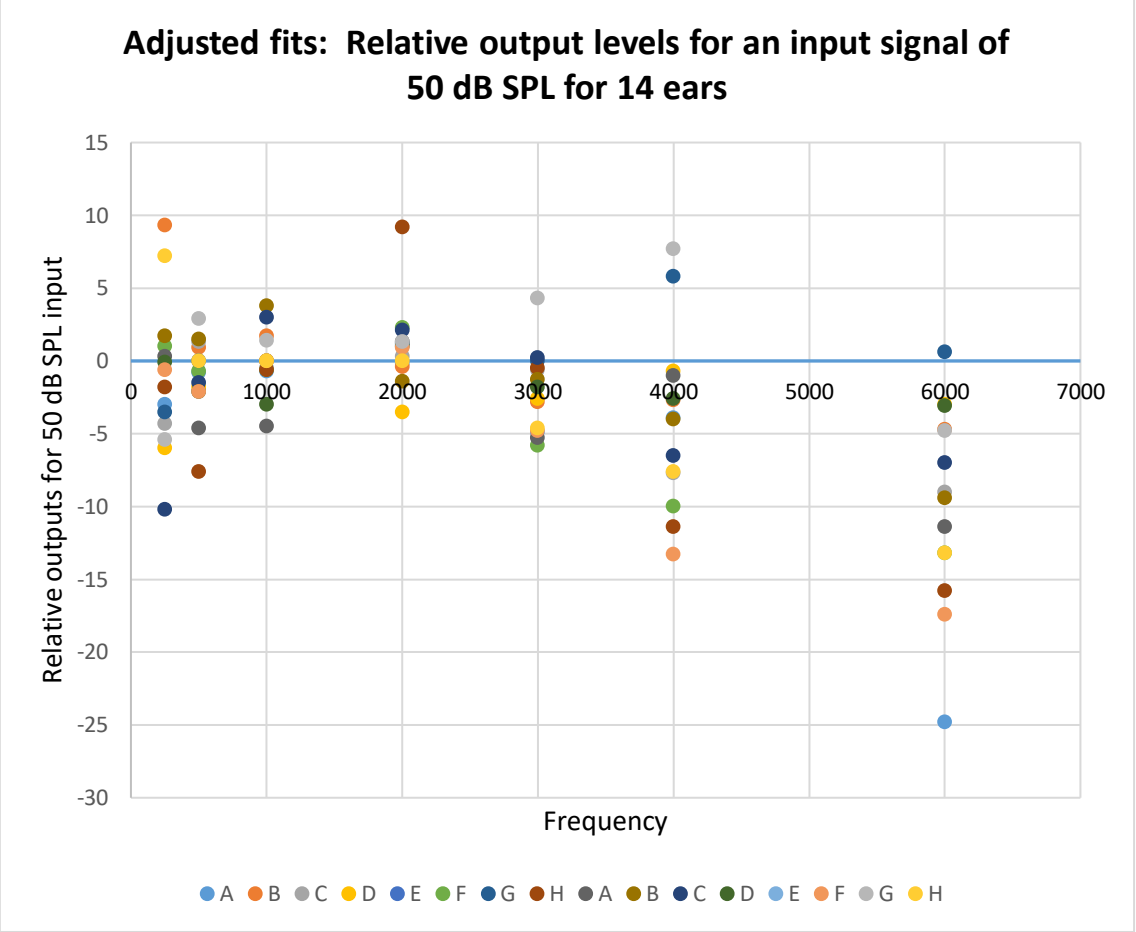
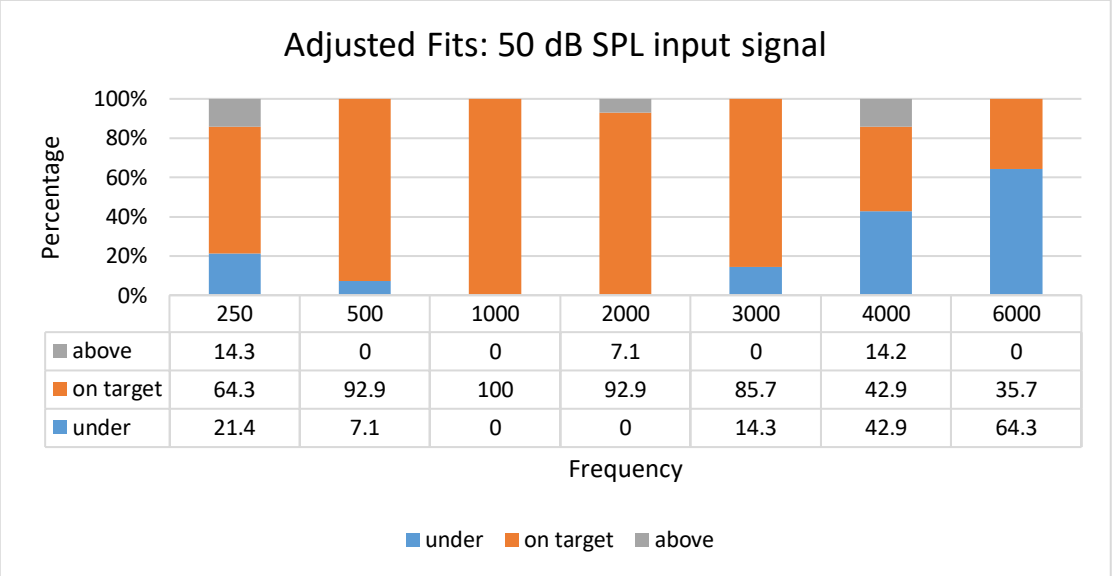


Figure 4.4: Distribution of relative output levels (differences between measured outputs and DSLv5.0 target values) according to three categories (above, on, under target) across frequencies for 14 ears (adjusted fits): 50 dB SPL input



	250	500	1000	2000	3000	4000	6000
above	14.3	0	0	7.1	0	14.2	0
on target	64.3	92.9	100	92.9	85.7	42.9	35.7
under	21.4	7.1	0	0	14.3	42.9	64.3

Figure 4.5: Relative output levels (difference between the measured outputs and the DSLv5.0 target values) for an input signal of 65 dB SPL for 16 ears (initial fits). The 0 value (blue line) represents prescriptive targets.

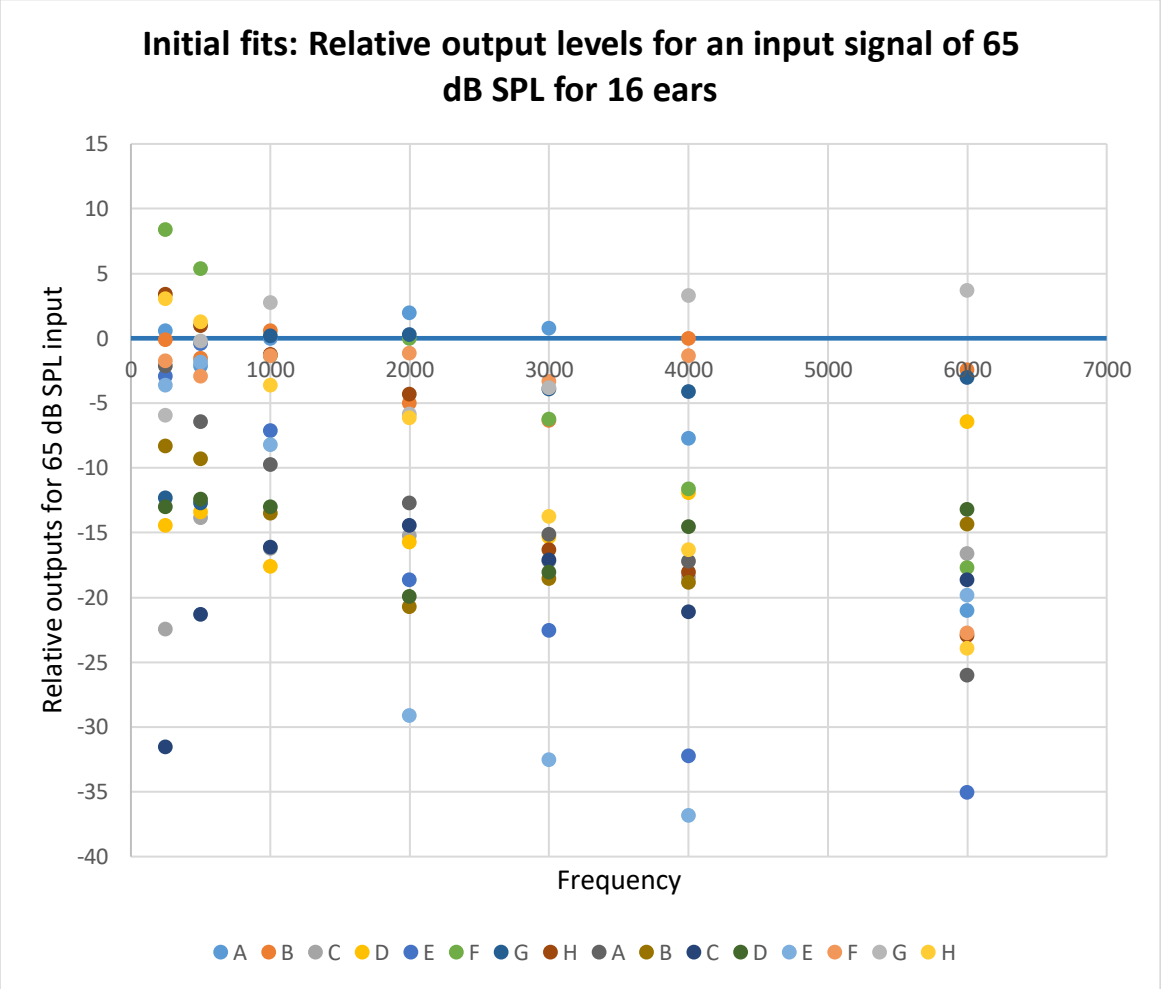
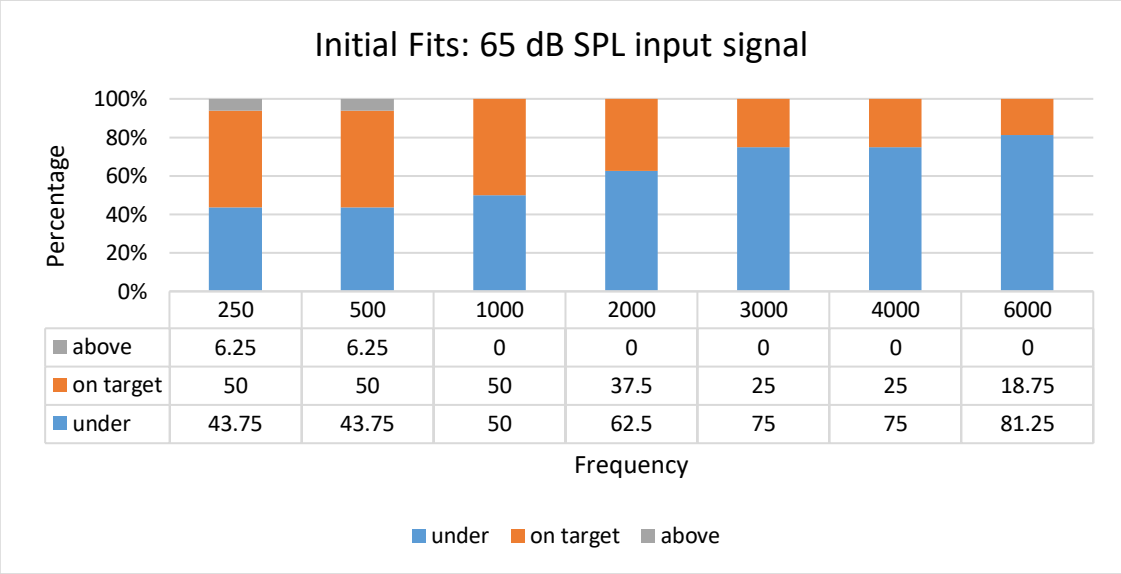


Figure 4.6: Distribution of relative output levels (differences between measured outputs and DSLv5.0 target values) according to three categories (above, on, under target) across frequencies for 16 ears (initial fits): 65 dB SPL input



	250	500	1000	2000	3000	4000	6000
above	6.25	6.25	0	0	0	0	0
on target	50	50	50	37.5	25	25	18.75
under	43.75	43.75	50	62.5	75	75	81.25

Figure 4.7: Relative output levels (difference between the measured outputs and the DSLv5.0 target values) for an input signal of 65 dB SPL for 16 ears (adjusted fits). The 0 value (blue line) represents prescriptive targets.

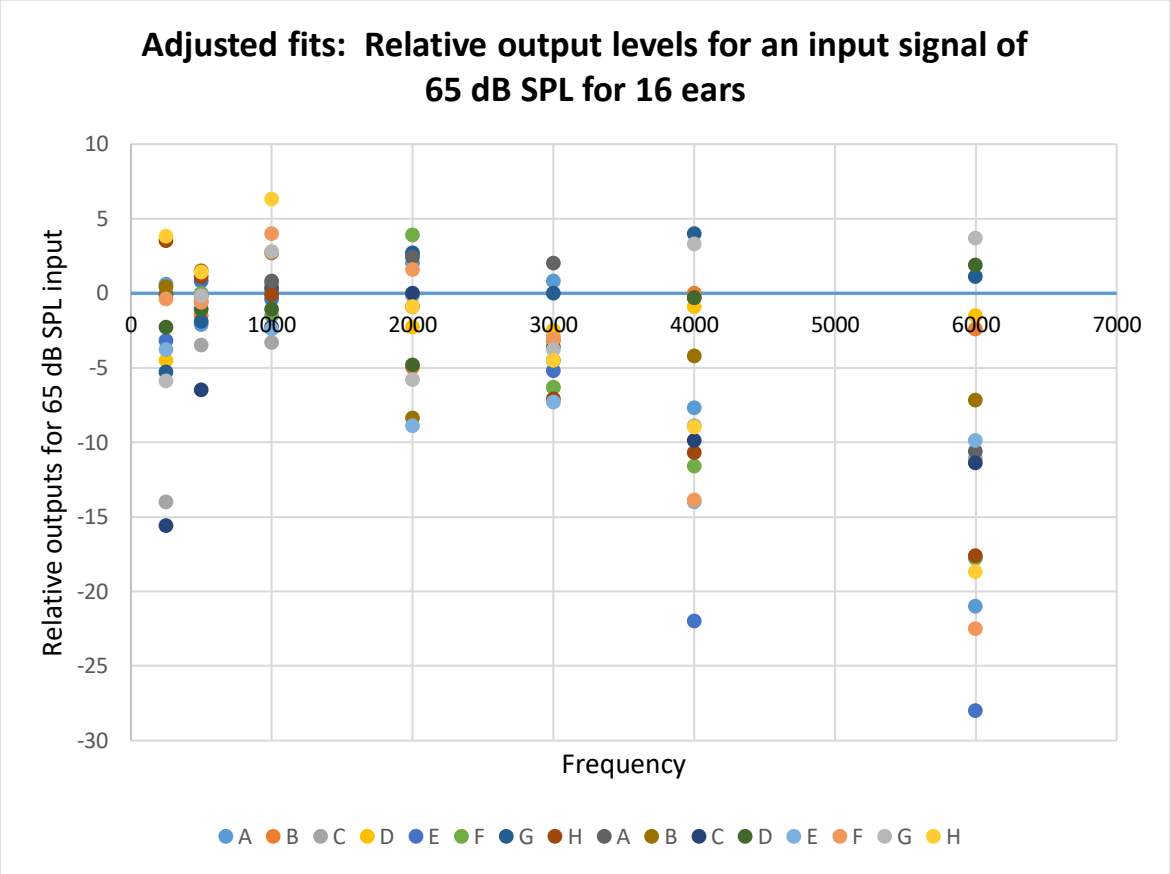
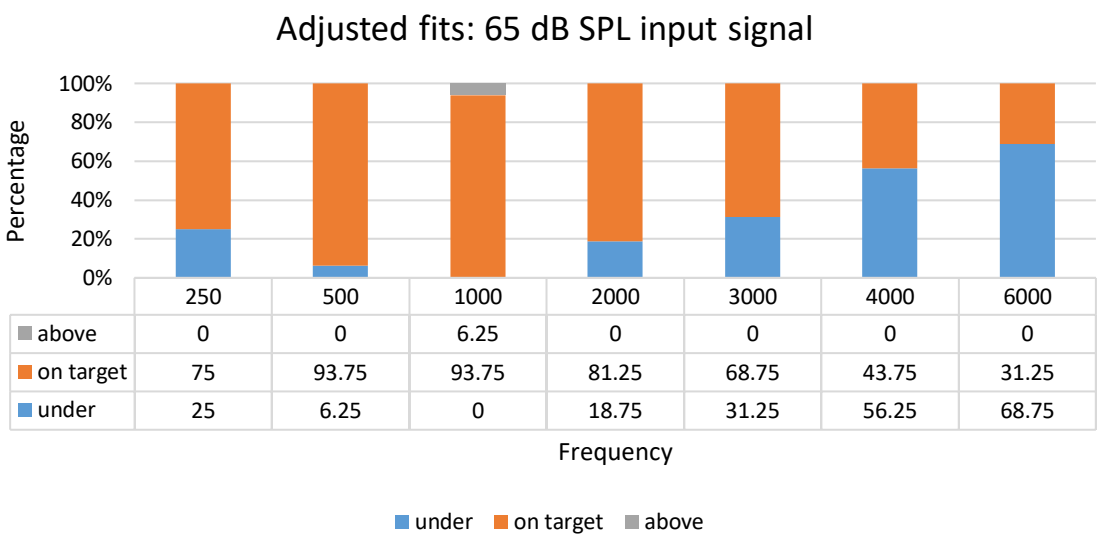


Figure 4.8: Distribution of relative output levels (differences between measured outputs and DSLv5.0 target values) according to three categories (above, on, under target) across frequencies for 16 ears (adjusted fits): 65 dB SPL input



	250	500	1000	2000	3000	4000	6000
above	0	0	6.25	0	0	0	0
on target	75	93.75	93.75	81.25	68.75	43.75	31.25
under	25	6.25	0	18.75	31.25	56.25	68.75

Figure 4.9: Relative output levels (difference between the measured outputs and the DSLv5.0 target values) for an input signal of 80 dB SPL for 16 ears (initial fits). The 0 value (blue line) represents prescriptive targets.

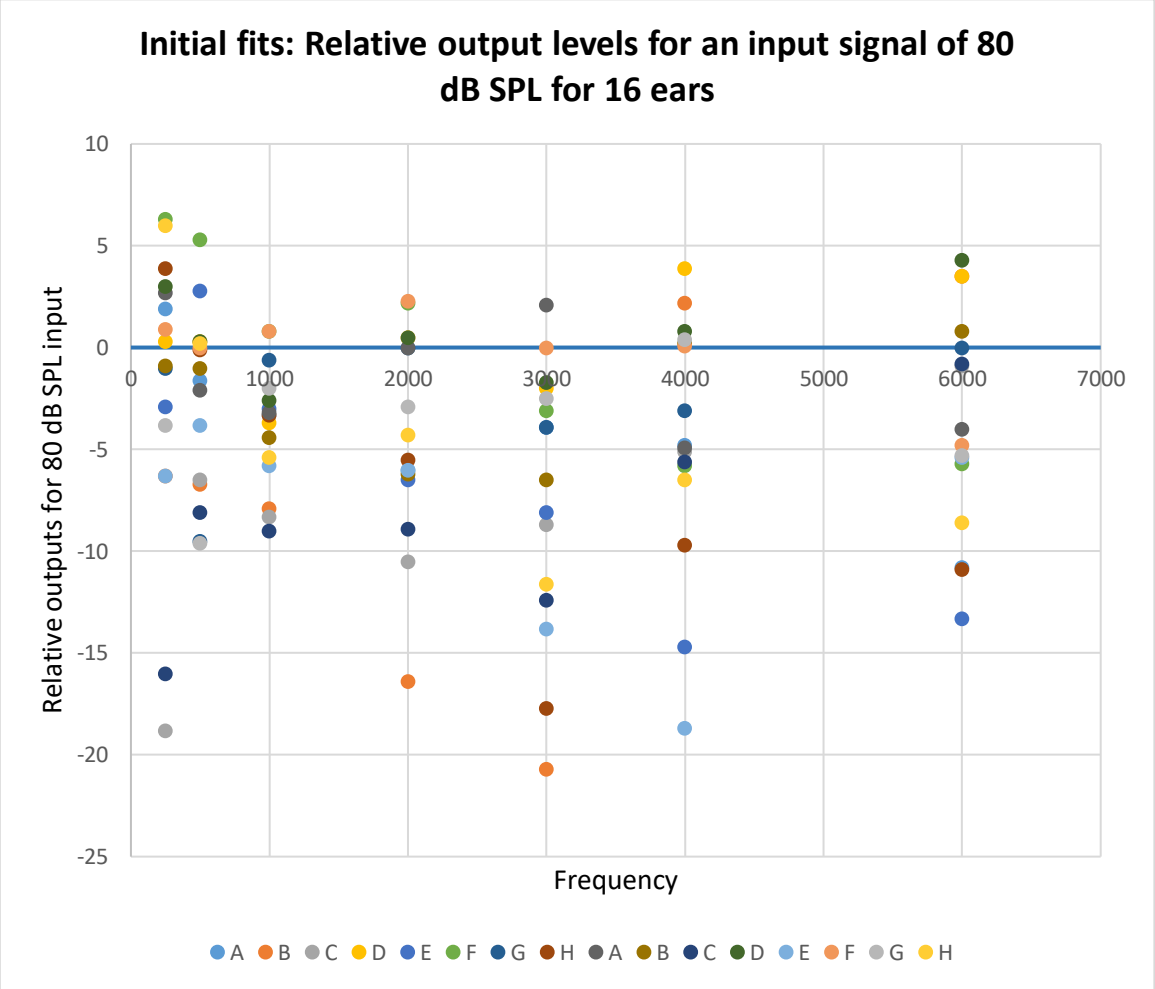
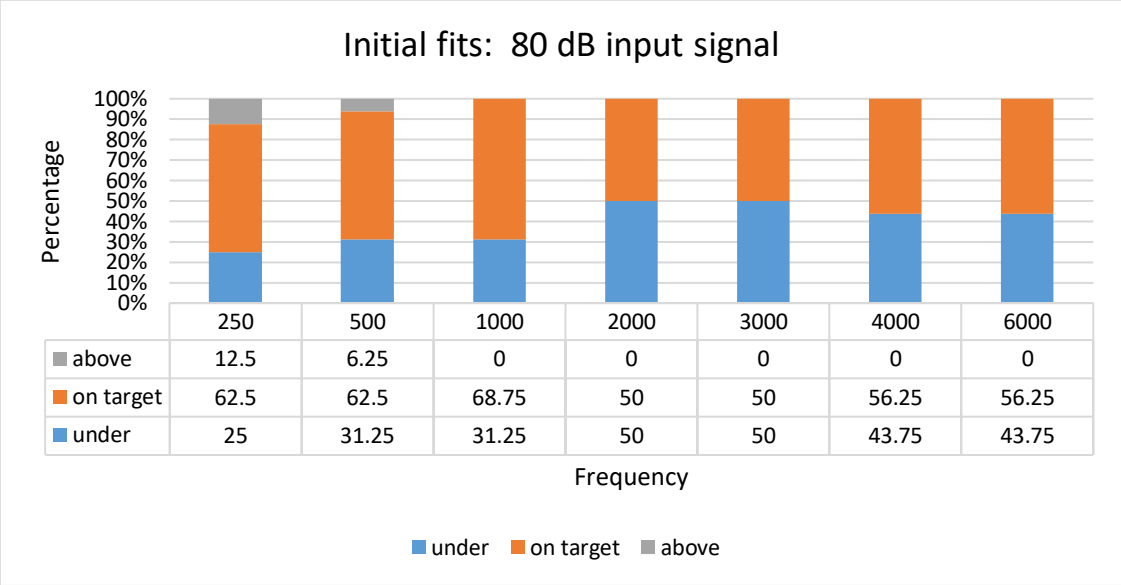


Figure 4.10: Distribution of relative output levels (differences between measured outputs and DSLv5.0 target values) according to three categories (above, on, under target) across frequencies for 16 ears (initial fits): 80 dB SPL input



	250	500	1000	2000	3000	4000	6000
above	12.5	6.25	0	0	0	0	0
on target	62.5	62.5	68.75	50	50	56.25	56.25
under	25	31.25	31.25	50	50	43.75	43.75

Figure 4.11: Relative output levels (difference between the measured outputs and the DSLv5.0 target values) for an input signal of 80 dB SPL for 16 ears (adjusted fits). The 0 value (blue line) represents prescriptive targets.

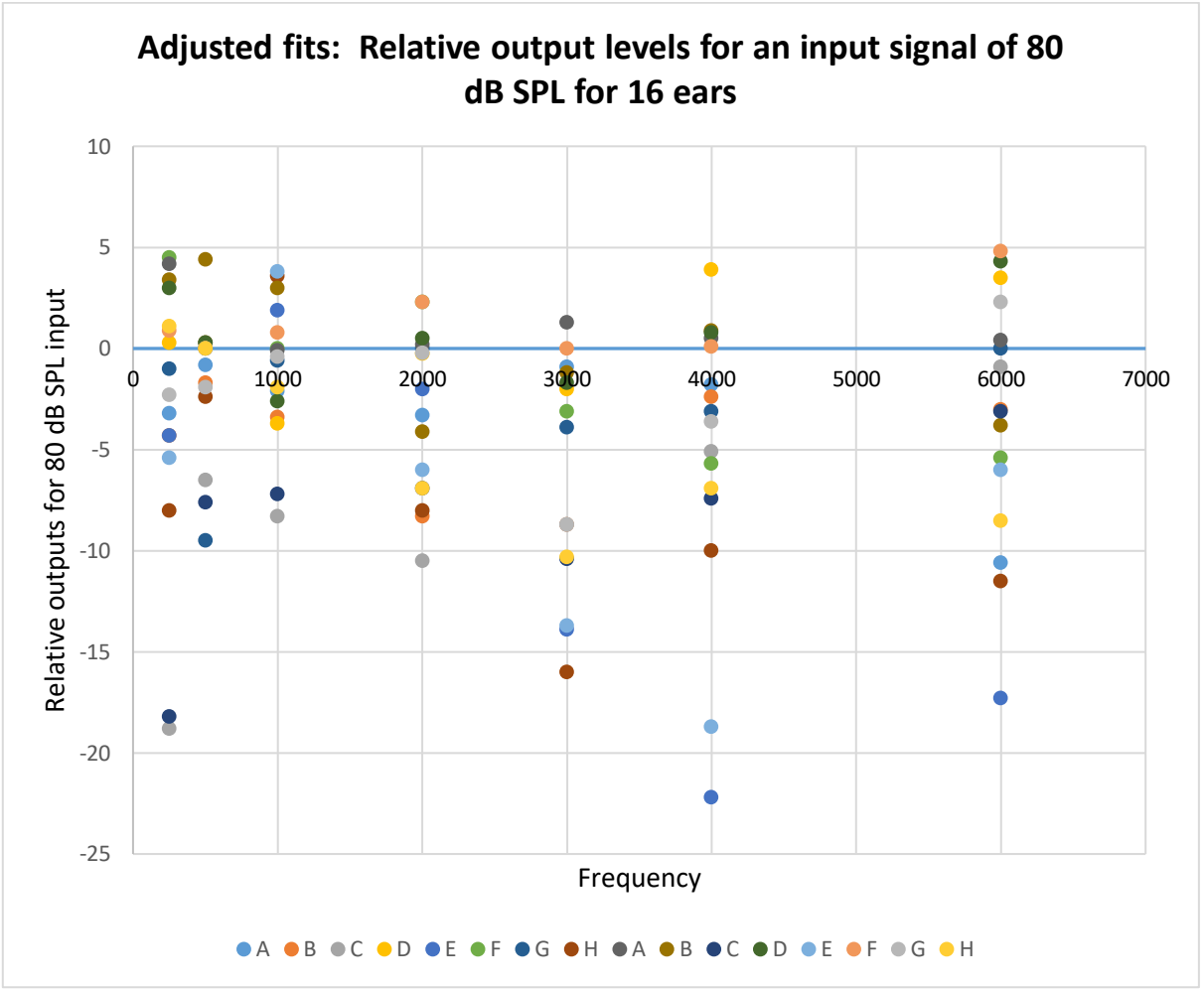
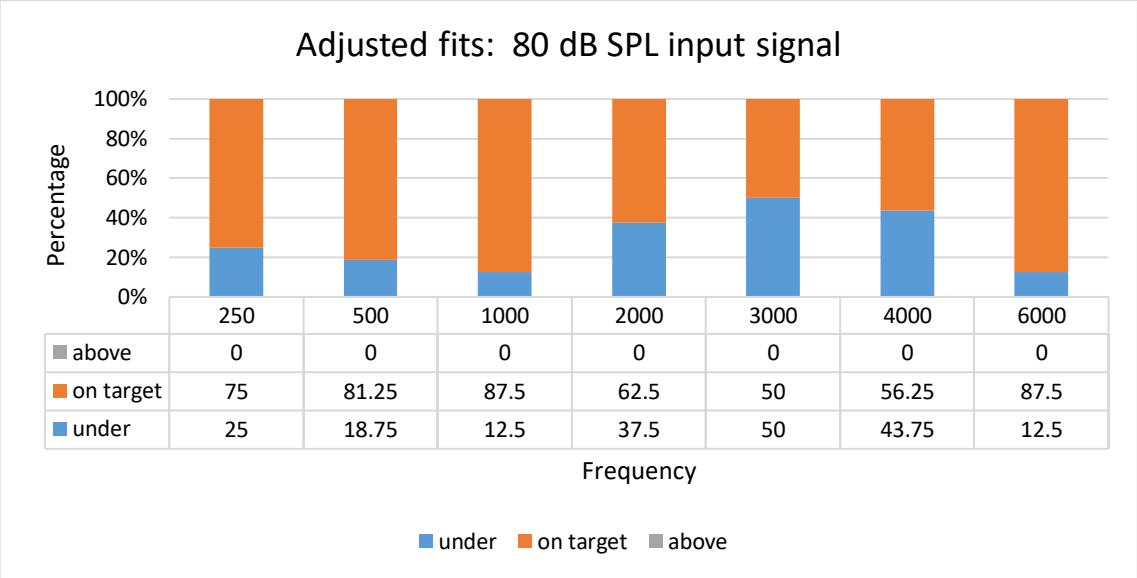


Figure 4.12: Distribution of relative output levels (differences between measured outputs and DSLv5.0 target values) according to three categories (above, on, under target) across frequencies for 16 ears (adjusted fits): 80 dB SPL input



	250	500	1000	2000	3000	4000	6000
above	0	0	0	0	0	0	0
on target	75	81.25	87.5	62.5	50	56.25	87.5
under	25	18.75	12.5	37.5	50	43.75	12.5

Table 4.1 shows a summary of key results for REMs.

Table: 4.1 Summary of Results for REMs	
Figures and Input	Summary of results
Figures 4.1 and 4.2 Initial Fit 50 dB input	Under-amplification occurred in all frequencies except 1000 Hz. Under-amplification was worse above 2000Hz.
Figures 4.3 and 4.4 50 dB input Adjusted Fit	Under-amplification was a feature in adjusted fittings although it improved at frequencies 250 Hz to 3000 Hz. Under-amplification improved slightly at 6000 Hz. Five ears (35.7%) at 6000 Hz had relative outputs in the acceptable tolerance range (compared to three ears (21.4%) for initial fittings). In trying to improve match to prescriptive targets, over-amplification occurred at 250 Hz, 500 Hz and 4000 Hz.
Figures 4.5 and 4.6 65 dB input Initial Fit	Significant under-amplification occurred across all frequencies. Under-amplification ranges from 5.4 dB to 36.8 dB outside the tolerance range. The number of ears within the acceptable tolerance range decreases with higher frequency.
Figures 4.7 and 4.8 65 dB input Adjusted Fit	Improved match to prescriptive targets was achieved overall, although under-amplification remained at all frequencies. Matching close to prescriptive target became increasingly difficult above 2000 Hz.
Figures 4.9 and 4.10 80 dB input Initial Fit	Under-amplification is a feature across all frequencies. The worst under-amplification at 50% is at 2000 Hz and 3000 Hz. There is some over-amplification at 250 Hz and 500 Hz.

Figures 4.11 and 4.12 80 dB input Adjusted Fit	Over-amplification was resolved. Under-amplification remained a feature across all features, although deviations decreased. The biggest decrease in under-amplification was at 6000 Hz. There was no improvement at match to prescriptive target at 3000 Hz.

Figures 4.1 to 4.12 indicate an overall trend for under-amplification. The worst under-amplification occurred in initial fits indicating that optimal listening levels are not being achieved for children when individual verification is not used to fit hearing aids. Using individually measured RECDs to fit hearing aids improved match to prescriptive targets at all input levels. It remained a challenge to match targets closely above 2000Hz, although improvements were made. The worst under-amplification occurred at 65 dB SPL input level in initial fittings. Deviations from prescriptive target at signal input levels of 50 dB SPL and 65 dB SPL were highest at low frequency 250 Hz and high frequency 4000Hz and 6000 Hz for adjusted fittings. Table 4.2 shows the overall percentage of fittings which were within the tolerance range ±5 dB in both initial fittings and adjusted fittings for all input levels.

Table 4.2: Overall percentage of fittings within ±5 dB of prescriptive target.

Input level dB SPL	**Fitting**	**On target**
50 dB SPL	Initial fitting	61.2%
	Adjusted fitting	73.5%
65 dB SPL	Initial fitting	36.6%
	Adjusted fitting	69.6%
80 dB SPL	Initial fitting	58%
	Adjusted fitting	71.4%

The greatest improvement in match to prescriptive target was made at 65 dB SPL input level.

4.1.1.2 RMSE

Figures 4.13 to 4.18 show the RMSE of the fit to DSLv5.0 prescriptive targets for each input level of 50, 65 and 80 dB SPL as a function of PTA.

Figure 4.13: Proximity of initial hearing aid fitting to DSLv5.0 prescriptive target in RMSE (dB) plotted by PTA: 14 ears

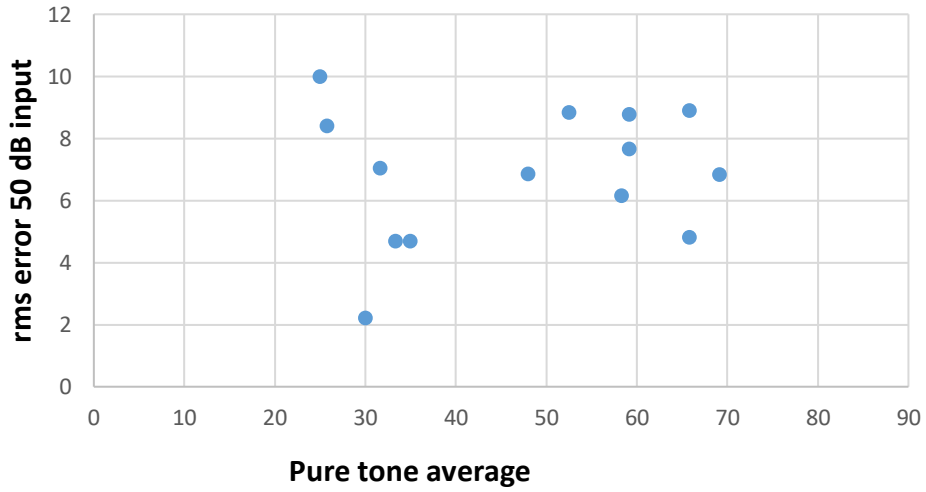


Figure 4.14: Proximity of adjusted hearing aid fitting to DSLv5.0 prescriptive target in RMSE (dB) plotted by PTA: 14 ears

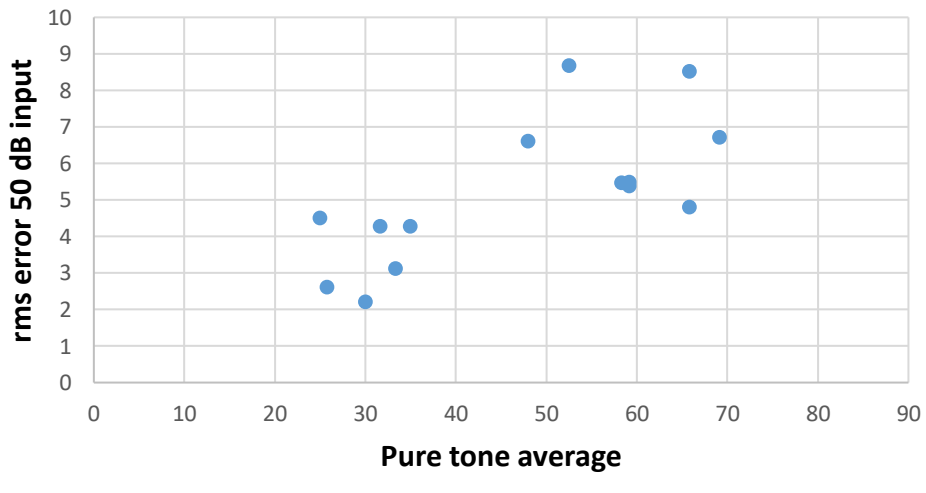


Figure 4.15: Proximity of initial hearing aid fitting to DSLv5.0 prescriptive target in RMSE (dB) plotted by PTA: 16 ears

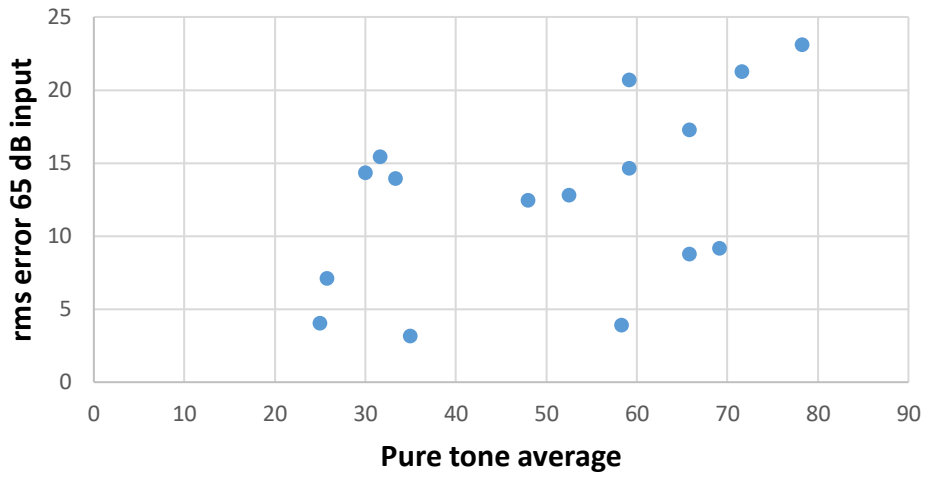


Figure 4.16: Proximity of adjusted hearing aid fitting to DSLv5.0 prescriptive target in RMSE (dB) plotted by PTA: 16 ears

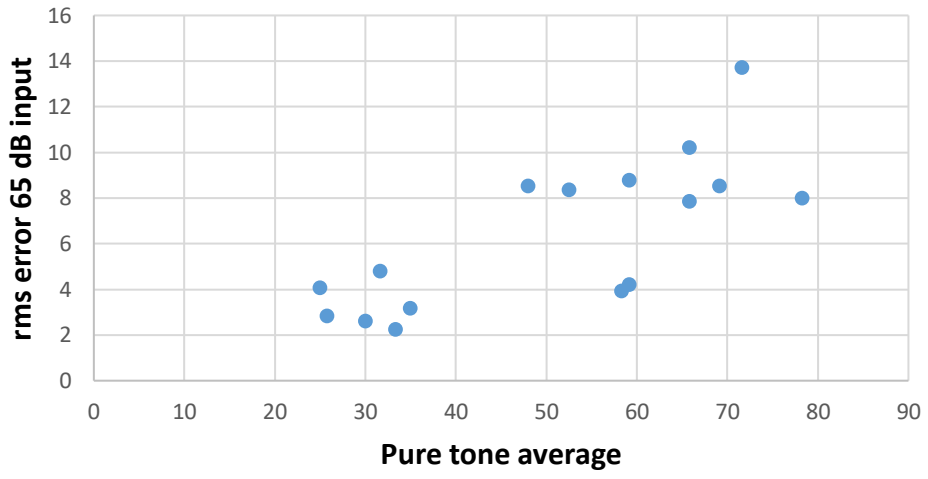


Figure 4.17: Proximity of initial hearing aid fitting to DSLv5.0 prescriptive target in RMSE (dB) plotted by PTA: 16 ears

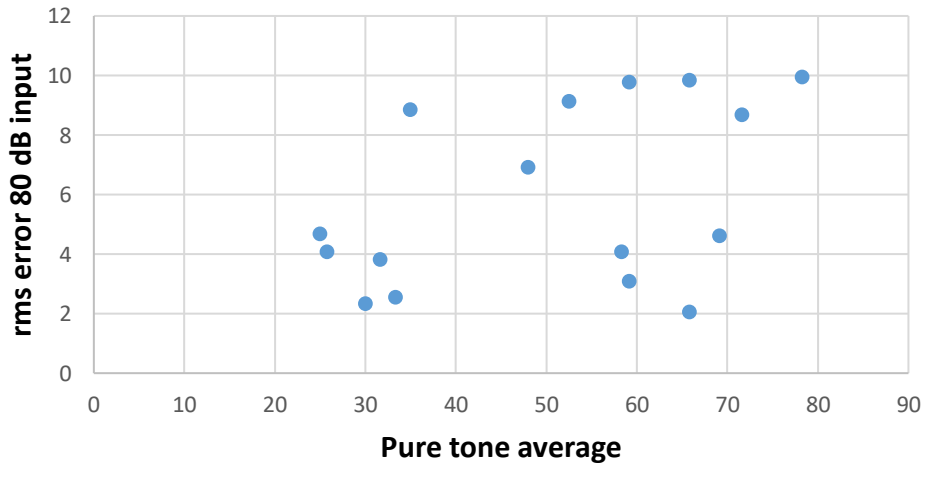
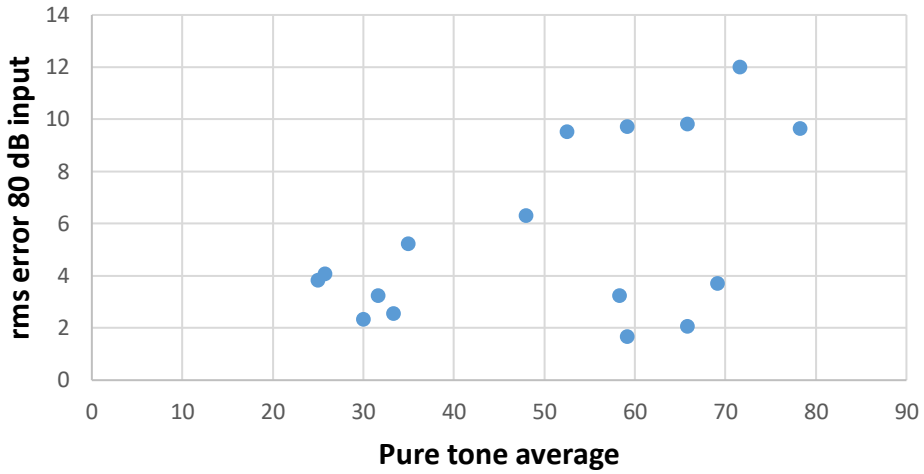


Figure 4.18: Proximity of adjusted hearing aid fitting to DSLv5 prescriptive target in RMSE (dB) plotted by PTA: 16 ears



A trend showing the effect of PTA is not apparent in the initial fitting at 50 dB SPL input level (Figure 4.13). A trend for the effect of PTA on match to prescriptive targets can be seen in the adjusted fitting at 50 dB SPL (Figure 4.14). Figures 4.15 to 4.18 show a trend of increasing RMSE with increasing PTA for both initial fits and adjusted fits at 65b dB SPL and 80 dB SPL input levels.

Table 4.3 shows percentages of fits which exceeded 5 dB RMSE.

Table 4.3: Percentage of fits exceeding 5 dB RMSE at each input level for initial fits and adjusted fits.

Input Level dB SPL	More than 5 dB RMSE for initial fits percentage	More than 5 dB RMSE for adjusted fits percentage
50	71.4	37.5
65	81.25	50
80	43.75	37.5

Adjusting fittings with individually measured RECDs improved matches to prescriptive targets at all input levels as shown by RMSE. Initial observation of scatter plots (Figures 4.13 to 4.18) indicate an influence of PTA on RMSE.

To evaluate the degree of hearing loss on proximity of the fitting to prescriptive target, the relationship between PTA and RMSE was evaluated using correlation (Table 4.4).

Table 4.4: Correlation for PTA and RMSE			
Fitting	dB SPL input level	Correlation (r)	Strength
Initial	50	0.14	weak
Initial	65	0.49	moderate
Initial	80	0.42	moderate
Adjusted	50	0.71	strong
Adjusted	65	0.75	strong
Adjusted	80	0.5	moderate

There is a stronger correlation found between PTA and RMSE in the adjusted settings at 50 and 65 dB SPL inputs. It was more difficult to match prescriptive targets for the participants with more severe losses. It is acknowledged that sample numbers are small.

4.1.1.3 Repeated ANOVA Measure

A repeated ANOVA was calculated for an input level of 65 dB SPL to detect any influence of frequency on adjusting to prescriptive targets. Table 4.5 shows results.

Table 4.5: Repeated ANOVA for input level 65 dB SPL across frequencies	
Null hypothesis: Frequency does not affect proximity to target in adjusted fitting at 65 dB SPL input level.	
F Statistic - F (15,6) = 36.52.	P Value - 0.00012174.
The null hypothesis is rejected - there was a statistically significant effect of frequency on proximity to prescriptive target in adjusted fittings.	

4.1.2 Speech Perception

A simple comparison was made for speech perception scores at initial fitting and 4 weeks after REM-adjusted fitting. AB word lists were used for all testing.

Figures 4.19 to 4.23 show speech perception results for initial fittings and REM-adjustments.

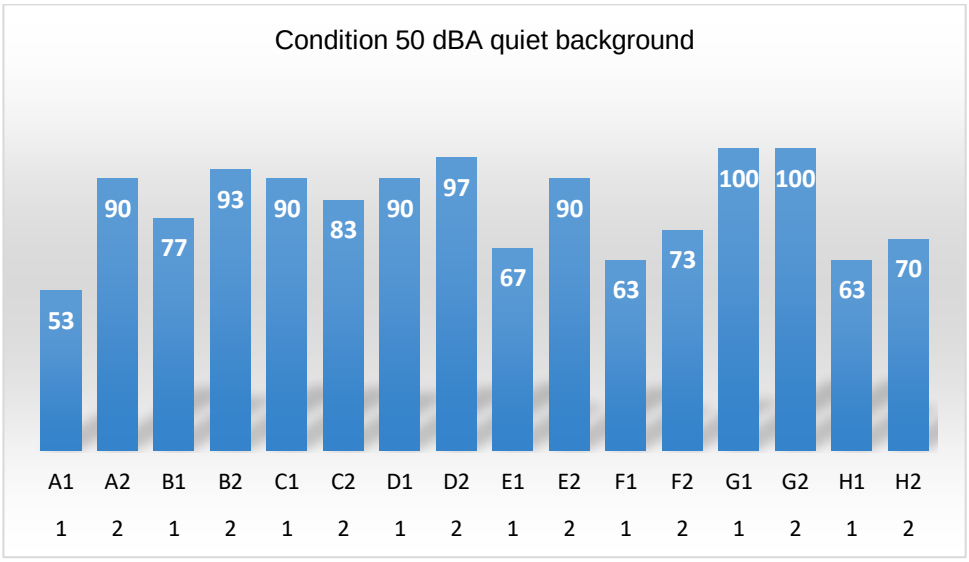


Figure 4.19: Speech perception scores for initial fittings and REM-adjusted fittings. A1 to H1 = initial fittings. A2 to H2 = Rem-adjusted fittings: 50 dBA

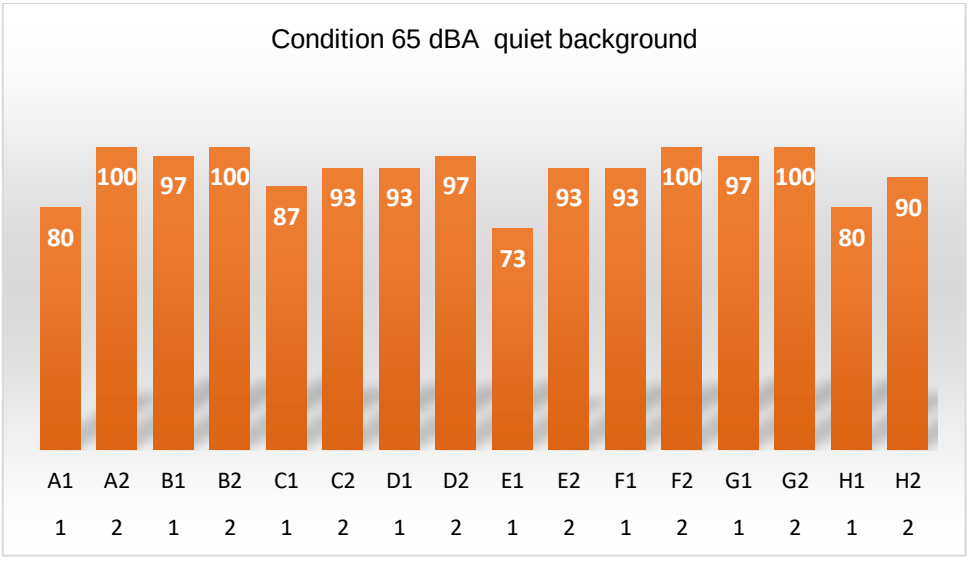


Figure 4.20: Speech perception scores for initial fittings and REM-adjusted fittings. A1 to H1 = initial fittings. A2 to H2 = REM-adjusted fittings: 65 dBA

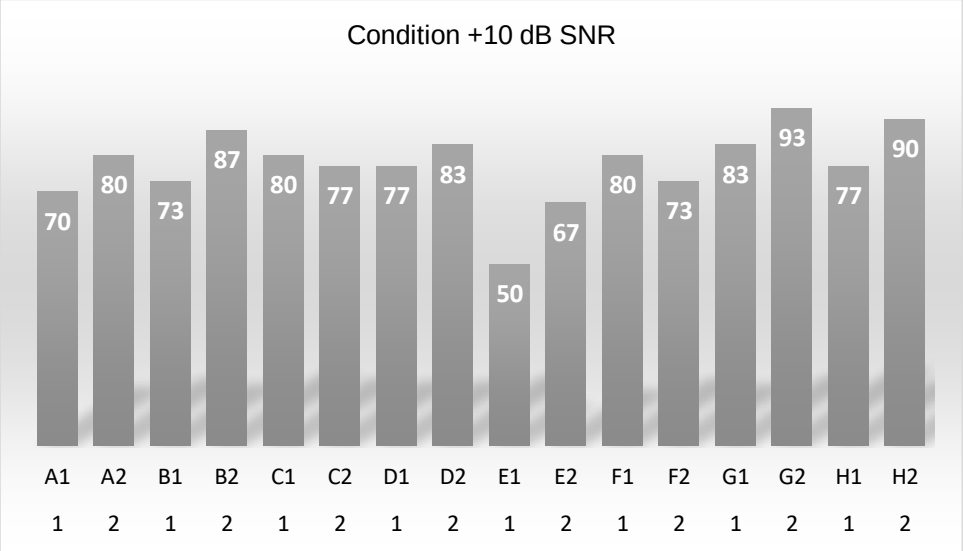


Figure 4.21: Speech perception scores for initial fittings and REM-adjusted fittings. A1 to H1 = initial fittings. A2 to H2 = REM-adjusted fittings: +10 dB SNR

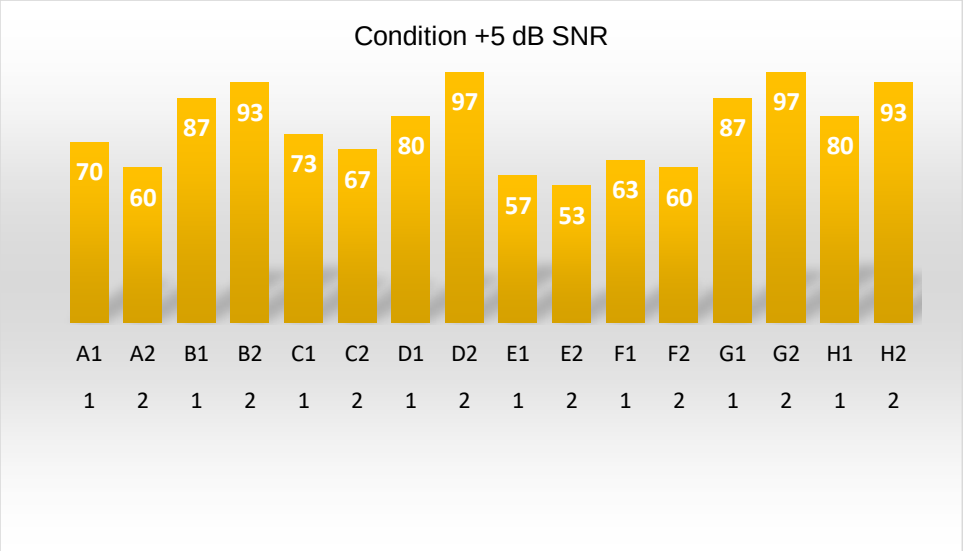


Figure 4.22: Speech perception scores for initial fittings and REM-adjusted fittings. A1 to H1 = initial fittings. A2 to H2 = REM-adjusted fittings: +5 dB SNR

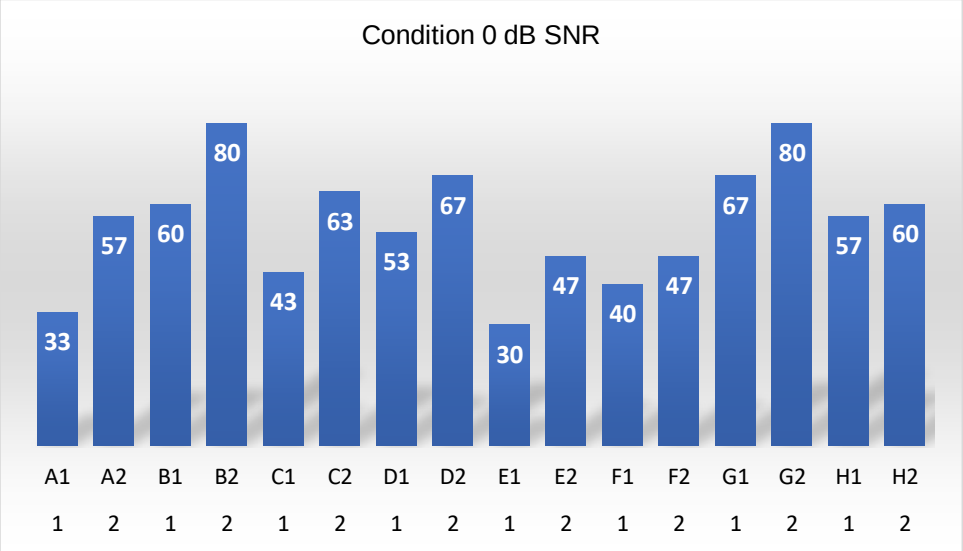


Figure 4.23: Speech perception scores for initial fittings and REM-adjusted fittings. A1 to H1 = initial fittings. A2 to H2 = REM-adjusted fittings: 0 dB SNR

Difference in scores between initial fitting and REM-adjusted fitting are shown in Table 4.6:

	Child A	Child B	Child C	Child D	Child E	Child F	Child G	Child H
BEPTA dB	58.33	31.67	59.17	30	71.6	65.8	25	48
50 dBA quiet: percentage difference in score	+ 37	+16	-7	+7	+23	+10	0	+7
65 dBA quiet: percentage difference in score	+ 20	+3	+6	+4	+20	+7	+3	+10
+10 dB SNR: percentage difference in score	+ 10	+14	-3	+6	+17	-7	+10	+13
+ 5 dB SNR: percentage difference in score	-10	+6	-6	+17	-4	-3	+10	+13
0 dB SNR: percentage difference in score	+24	+20	+20	+14	+17	+7	+13	+3

Table 4.6: Percentage difference in scores for each child in different conditions between initial fitting and REM-adjusted fitting. Better ear pure tone average = BEPTA

The most significant differences in scores were observed for child A and child E. Both Child A and Child E showed a significant initial reaction to REM-adjustment (reporting sounds they had not noticed previously).

The class teachers of both child A and child E had no knowledge of hearing aid adjustments. Both teachers reported a significant difference in the behaviour and attention of these children.

Improvements were shown in all scores in the 50 dBA in quiet condition except for 2 children. The most significant improvements were for child A and child E. The reduction in score for child C of 7% represents a difference in perception of 2 phonemes. Child G already scored 100% at initial fitting. All children improved scores at 65 dBA in quiet. However, in 6 out of 8 scores there was improvement of 10% or less, representing about 3 phonemes. Larger differences were observed when background noise was introduced.

The most significant differences in scores for all children were observed in the 0 dB SNR condition. 6 out of 8 children increased their score by more than 10% in this condition after REM-adjustment.

4.1.2.1 T-Tests

A one tailed T-Test was calculated to investigate if the total mean speech perception score after REM-adjusted fitting for each child was significantly more than the total mean speech perception score for initial fitting. Table 4.7 shows speech perception scores for each child and mean scores for initial fit and after REM-adjusted fit.

Table 4.7: Speech perception scores for each condition. I = initial score. R = score after REM-adjustment (4 weeks after adjustment)												
Condition	50 dBA quiet		65 dBA quiet		+10 dB SNR		+ 5 dB SNR		0 dB SNR		Means of total scores	
Speech perception scores	Percentage scores		Percentage scores		Percentage scores		Percentage scores		Percentage scores		Percentage scores	
Initial or Rem-adjusted	I	R	I	R	I	R	I	R	I	R	I	R
Child A	53	90	80	100	70	80	70	60	33	57	61.2	77.4
Child B	77	93	97	100	73	87	87	93	60	80	79	91
Child C	90	83	87	93	80	77	73	67	43	63	75	77
Child D	90	97	93	97	77	83	80	97	53	67	79	88
Child E	67	90	73	93	50	67	57	53	30	47	55	70
Child F	63	73	93	100	80	73	63	60	40	47	68	71
Child G	100	100	97	100	83	93	87	97	67	80	87	94
Child H	63	70	80	90	77	90	80	93	57	60	71	81

A one-tailed T-Test (Table 4.8) was carried out on the mean scores, that is, the mean of total scores for initial fits and the mean of total scores for REM-adjusted fits.

Table 4.8: P values for one tailed t-test. A difference is significant if the P value is less than 0.05.	
Child	P value
A	0.05
B	0.01
C	0.36 (not significant)
D	0.01
E	0.02
F	0.22 (not significant)
G	0.02
H	0.004

Six out of eight children showed a significant difference of improvement between the 2 conditions at the 0.05 level. There were only very small differences between initial and REM-adjusted fits observed for child C except for the 0 dB SNR condition. Child F noticed little difference after adjustment. This was partly due to the difficulties experienced with adjusting Phonak hearing aids in the REM-system.

4.1.3 Questionnaires

There are five Health Trusts in Northern Ireland with Audiology Services. One Trust declined to participate in the survey. Returns were not received from one other Trust despite reminders. Eleven out of twenty questionnaires were returned from the three Trusts which responded. Eleven out of thirty two questionnaires were returned in total from the five Trusts.

Table 4.9 shows qualifications held by respondents.

Table 4.9: Respondent qualifications: respondents obtained their qualifications between 1980 and 2015 resulting in a wide range of experience and a range of training experiences.

Qualification	Number of respondents
British Association of Audiology Technicians Parts 1 and 2	6
BSc in Audiology	5
Additional MSc in Audiology	2

Analysis of results are presented in subsections:

4.1.3.1 Sources of knowledge

Sources of knowledge used in practice are shown in Table 4.10.

Item	Mean Score (Standard Deviation)	Rank
Personal experience of caring for patients/clients over time	5.1 (0.67)	1
Information I learn about each patient/client as an individual	5.0 (0.69)	2
Intuition about what seems to be 'right' for the patient/client	4.8 (0.67)	3
Information I get from local policy and protocols	4.6 (0.6)	4
Information I get from national guidelines	4.5 (0.94	5
Information I learned from my training	4.5 (0.83)	6
Information I get from attending in-service training conferences	4.5 (0.7)	7
Information more experienced clinical audiologists share	4.3 (0.7)	8
Information I learn from manufacturers' representatives	4.3 (0.7)	9
Information my fellow audiologists share	4.1 (0.65)	10
Information I get from product literature	3.9 (1.12)	11
What doctors discuss with me	3.9 (1.03)	12
Information I get from audit reports	3.6 (1.19)	13
Articles published in audiology journals	3.5 (1.33)	14
What has worked for me for years	3.3 (1.48)	15
Articles published in other research journals	3.1 (1.08)	16
Information in text books	3.0 (1.01)	17
Articles published in non-peer reviewed journals	2.7 (1.13)	18
The way that I have always done it	2.5 (1.35)	19
Information I get from the internet	2.5 (0.79)	20
Information I get from media (TV)	1.2 (0.30)	21

Table 4.10: Sources of knowledge used in practice. 5-point Likert scale: (never use) to 5 (always use).

The most frequently agreed upon sources of knowledge were personal experience acquired over time, information from experience with patients as

individuals and intuition about patients. Information gained from the internet or media was least used.

4.1.3.2 Barriers to changing Practice

Table 4.11 shows perceived barriers to changing practice based on best evidence.

Item	Mean Score (Standard Deviation)	Rank
There is insufficient time at work to read research	3.63 (0.92)	1
There is insufficient time at work to implement changes in practice	2.82 (1.07)	2
I lack the authority in the workplace to change practice	2.72 (1.1)	3
There are insufficient financial resources to change practice	2.63 (1.12)	4
The culture of my team is not receptive to changing practice	2.36 (0.92)	5
There is lack of managerial support	2.36 (0.92)	5
Our practice lacks a leader with knowledge in best evidence	2.27 (0.79)	6
Staff lack the training required to change practice	2.18 (0.87)	7
There are insufficient equipment resources to change practice	2.09 (1.04)	8
Staff lack the knowledge required to change practice	1.73 (0.79)	9
I do not feel confident about beginning to change my practice	1.55 (0.52)	10

Table 4.11: Perceived barriers to changing practice. 4-point Likert scale: 1 (disagree strongly) to 4 (agree strongly)

Insufficient time at work to read research and to implement change were ranked as the highest barriers. Confidence to change practice was the least cited barrier with all respondents disagreeing that they would not have the confidence to change practice. Standard deviations were quite high reflecting a range of views for each item.

Respondents were invited in an open-response format to provide any additional views on the implementation of evidence-based practice. Tables 4.12 and 4.13 provide a summary of facilitators and barriers identified.

Table 4.12: Self-reported factors that would facilitate implementation of evidence-based practice
• Better availability of specific paediatric training
• Increased peer review in clinics
• Additional staff
• Additional rooms with equipment
• Additional funding
• More time allocated to do reading
• More in-house training

Table 4.13: Self-reported barriers to implementation of evidence-based practice
• Increasing waiting lists
• Staff shortages
• Lack of funding
• Lack of structured hierarchy of staff
• Lack of room capacity
• Lack of IT infrastructure
• Poor triage of patients
• Lack of time to perform additional tests due to high volume of patients
• Lack of equipment

4.1.3.3 Contribution of factors in improving outcomes

This question was an attempt to ascertain views on the importance of a range of factors in improving outcomes for children with hearing loss. Table 4.14 shows scores.

Table 4.14: Contribution of factors in improving outcomes for children with hearing loss

Item	Mean Score (Standard Deviation)	Rank
Parental support and involvement	4.0 (0)	1
Well trained paediatric audiologists	3.82 (0.4)	2
Early identification and early fitting of amplification	3.82 (0.4)	2
Support from other services e.g. Teachers of the Deaf	3.73 (0.47)	3
Good multi agency working	3.73 (0.47)	3
Use of published guidelines e.g. MCHAS / BSA to guide hearing aid fitting	3.45 (0.69)	4
Use of evidence based prescription to generate targets (DSL, NAL)	3.27 (1.01)	5
Individually measured real-ear measurements to facilitate close fitting to prescriptive targets	3.01 (1.14)	6

Parental support was ranked as the most important factor with all respondents in agreement. The use of REMs and evidence-based prescriptions were ranked as the least important factors, although standard deviations of 1.01 and 1.14 reflect a wide range of views.

4.1.3.4 Methods for Verification

Audiologists were asked what methods they use for verification (Table 4.15).

Table 4.15: Methods used for verification			
Age Group	0 – 36 months	3 – 5 years	5 – 16 years
Functional Gain	81.8%	81.8%	81.8%
REMs	9.1%	9.1%	36.4%

These results show that functional gain is used in most cases. Verification with individually measured REMs is more often used with the older age group, perhaps because it is easier to use REMs with this age group.

4.2 Qualitative Analysis

4.2.1 Interviews

The audiologists interviewed all want to deliver a high standard of service, but they are realistic about the practical challenges facing services. QSs for Paediatric Audiology were felt to be a key to implementing guidelines and for releasing resources for both training and physical considerations such as room capacity and adequate equipment.

The interview schedule and a full range of text from interviews is included in Appendix B.

The themes identified from interviews were:

- Time
- Training Needs
- QSs
- Confidence
- Resources
- Benefit of REMs
- Attitude to Change

4.2.1.1 Time

As expected from the literature and from the questionnaire in this study, time was mentioned frequently in interview responses. The theme of time included:

a. The pressure of appointment length and waiting lists:
   'We could do REMs on children if we had time to do it.'

   'Trust culture is to get through it. There has to be a balance with appointments and waiting lists. We are being squeezed to meet targets – this involves adult work.'

Three respondents indicated that a solution to time pressures could partly be addressed by better triage.

> *'We don't have control over appointments so we can't really plan. The hospital service is Consultant led – if it was Audiology led, we could use the time better.'*

One respondent who had worked in a different Trust felt that longer appointments resulted in a trade-off of reduced return appointments.

b. Time for research;
   'Time for study or continual professional development is not prioritised. People have lives so we can't always do this at home.'

4.2.1.2 Training Needs

Most training for digital hearing aids and REMs was obtained from manufacturers.

> *'There was no training for earmoulds and fitting hearing aids to babies except from manufacturers.'*

> *'We get training through hearing aid companies, training in their software and their hearing aids…there wasn't enough money to put into training.'*

All respondents agreed that training is required for staff working with infants and young children. All except one respondent felt that they needed more training. Interviewees felt that the numbers they deal with are small and so it is difficult to maintain skills.

> *'The training I got for REMs was with adults. I was given a sheet of information, then I did one on another audiologist.'*

For newborn screening, new skills had to be learned.'

'Lack of training creates a pressure.'

The lack of support from MCHAS was given as a reason by all interviewees for both lack of training and lack of funding. It was perceived that this resulted in a roll out of newborn screening with inadequate resources and poor access to initial training.

'We are the poor relations, MCHAS didn't reach Northern Ireland.'

'I know MCHAS training was available in England, but the funding wasn't available here.'

4.2.1.3 QSs

QSs were seen as a major barrier to adherence to guidelines by all but one respondent.

'We are looking at QSs for adults. We won't be doing QSs for kids until we are fully done with adults.'

There was a sense of practice being led by public demand. Action on Hearing Loss had an influence on the introduction of QSs for adults which occurred in 2013.

'*There is more publicity for adults and they are more demanding.'*

'Most staff didn't engage with REMs before the standards for adults came in. To REM seemed more hassle than it was worth.'

It was clear that interviewees felt that QSs would help to support the introduction of REMs, probably because managers could provide more support if backed by QSs.

'QSs should be implemented so that these 0-3 children can be verified. I would like to see everyone doing the same.'

4.2.1.4 Confidence

Confidence can be developed as a result of training, practice and maintenance of skills.

> *'You can be nervous – no confidence, because it's new and you would need training. It's getting over that hurdle of doing the first two or three and just getting on with it.'*

> *'Confidence is a huge one. Doing fittings with babies, the wriggly nature of babies. Parents are watching intently and there are parents' stress levels as well.'*

One interviewee in relating the experience of completing REMs with adults, described how experience can help, both with confidence in technique and confidence in validity of the results.

> *'Doing REMs at my hospital stalled. We thought, sure, you're going to adjust it anyway because the patient won't like it. I think we may have been looking for an excuse not to do it. Now, minds are changed because confidence has grown, we know how to do it and we are more convinced that it's better to use a verified baseline. I can counsel the patient better because I understand it. I'm more confident to leave the fitting as fitting to targets, I trust it more.'*

Peer to peer support was also felt to build confidence.

> *'Existing staff that had been around for a long time felt uncomfortable doing REMs.'*

One interviewee felt that peer to peer support would be a more acceptable mechanism for training audiologists at different management levels.

4.2.1.5 Resources

All interviewees listed practical barriers to do with resources including staff, room capacity and equipment.

> *'There is hassle because of the equipment, you have to go from screen to screen, mute at this point, close screens down in the right order. This makes it awkward and very irritating.'*

'If equipment is hard to use, you're not going to use it.'

'There is only one audiologist working here with children. What happens if_____ goes off sick?'

4.2.1.6 Views on REMs

All but one interviewee felt that REMs are an important stage in providing amplification for infants and young children.

'In an ideal world we should do REMs with children….it is more important in children than in adults.'

'If I'm being honest, REMs are essential for 0-3 years, although a lot of children are headed for implants.'

There may be a justification for not doing REMs as more children are referred for and receive implants. However, this same audiologist acknowledged

'The 0-3s are the most important group and the mild to severe group.'

The interviewee who did not believe that REMs are an important part of amplification for children argued,

'None of our children are disadvantaged because of not doing REMs. I would rather programme to aided thresholds, I rely on aided VRA.'

This interviewee felt that attempting to match to targets was unrealistic.

'REMS make you want to match to an unrealistic target because you can never match precisely. It is more important how the child responds to hearing aids.'

All interviewees valued good flow of information and links with other services e.g. TODs, especially in the absence of performing REMs.

We're doing pretty well without REMs, our audiologists listen to other disciplines like TODs, you need good team work.'

If we're not doing REMs for whatever the reason, at least there is communication between teachers, speech and language therapists, paediatricians to build up the bigger picture.'

4.2.1.7 Attitude to Change

It was clear from the responses that audiologists are not averse to change and that they want to provide a good service for children with hearing loss.

'*I am OK with change. As an audiologist you have to be open to change.'*

However,

'Change is hard when you've been doing something for years.'

Change is easier if you can see its advantages.

'Change is good if I can see the benefits of it and if I'm given the time to investigate it.'

'I'm an early adopter. I get quite excited if there's a value to it. It's always difficult to make a change unless you can see the physical results of doing something different.'

5. Discussion

5.1 REMs

Early amplification is an important contributor to better language outcomes for children with hearing loss. Recently, the effects of individual variability in aided audibility and hearing aid use have been studied more extensively (McCreery et al, 2015; Tomblin et al, 2015; Koehlinger et al, 2013; Stiles et al, 2012). Paediatric hearing aid fittings may be significantly more variable and populations of children wearing hearing aids may have a wider range of auditory experience than expected (McCreery et al, 2013).

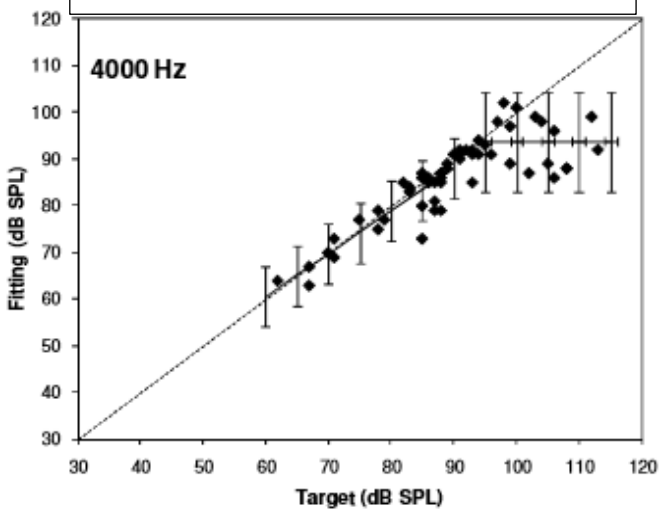
The first aim of this study was to investigate the difference in hearing aid gain between initial settings and DSLv5.0 prescriptive targets at three input levels of 50, 65 and 80 dB SPL. The results show that the proximity to prescriptive targets at initial fit settings is below target at all input levels. 81.25% of fittings exceeded 5 dB RMSE for initial fits. This has been found in other studies: McCreery et al (2015 & 2013) found around 50% of fittings exceeded 5 dB RMSE and Strauss & Van Dijk (2008) found that only 25% fittings were within the range of ±5 dB of targets.

The second aim of this study was to investigate the use of REMs to improve the match to prescriptive target. There is increasing data to show that relying on manufacturers' automatic fittings and on age-related estimates of external ear canal resonances rather than an objective verification using probe-microphone measurements contributes to inconsistent fittings (Munro et al, 2016; Strauss & Van Dijk, 2008; Hawkins & Cook, 2003). Importantly, Aazh & Moore (2007) found that adjustment based on REMs always improved matches to prescriptive targets compared to initial fittings.

In this study, results show that REM-adjustments improved the match to prescriptive targets at all input levels. For initial fittings at 65 dB input, 36.6% were found to be within 5 dB of prescriptive target compared to 69.6% within 5 dB of prescriptive target after adjustment. Other studies found higher percentages of match to targets after REM-adjustment but a wider tolerance range (10 dB) was used and fewer frequencies (500 to 4000 Hz) were tested (Munro et al, 2016; Aazh & Moore, 2007).

This study experienced increased difficulty resolving match to prescriptive target for more severe losses, although improvements were made. A group of Canadian audiologists found that fitting to target for severe losses at 4000 Hz resulted in under-amplification (Moodie 2009), shown in Figure 5.1.

Figure 5.1: Results of fitting to target for 65 dB speech input. From Moodie (2009)



In the present study, at 65 dB input, the greatest deviations for adjusted fittings are at 4000 Hz and 6000 Hz. These deviations are for the child with the highest PTA in this study (78.3 dB). A repeated ANOVA for 65 dB SPL input indicated a significant influence of frequency on adjusting to targets. Difficulties in matching to prescriptive target at higher frequencies are likely due to the limits of the hearing aid technology being used. It may also be due to positioning of the probe-tube tip which should be within 5 mm of the ear drum for frequencies up to 6 kHz (Munro 2004). This may have affected results at 4000 and 6000 Hz. It is important to investigate whether a better fit to prescriptive targets can be achieved at 4000 Hz for more severe losses (Moodie 2009). Difficulties matching targets at higher frequencies compromises high frequency speech sounds important for children learning language (Stelmachowicz 2004). Frequency compression hearing aids could be considered if targets at high frequencies cannot be met. However, verification of hearing aids with frequency compression presents further challenges and requires a modified approach (Glista & Scollie, 2009).

Matches to prescriptive targets were not completely resolved for the children in this study with particular difficulty at low frequency (250 Hz) and higher frequencies (above 2000 Hz). This may partly be due to the limits of hearing aids

as well as the experience and skills of the audiologist. Skills for verifying hearing aid fittings for children were learned during the study. There was little access to more experienced practitioners for support and advice. Less experienced clinical sites may result in greater fitting errors (McCreery et al, 2013).

However, initial fittings were found to be inadequate and a better match to prescriptive gain was achieved by using REMs.

Individually verifying prescriptive targets is important because aided audibility is an important predictor of language growth and may have a larger influence on development than PTA (Tomblin et al, 2015; Stiles et al, 2012). Inaccurate fittings may lead to the loss of the developmental advantages of early identification (Moeller & Tomblin, 2015; Moodie 2009). When prescriptive targets are matched as closely as possible using REMs, then outcome evaluations can be more robust as a known baseline of a good fitting has been established. Given that closer proximity to prescriptive target can be achieved as shown in this study, REMs should be routinely used in clinical practice for children for fitting hearing aids. As a child's ear grows, the HL required to generate a given SPL will increase and to take this into account, it is important to employ REMs when an earmould is changed. If this is not practical, then REMs should at least be carried out at agreed regular intervals (McCreery et al, 2015).

5.2 Speech Perception

A third aim of this study was to collect some outcome data related to the initial and REM-adjusted fittings for the participants. Speech perception scores were used as an outcome.

Two participants showed large differences in speech perception scores and a general trend was seen in improvements for most participants. A one tailed T-Test found that all but two participants showed a significant difference in speech perception between the two conditions of initial and REM-adjusted fit at the 0.05 level. It is noted that it is difficult to measure and interpret differences in scores for speech perception because of the variables which can affect results e.g. the child's phonological memory and receptive vocabulary. Measuring speech perception is complex as it is difficult to control for variables.

Stiles et al (2012) reported better vocabulary development for children with mild to moderately severe hearing loss who had greater aided audibility as measured by SII. SII scores were not available on the equipment used in this clinic. It would have been useful to link SII scores to speech perception scores. Some normative data for SII scores associated with good paediatric fittings has been produced as guidance (Moodie 2009).

It has been shown that the main effects of PTA and RMSE from prescriptive targets are significant predictors of aided SII (McCreery et al, 2015) who found that children with thresholds > 50 dBHL and deviations from target >5 dB RMSE are more likely to fall outside the normative range for audibility than children with milder losses or smaller deviations from target.

In this study, the children with the largest improvements in speech perception scores (A and E) also had the largest deviations from prescriptive targets in initial fits. Studies may underestimate the difficulties which children experience in real life listening situations. Children require more favourable SNR in noise. This is partly due to differences in phonological development. Adults have relatively stable categories for the various acoustic sound forms in a language (Alexander 2013). In this study, the greatest differences in speech perception results were found in the 0 dB SNR condition. Closer match to prescriptive targets supported listening in noise. Speech recognition in noise may help to differentiate children who are at risk for listening difficulties (McCreery et al, 2015). Minimising error of fitting to prescriptive targets can support higher and more consistent audibility and support children wearing hearing aids who are learning in complex listening environments with the increasingly complex language demands of the school curriculum.

5.3 Audiologists Questionnaire

Uus et al (2005) asked whether introducing a newborn hearing screen will result in services improving to provide the necessary assessments and management of cases, or whether introducing a screen should wait until services are put in place. In Scotland, a gap in audiology services was identified and QSs were implemented first. Value for money was expected from the outcomes of QSs. In Northern Ireland (NI), the opposite is true in that outcomes are being used to argue for the need for QSs. Results from this questionnaire indicate that

audiology services in NI may not have caught up with the implementation of new ways of working as a result of newborn screening. The will to provide good or excellent services in paediatric audiology is there, but a wide variety of obstacles exist at the practitioner level, the context in which the practitioner works and in the broader health care system.

This part of the study aimed to investigate attitudes to change, to the use of REMs for children and to any barriers and/or solutions in this specific context.

5.3.1 Sources of Knowledge Used in Practice

Knowledge from their patients, their experience and their intuition were the highest ranked sources of knowledge to guide practice. Standard deviation was low indicating general agreement. Audiology is patient focused and each patient will bring individuality to each case. Some professionals fear that evidence-based practice minimizes years of clinical experience. Ratner (2006) suggests that as we explore how to disseminate best-practice guidelines, we should investigate how such recommendations mesh with clinicians' experiences.

The audiologists report that the greatest barriers to changing practice on the basis of evidence are insufficient time at work to read research and insufficient time at work to implement changes in practice. These results are similar to other studies (Moodie 2012; Kajermo et al, 2010; Thompson et al, 2008; Zipoli & Kennedy, 2005).

The majority of respondents to this questionnaire state that they have the knowledge and confidence for change. Moodie (2012) argues for the necessity of involving audiologists in the formulation and implementation of best-practice guidelines. Comments reflected this showing that audiologists were enthusiastic for change when they experienced benefit for themselves.

'How I have always done it' was least used but the standard deviation was high indicating a range of responses. Change may be complex and difficult (Bess 1998) and may depend on a range of human factors, including lack of appreciation of the evidence or lack of appropriate patient-specific feedback (Greenhalgh 2010).

Time and resources were identified as both barriers and facilitators to providing evidence-based care. Resources included staffing levels, access to training, room capacity, equipment and IT infrastructure.

5.3.2 Contributing Factors to Outcomes

The majority of respondents use functional gain to verify hearing aid fittings for children. The use of REMs to improve proximity to prescriptive targets and the use of evidence-based prescriptions were scored as the least important factors in improving outcomes for children with hearing loss. The use of published guidelines included one score out of eleven which greatly differed from the others. As the majority of respondents agreed that the use of published guidelines is important, it is puzzling that using REMs and evidence-based prescriptions were considered to be the least important. This is perhaps because, as REMs are not in routine clinical use, there is less confidence in their benefit. Evidence-based prescriptions may have been interpreted as meaning stand-alone generic prescriptions rather than evidence-based prescriptions available in the manufacturer's software.

Parental support was considered to be the most important contributor to outcomes. Research indicates that high levels of family involvement correlate with positive language outcomes (Moeller et al, 2013; Moeller 2000).

Multi-agency working scored highly and respondents agreed that good communication with TODs made up somewhat for the lack of REMs. However, evaluation of outcome from a defined baseline would be more effective. TODs could make more informed evaluations of outcomes if they had information on REMs fittings, including matches to targets.

5.4 Audiologists Interview

5.4.1 Time

Lack of time was mentioned extensively in interviews. Time as a barrier is complex. It includes both lack of physical time and the value placed on an observable level of busyness (Thompson et al, 2008). Creating an environment that fosters reflection, research and access to peer support could have a positive effect on adherence to guidelines, but would also impact on appointment times and waiting lists.

5.4.2 Opinion on REMs

One interviewee had little faith in the validity of REMS and in the ability to match precisely to targets, questioning the evidence-base available. There is a lack of evidence available at the standard of RCTs due to the difficulties of withholding treatment. However, a shortage of evidence does not mean a lack of effectiveness (Shaw 2012) and it is known that manufacturer default settings are often inadequate (McCreery et al, 2013). If you do not carry out REMs it is difficult to be certain whether a child could perform better if provided with more audibility. In this study, an improved match to prescriptive targets was achieved. In Moodie's study (2009), 80% of fittings were achieved within ±5 dB of prescriptive targets. It is important to note that precise match to target may be difficult, but there is likely an acceptable range around the target where the goals of amplification will still be met (Moodie 2009).

If someone does not perceive the advantages of a change, it is unlikely they will incorporate it easily into their practice (Greenhalgh 2010; Gustafon et al, 2003).

Seeing the benefit of a practice for yourself affects motivation to change. One interviewee in particular spoke of how her confidence in the validity of results increased with experience of practicing REMs with adults.

The current arrangements of good flow of information with other services was felt to be a protective factor.

5.4.3 Training Needs

Well trained paediatric audiologists were considered to be the second most important factor contributing to outcomes for children with hearing loss. Two out

of eleven respondents hold an MSc qualification as recommended by NDCS Guidelines for Audiology (2016). Interviews indicate that audiologists would welcome further training.

5.4.4 Confidence

Confidence is an issue when faced with a new way of working. Audiologists have to balance the challenge of best practice with the reality of daily clinical life (Moodie 2012). Stress and lack of confidence can be caused by, e.g. appointment times which aren't long enough and uncooperative children. As one interviewee said, 'Children can smell fear.' Small numbers of children result in difficulties in maintaining skills and this in turn affects confidence.

5.4.5 Resources

Resources required for the implementation of any practice outlined in guidelines can be difficult to overcome. The uptake by audiologists of new guidelines on tympanometry for babies was reasonably smooth and widespread. This was because there was no need for training, new skills or extra resources. The contexts in which practitioners work have a significant impact on working practices and the ability to change practice. Available resources, staff capacity and efficiency of the system are constraints on practice. Resources are in turn affected by the broader healthcare system. In NI, for example, a lack of trained audiologists may be a result of people having to train elsewhere in the UK and therefore they may be less likely to return for employment in NI.

5.4.6 QSs

Gerrish et al (2007), in their work with nurses, report that much of the responsibility for evidence-based practice has been placed on individual practicing nurses. However, they argue that implementing evidence-based practice in healthcare settings is complex and that healthcare organisations should support the culture of evidence-based practice and provide resources for its implementation. This argument could equally be applied to audiology. However, managers may find it more difficult to access funding if there are no QSs for Paediatric Audiology to drive outcomes. Heads of Services are currently looking at the Scottish QSs for Paediatric Audiology with a view to adopting these. All interviewees referenced the lack of influence of MCHAS and QSs for Paediatric Audiology. REMS for adults were only fully adopted when QSs for

Adult Audiology were introduced in 2013. As Bess (1998) stated, best-practice guidelines are of limited value unless they are embedded in a broader programme that addresses the need for implementation. The experience of this study demonstrates that implementation is difficult to achieve from the bottom up by individual practitioners. NDCS guidance for paediatric audiology appears to have had a limited effect, perhaps because guidance is not linked to quality assurance. QSs could be a driving force for planning for implementation of best-practice such as verification with REMs for children.

5.5 Conclusions

Early identification and early intervention with amplification have improved outcomes for children with hearing loss (Wake et al, 2016). However, language and vocabulary, although improved, remain below population means (Stiles et al, 2012). Early intervention is crucial, but in order to improve the benefits gained, there should be focus on the science of intervention and amplification (Wake et al, 2016). This should include the amount of audibility provided by REM-adjusted hearing aid fittings. Hearing aid fittings could be better (McCreery et al. 2013) and this could be improved by ongoing hearing aid REM-verification.

This study shows that a substantive, proactive and targeted effort is required for knowledge to be used (Moodie 2012) and this is only successful with support from all levels including practitioners, managers and the wider healthcare system. This study demonstrated that using REMs for verification improved proximity to prescriptive targets and produced a general trend of improvement in speech perception scores. A successful trigger experience such as this improves adoption of practice (Ratner 2006), but the prevailing organisational context determines implementation of practice. Grol and Grimshaw (2003) defined a summary of factors involved in the implementation of any change (Table 5.1).

Table 5.1: Factors to address when implementing change
1. Involve the relevant people.
2. Develop a proposal for change that is evidence based.
3. Study the main difficulties in achieving the change.
4. Select a set of strategies and measures at different levels linked to the problem within budget.
5. Define indicators for measurement of success.
6. Monitor progress at regular intervals.

Table 5.2 shows how this model could be used:

Table 5.2: Factors to address when implementing change in this clinic
1. Set up a working group of audiologists, service manager, representative from ENT, TOD or educational audiologist.
2. Develop a proposal for change based on data from this study, QSs for Paediatric Audiology Scotland and best-practice guidelines.
3. Study the main difficulties in achieving the change – begin with difficulties identified in this study.
4. Select a set of strategies – prioritise these within constraints of current budget – pay particular attention to the impact of time for training and peer support needs and for longer appointment times.
5. Define indicators for measurement of success – for example, the number of new hearing aid issues verified with REMs, data on matches to targets, a written policy for the provision of amplification to children.
6. Monitor progress at regular intervals – ask for feedback from audiologists on using REMs, ask for feedback from TODs on outcome evaluations.
7. Review and evaluate further strategies to improve implementation.

It is planned that this study will be shared with the manager of Paediatric Audiology. It has been noted that throughout the duration of the study that staff have been prompted to be reflective about their practices when fitting hearing aids to young children.

5.5.1 Limitations

The numbers involved in this study were small reducing the power of statistical calculations.

Hearing aids employing frequency compression were the most difficult to verify with REMs.

Speech perception as a measure may not be sensitive enough to demonstrate longer term auditory development effects of matching more closely to prescriptive targets. Item familiarity supports accurate decoding of words of even poorly audible speech cues (Stiles et al, 2012) and may obscure any effect on long term audibility.

5.5.2 Further Work

Future work in this clinic could involve monitoring quality of hearing aid fittings. Data could be collected for typical fits as a function of degree of hearing loss using REMS. Then typical fit-to-target zones and under-target zones could be developed for this particular clinic to help evaluate hearing aid fittings. As skills are developed, the impact of moving the probe-tube closer to the tympanic membrane to achieve better matched fittings could be examined.

Further work is required for verifying fittings where frequency lowering is employed.

A multidisciplinary team involving managers and audiologists could develop a protocol for implementing REMs for children. This would allow audiologists to assist in customising the protocol ensuring better adherence.

It would be useful to develop a package of outcome measures including proximity to prescriptive targets in fittings, SII scores compared with normative scores for paediatric fittings, speech perception scores and information gathered from outcome evaluation questionnaires.

6. References

Aarts, N. & Caffee, C. (2005) 'Manufacturer predicted and measured REAR values in adult hearing aid fitting: accuracy and clinical usefulness'. *International Journal of Audiology.* 44. pp. 293-301.

Aazh, H. & Moore, B. (2007) 'The value of routine real ear measurement of the gain of digital hearing aids'. *Journal of the American Academy of Audiology.* 18. pp. 653-664.

Abrams, H., Chisolm, T., McManus, M., McArdle, R. (2012) 'Initial-fit approach versus verified prescription: comparing self-perceived hearing aid benefit'. *Journal of the American Academy of Audiology*. 23. pp. 768-778.

Abrams, H. & McArdle, R. (2006) 'Measuring patient outcome'. *A Sound Foundation Through Early Amplification.* Available at: https://www.phonakpro.com/content/dam/phonak/b2b/Events/conference_proceedings/adult_conference_chicago_2006/tuesday/2006proceedings_abrams_mcardle.pdf [Accessed: 29 July, 2015].

Alexander, J. (2013) 'Individual variability in recognition of frequency-lowered speech'. *Seminars in Hearing.* 34(2). pp. 86-107.

American Academy of Audiology (2013) *Clinical practice guidelines: pediatric amplification.* Available at: http://www.audiology.org/publications-resources/document-library/pediatric-rehabilitation-hearing-aids [Accessed: 24 August, 2015].

Anderson, G. & Arsenault, N. (2005) *Fundamentals of educational research.* 2nd edn. London: Taylor & Francis.

Bagatto, M. (2012) '*Development and evaluation of an audiological outcome measure guideline for use with infants, toddlers and preschool children'.* Thesis. University of Western Ontario - electronic thesis and dissertation repository. Paper 688.

Bagatto, M., & Moodie, S. (2007) 'Learning the art to apply the science: common questions related to pediatric hearing instrument fitting'. *AudiologyOnline* [Online]. Available at: http://www.audiologyonline.com/articles/learning-art-to-apply-science-933 [Accessed: 29 July, 2015].

Bagatto, M., Moodie, S., Scollie, S., Seewald R., Moodie, S., Pumford J., Liu, R. (2005) 'Clinical protocols for hearing instrument fitting in the desired sensation level method'. *Trends in Amplification.* 9(4). pp. 199-226.

Bagatto, M. & Scollie, S. (2011) 'Current approaches to the fitting of amplification to infants and young children'. In Seewald, R. & Tharpe, A. (eds.) *Comprehensive handbook of pediatric audiology.* San Diego: Plural Publishing. pp. 527-552.

Bagatto, M., Scollie, S., Seewald, R., Moodie, S., Hoover, B. (2002) 'Real-ear-to-coupler-difference predictions as a function of age for two coupling procedures'. *Journal of the American Academy of Audiology.* 13. pp. 407-415.

Bamford, J., Beresford, D., Mencher, G., DeVoe, S., Owen, V., Davis, A. (2001) 'Provision and fitting of new technology hearing aids; implications from a survey of some 'good practice' services' in UK and USA'. *A Sound Foundation Through Early Amplification.* Available at: https://www.phonakpro.com/content/dam/phonak/b2b/Events/conference_proceedings/2nd_pediatric_conference_2001/2001proceedings_chapter18.pdf [Accessed: 24 August, 2015].

Bess, F. (1998) 'Endnote address: early amplification for children: implementing change'. *A Sound Foundation Through Early Amplification.* Available at: http://www.phonak.com/content/dam/phonak/b2b/Events/conference_proceedings/1st_pediatric_conference_1998/1998proceedings_22.pdf [Accessed: 28 August, 2015].

Bretz, K. (2006) *A comparison of three hearing aid manufacturers' recommended first fit to two generic prescriptive targets with the pediatric population.* Thesis (Doctor of Audiology). Washington University School Of Medicine.

British Society of Audiology and British Academy of Audiology (2008) *Guidance on the use of real ear measurements to verify the fitting of digital signal processing hearing aids.* Available at: http://www.thebsa.org.uk/resources/ [Accessed: 20 August, 2015].

Child Amplification Laboratory, National Centre for Audiology UWO (2010) *The University of Western Ontario Pediatric Audiological Monitoring Protocol Version 1.0, Revision 2.* Available at: https://www.dslio.com/wp-

content/uploads/2014/03/2_UWO_PedAMP_v1.0_for_printing_Revision_2_Dec_11.pdf [Accessed: 20 August 2015].

Ching, T. (2016) 'Population outcomes of children with hearing loss: early treatment is crucial but not sufficient – Marion Downs lecture in pediatric audiology'. *American Academy of Audiology* [Online]. Available at: https://www.eaudiology.org/products/population-outcomes-of-children-with-hearing-loss-early-treatment-is-crucial-but-not-sufficient-marion-downs-lecture-in-pediatric-audiology [Accessed: 5 May, 2016].

Ching, T. (2015) 'Is early intervention effective in improving spoken language outcomes of children with congenital hearing loss?' *American Journal of Audiology.* 24(3) September. pp. 345-348.

Ching, T. & Dillon, H (2013) 'Major findings of the LOCHI study on children at 3 years of age and implications for audiological management'. *International Journal of Audiology.* 52 (S2). pp. S65-68.

Ching, T., Day, J., Zhang, V., Dillon, H., Van Buynder P., Seeto, M., Hou, S., Marnane, V., Thomson, J., Street, L., Wong, A., Burns, L., Flynn, C. (2013) 'A randomised control trial of nonlinear frequency compression versus conventional processing in hearing aids: speech and language of children at 3 years of age'. *International Journal of Audiology.* 52 (S2) December. pp. S46-S54.

Chisolm, T. & Abrams, H. (2010) 'Moving evidence into practice: a conceptual framework for EBP in hearing healthcare'. *Academy of Rehabilitative Audiology 2010 ARA Institute Program.* San Francisco. Available at: https://audrehab.org/2010%20Institute%20Presentations/ChisolmAbrams.pdf [Accessed: 15 September, 2015].

Cohen, L., Manion, L., Morrison, K. (2000) *Research methods in education.* 5th edn. London: RoutledgeFalmer.

Cox, R. (2005) 'Evidence based practice in provision of amplification'. *Journal of the American Academy of Audiology.* 16(7). pp. 419-438.

Dillon, H. (2012) *Hearing aids.* 2nd edn. New York: Thieme.

Dillon, H. & Keidser, G. (2003). 'Is probe-mic measurement of hearing aid gain-frequency response best practice?' *Hearing Journal.* 56(10). pp. 28-30.

Eccles, M., Armstrong, D., Baker, R., Cleary, K., Davies, H., Davies, S., Glasziou, P., Ilott, I., Kinmouth, A., Leng, G., Logan, S., Marteau, T., Michie, S., Rogers, H., Rycroft-Malone, J., Sibbald, B. (2009) 'An implementation research agenda'. *Implementation Science* {Online]. 4(18). Available at: http://www.implementationscience.com/content/4/1/18 [Accessed: 14 September, 2015].

Ely, M., Anzul, M., Friedman, T., Garner, D., McCormack-Steinmetz, A. (2003) *Doing qualitative research.* London: Falmer Press.

Fitzpatrick, E., Crawford, L., Ni, A., Durieux-Smith, A. (2011) 'A descriptive analysis of language and speech skills in 4- to 5-yr-old children with hearing loss'. *Ear and Hearing.* 32(5) September/October. pp. 605-616.

Fitzpatrick, E., Durieux-Smith, A., Eriks-Brophy, A., Olds, J., Gaines, R. (2007) 'The impact of newborn hearing screening on communication development'. *Journal of Medical Screening.* 14(3). pp. 123-131.

Flexer, C. (2011) 'Cochlear implants and neuroplasticity: linking auditory exposure and practice'. *Cochlear implants International.* 12 (S1). pp. S19-S21.

Flick, U. (2008) *Designing qualitative research.* London: Sage.

Flyvberg, B. (2006) 'Five misunderstandings about case study research'. *Qualitative Inquiry.* 12 (2) April. pp. 219-245.

Funk, S., Champagne, M., Wiese, R., Tornquist, E. (1991) 'Barriers to using research findings in practice: the clinician's perspective'. *Applied Nursing Research.* 4. pp. 90-95.

Gerrish, K., Ashworth, P., Lacey, A., Bailey, J., Cooke, J., Kendall, S., McNeilly, E. (2007) 'Factors influencing the development of evidence-based practice: a research tool'. *Journal of Advanced Nursing.* 57(3) February. pp. 328-338.

Glista, D. & Scollie, S. (2009) 'Modified verification approaches for frequency lowering devices'. *AudiologyOnline* [Online.] Available at: http://www.audiologyonline.com/articles/modified-verification-approaches-for-frequency-871 [Accessed 24 August, 2015].

Glista. D., Scollie, S., Bagatto, M., Seewald, R., Parson, V., Johnson, A. (2009) 'Evaluation of nonlinear frequency compression: clinical outcomes'. *International Journal of Audiology.* 48. pp. 632-644.

Graham, I., Logan, J., Harrison, M., Straus, S., Tetroe, J., Caswell, W., Robinson, N. (2006) 'Lost in knowledge translation: time for a map?' *The Journal of Continuing Education in the Health Professions.* 26. pp. 13-24.

Gravel, J. (2004) 'Evidence-based practice in pediatric audiology'. *A Sound Foundation Through early Amplification.* Available at: http://www.phonakpro.com/content/dam/phonak/b2b/Events/conference_proceedings/adult_conference_chicago_2004/thursday/proceedings_chicago04_1.pdf [Accessed: 22 July, 2015].

Greenhalgh, T. (2010) *How to read a paper; the basics of evidence-based medicine.* 4th edn. Chichester: Wiley Blackwell.

Grimshaw, J., Eccles, M., Tetroe, J. (2004) 'Implementing clinical guidelines: current evidence and future implications'. *Journal of Continuing Education in the Health Professions.* 24 (S1). pp. S31-37.

Grol, R. & Grimshaw, J. (2003) 'From best evidence to best practice: effective implementation of change in patients' care'. *The Lancet.* 36 October. pp. 1225-1230.

Gustafon, D., Sainfort, F., Eichler, M., Adams, L., Bisognano, M., Steudel, H. (2003) 'Developing and testing a model to predict outcomes of organisational change'. *Health Services Research.* 38(2). pp. 751-776.

Hakkennes, S. & Dodd, K. (2008) 'Guideline implementation in allied health professions: a systematic review of the literature'. *Quality and Safety in Healthcare.* 17. pp. 296-300.

Harrison, M., Legare, F., Graham, I., Fervers, B. (2009) 'Adapting clinical practice guidelines to local context and assessing barriers to their use'. *Canadian Medical Association Journal.* pp. E78-E84.

Harrison, R. (2011) 'Development of the auditory system from periphery to cortex'. In Seewald, R. & Tharpe, A. (eds.) *Comprehensive handbook of pediatric audiology.* San Diego: Plural Publishing. pp. 23-46.

Hawkins, D. & Cook, J. (2003) 'Hearing aid software predictive gain values: how accurate are they?' *The Hearing Journal.* 56(7). pp. 26-34.

Hyde, M. (2004) 'Evidence-based practice, ethics and EHDI program quality'. *A Sound Foundation through Early Amplification.* Available at:

https://www.phonakpro.com/content/dam/phonak/b2b/Events/conference_proceedings/adult_conference_chicago_2004/saturday/proceedings_chicago04_23.pdf [Accessed: 15 August, 2015].

James, T. (2014) *Hearing aid verification; real ear measurements.* [PowerPoint slides] Lecture handouts. University of Hertfordshire.

Jones, C. & Launer, S. (2010) 'Pediatric fittings in 2010: the sound foundations cuper project'. *International Pediatric Audiology Conference. A Sound Foundation through Early Amplification.* Available at: https://www.phonakpro.com/content/dam/phonak/gc_hq/b2b/en/events/2010/Proceedings/Pho_Chap_12_Jones_Final.pdf [Accessed: 15 August, 2015].

Kajermo, K., Bostrom, A., Thompson, D., Hutchinson, A., Estabrooks, C., Wallin, L. (2010) 'The barriers scale – the barriers to research utilization scale: a systematic review'. *Implementation Science* [Online]. 5(32). Available at: doi:10.1186/1748-5908-5-32 [Accessed: 26 August, 2016].

Kennedy, C., McCann, D., Campbell, M., Law, C., Mullee, M., Petrou, S., Watkin, P., Worsfold, S., Yuen H., Stevenson, J. (2006) 'Language ability after early detection of permanent childhood hearing impairment'. *The New England Journal of Medicine.* 354 May. pp. 2131-2141.

Kent, R. (2006) 'Evidence-based practice in communication disorders: progress not perfection'. *Language, Speech and Hearing Services in Schools.* 37. pp. 268-270.

Kochkin, S. (2011) 'Marke trak VIII: reducing patient visits through verification and validation'. *The Hearing Review.* 18(6). pp. 10-12.

Koehlinger, K., Van Horne, A., Moeller, M. (2013) 'Grammatical outcomes for 3- and 6-year-old children who are hard of hearing'. *Journal of Speech Language and Hearing Research.* 56(5) October. pp. 1701-1714.

Koshy, V. (2010) *Action research for improving educational practice.* 2nd edn. London: Sage.

Kuk, F. & Ludvigsen, C. (2003) 'Reconsidering the concept of the aided threshold for nonlinear hearing aids'. *Trends in Amplification.* 7(3). p. 77-97.

Leavitt, R. & Flexer, C. (2012) 'The importance of audibility in successful amplification of hearing loss'. *Hearing Review.* 19(13). pp. 20-23.

Limb, C. (2011) ‘The need for evidence in an anecdotal world’. *Trends in Amplification.* 15(1-2). pp. 3-4.

McCreery, R. (2013) ‘Building blocks: the trouble with functional gain in verifying pediatric hearing aids’. *Hearing Journal.* 66(3). pp. 14-16.

McCreery, R., Bentler, R., Roush, P. (2013) ‘The characteristics of hearing aid fittings in infants and young children’. *Ear Hear.* 34(6). pp. 701-710.

McCreery, R., Walker, E., Spratford, M., Bentler, R., Holte, L., Roush, P., Oleson, J., Van Buren, J., Moeller, M. (2015) ‘Longitudinal predictors of aided speech audibility in infants and children’. *Ear and Hearing.* 36 (S1). pp. 24S-37S.

McCreery, R., Walker, E., Spratford, M., Oleson, J., Bentler, R., Holte, L., Roush, P. (2015) ‘Speech recognition and parent ratings from auditory development questionnaires in children who are hard of hearing’. *Ear and Hearing.* 36(S1). pp. 60S–75S.

McCreery, R. & Stelmachowicz, P. (2011) ‘Audibility-based predictions of speech recognition for children and adults with normal hearing’. *The Journal of the Acoustical Society of America.* 130(6) December. pp. 4070-4081.

Michie, S., Van Stralen, S., West, R. (2011) ‘The behaviour change wheel: a new method for characterising and designing behaviour change interventions’. *Implementation Science.* 6(42).

Modernising Children’s Hearing Aid services (2005) *Guidelines for the fitting, verification and evaluation of digital signal processing hearing aids within a children’s hearing aid service.* Available at: research.bmh.manchester.ac.uk/mchas/aboutus/guidelines [Accessed: 24 August, 2015].

Moeller, M. (2000) ‘Early intervention and language development in children who are deaf and hard of hearing’. *Official Journal of the American Academy of Pediatrics* [Online]. 106(3) September. pp. 1-9. Available at: http://www.pediatrics.org/cgi/content/full/106/3/e43 [Accessed: 7 March, 2014].

Moeller, M., Carr, G., Seaver, L., Stredler-Brown, A., Holzinger, D. (2013) ‘Best practices in family-centred intervention for children who are hard of hearing: an

international consensus statement'. *Journal of deaf Studies and Deaf Education.* 18(4). pp. 429-445.

Moeller, M. & Tomblin, J. (2015) 'An introduction to the outcomes of children with hearing loss study'. *Ear and Hearing.* 36(S1). pp. 4S-13S.

Moeller, M., Tomblin, J., Yoshinago-Itano, C., Connor, C., Jerger, S. (2007) 'Current state of knowledge: language and literacy of children with hearing impairment'. *Ear Hear.* 28 (6) December. pp. 740-753.

Moodie, S. (2012) *An integrated knowledge translation experience: use of the network of pediatric audiologists of Canada to facilitate the development of the University of Western Ontario Pediatric Audiological Monitoring Protocol (UWO PedAMP v 1.0).* Thesis (Phd). University of Western Ontario.

Moodie, S. (2011) 'Moving from evidence to practice: can knowledge translation and implementation science help audiology get there?' *AudiologyOnline* [Online]. Article 19419. Available at: http://www.audiologyonline.com/articles/20q-moving-from-evidence-to-804 [Accessed: 23 July, 2015].

Moodie, S. (2009) 'Clinician fit-to-DSL-targets: preliminary results from a network study'. *AudiologyOnline* [Online]. Available at: http://www.audiologyonline.com/audiology-ceus/course/clinician-fit-to-dsl-targets-930 [Accessed: 21 November 2015].

Mueller, G. & Picou, E. (2010) 'Survey examines popularity of real-ear probe-microphone measures'. *The Hearing Journal.* 63(5) May. pp. 27-32.

Mueller, G. (2006) *Hearing aid verification: old concepts and new considerations.* [Online]. Available at: http://www.phonak.com/content/dam/phonak/b2b/Events/conference_proceedings/adult_conference_chicago_2006/monday/2006proceedings_mueller.pdf [Accessed: 15 July, 2015].

Mueller, G. (2003) 'In the words of shakespeare: fitting test protocols are more honoured in the breach than the observance'. *The Hearing Journal.* 56(10). pp. 19-26.

Munro, K. (2004) 'Update on RECD measures in children'. *3rd Phonak conference Chicago. Sound Foundation Through early Amplification.* Available

at:
http://www.phonakpro.com/content/dam/phonak/b2b/Events/conference_proceedings/adult_conference_chicago_2004/thursday/2004proceedings_kmunro.pdf [Accessed: 22 July, 2015].

Munro, K., Puri, R., Bird, J., Smith, M. (2016) 'Using probe-microphone measurements to improve the match to target gain and frequency response slope as a function of earmould style, frequency and input level'. *International Journal of Audiology.* 55. pp. 215-223.

National Deaf Children's Society (2016) *Audiology service provision in the UK.* Available at: http://www.ndcs.org.uk/document.rm?id=11712 [Accessed: 9 March, 2017].

National Health and Medical Research Council (2000) *How to put the evidence into practice: implementation and dissemination strategies.* Available at: https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/cp71.pdf [Accessed: 16 August, 2016].

Palmer, C. (2010) 'Meeting hearing aid fitting goals'. *Starkey Audiology series* [Online]. 2(1). Available at: https://starkeypro.com/pdfs/sas/Starkey_Audiology_Series_v1i5.pdf [Accessed: 30 October, 2015].

Palmer, C. (2007) 'An evidence based approach to applying hearing instrument technology in pediatrics'. *Sound Foundation Through early Amplification.* Available at: https://www.phonakpro.com/content/dam/phonak/b2b/Pediatrics/webcasts/pediatric/com_21_p61899_pho_kapitel_10.pdf [Accessed: 12 September, 2015].

Phonak (2016) *Paediatric fitting guide junior target.* Available at: https://www.phonakpro.com/uk/en/support/other-support/target-fitting-software/overview-target.html [Accessed: 10 March, 2017].

Pope, C. (2003) 'Resisting evidence: the study of evidence-based medicine as a contemporary social movement'. *Health.* 7(3). pp. 267-282.

Pumford, J. & Sinclair, S. (2001) 'Real-ear measurement: basic terminology and procedures'. *AudiologyOnline* [Online]. Available at:

http://www.audiologyonline.com/articles/real-ear-measurement-basic-terminology-1229 [Accessed: 3o July, 2015].

Ratner, N. (2006) 'Evidence-based practice: an examination of its ramifications for the practice of speech-language pathology'. *Language, Speech and Hearing Services in Schools.* 37 October. pp. 257-267.

Roberts, D., Munoz, K., McCreery, R. (2012) 'Audiology, slow to implement practice guidelines, must explore solutions'. *The Hearing Journal*. 65 (10). pp. 34-37.

Rolfe, G. & Gardner, L. (2006) 'Towards a geology of evidence-based practice – a discussion paper'. *International Journal of Nursing Studies.* 43. pp. 903-913.

Roush, P. (2015) 'Hearing aid fitting in children: audibility matters'. *4th Latin American Pediatric Conference.* Available at: https://www.phonakpro.com/content/dam/phonak/gc_hq/b2b/en/events/2015/Sao%20Paulo/pat_roush.pdf [Accessed: 17 February, 2016].

Rycroft-Malone, J., Harvey, G., Seers, K., Kitson, A., McCormack, B., Titchen, A. (2004) 'An exploration of the factors that influence the implementation of evidence into practice'. *Journal of Clinical Nursing.* 13. pp. 913-924.

Sackett, D., Rosenberg, W., Muir Gray, J., Haynes, R., Richardson, W. (1996) 'Evidence based practice: what it is and what it isn't'. *British Medical Journal.* 312 January. pp. 71-72.

Seewald, R., Mills, J., Bagatto, M., Scollie, S., Moodie, S. (2008) 'A comparison of manufacturer-specific prescriptive procedures for infants'. *The Hearing Journal.* 61(11) November. pp. 26-34.

Seewald, R. & Scollie, S. (2003) 'An approach for ensuring accuracy in pediatric hearing instrument fitting'. *Trends in Amplification.* 7(1). pp. 29-40.

Shaw, G. (2012) 'Cover story: searching for answers: why don't audiologists use best practice guidelines?' *The Hearing Journal.* 65 (5). pp. 12-14.

Sininger, Y., Grimes, A., Christensen, E. (2010) 'Auditory development in early amplified children: factors influencing auditory-based communication outcomes in children with hearing loss'. *Ear and Hearing.* 31(2) April. pp. 166-185.

Stelmachowicz, P. (2004) 'Pediatric amplification: past, present and future'. *A Sound Foundation Through early Amplification.* Available at:

http://www.phonak.com/content/dam/phonak/b2b/Events/conference_proceedings/adult_conference_chicago_2004/thursday/proceedings_chicago04_2.pdf [Accessed: 28 August, 2015].

Stelmachowicz, P., Pittman, A., Hoover, B., Lewis, D. (2004) 'Novel word learning in children with normal hearing and hearing loss'. *Ear and Hearing.* 25(1). pp. 47-56.

Stelmachowicz, P., Pittman, A., Hoover, B., Lewis, D. (2002) 'Aided perception of /s/ and /z/ by hearing impaired children'. *Ear and Hearing.* 23. pp. 316-324.

Stiles, D., Bentler, R., McGregor, K. (2012) 'The speech intelligibility index and the pure-tone average as predictors of lexical ability in children fit with hearing aids'. *Journal of Speech, Language and Hearing Research.* 55 June. pp. 764 – 778.

Stiles, D. (2014) '20Q the audiologist as gatekeeper for language and cognition'. *AudiologyOnline* [Online]. Article 12453. Available at: http://www.audiologyonline.com/articles/20q-audiologist-as-gatekeeper-for-12453 [Accessed: 24 August, 2015].

Strauss, S. & van Dijk, C. (2008) 'Hearing instrument fittings of pre-school children: do we meet the prescription goals?' *International Journal of Audiology.* 47(S1). pp. S62-S71.

Taylor, B. (2015) 'The 'good enough' era and hearing healthcare'. *The Hearing Review* [Online]. 22(5). p. 10. Available at: http://hearinghealthmatters.org/hearingeconomics/2015/entering-just-good-enough-era/ [Accessed 15 August, 2016].

Tharpe, A. (1998) 'Service delivery for children with multiple impairments: how are we doing?' *A Sound Foundation Through Early Amplification.* Available at: http://www.phonak.com/content/dam/phonak/b2b/Events/conference_proceedings/1st_pediatric_conference_1998/1998proceedings_15.pdf [Accessed: 28 August, 2015].

Thompson, D., O'Leary, K., Jensen, E., Scott, S., O'Brien-Pallas, L., Estabrooks, C. (2008) 'The relationship between busyness and research utilization: it is about time'. *Journal of Clinical Nursing.* 17. pp. 539-548.

Tomblin, J., Harrison, M., Ambrose, S., Walker, E., Oleson, J., Moeller, M. (2015) ‘Language outcomes in young children with mild to severe hearing loss’. *Ear and Hearing.* 36(S1) pp. 76S-91S.

Tuller, L& Delage, H. (2013) ‘Mild-to-moderate hearing loss and language impairment: how are they linked?’ *Lingua* [Online]. 139. pp. 80-101. Available at: http://www.sciencedirect.com/science/article/pii/S002438411300226X [Accessed: 28 August, 2015].

U.S. Preventive Services Task Force (2001) ‘Recommendations and rationale newborn hearing screening’. *American Family Physician.* 64(12). pp. 1995-2000.

Uus, K., Bamford, J., Young, A., McCracken, W. (2005) ‘Readiness of paediatric audiology services for newborn hearing screening: findings and implications from the programme in England’. *International Journal of Audiology.* 44. pp.712-720.

Valente, M., Potts, L., Valente, I., Vass, W., Goebel, J. (1994) ‘Intersubject variability of real-ear sound pressure level: conventional and insert earphones’. *Journal of the American Academy of Audiology.* 5. p. 390-398.

Vohr, B., Jodoin-Krauzyk, J., Tucker, R., Johnson, M., Ahlgren, M., Pierre, L. (2011) ‘Expressive vocabulary of children with hearing loss in the first 2 years of life: impact of early intervention’*. Journal of Perinatology.* 31. pp. 274-280.

Wake, M., Ching, T., Wirth, K., Poulakis, Z., Mensah, I., Gold, L., King, A., Bryson, H., Reilly, S., Rickards, F. (2016) ‘Population outcomes of three approaches to detection of congenital hearing loss’. *Pediatrics* [Online]. 137 (1). Available at: http://pediatrics.aappublications.org/content/137/1/e20151722 [Accessed: 4 March, 2017].

Wake, M., Poulakis, Z., Hughes, E., Carey-Sargeant, C., Rickards, F. (2005) ‘Hearing impairment: a population study of age at diagnosis, severity and language outcomes at 7-8 years’. *Archives of Disease in Childhood.* 90. pp.238-244.

Wolfe, J., John, A., Schafer, E., Nyffeler, M., Boretzki, M., Caraway, T. (2010) ‘Evaluation of nonlinear frequency compression for school-age children with

moderate to moderately severe hearing loss'. *Journal of the American Academy of Audiology.* 21(10). pp. 618-628.

World Health Organisation (2009) *Newborn and infant hearing screening: current issues and guiding principles for action.* Available at: who.int/blindness/publications/Newborn_and_Infant_Hearing_Screening_Report.pdf [Accessed: 29 September, 2016].

Willig, C. (2013) *Introducing qualitative research in psychology.* 3rd edn. Berkshire: McGraw-Hill Education.

Yoshinago-Itano, C., Sedey, A., Coulter, D., Mehl, A. (1998) 'Language of early- and later-identified children with hearing loss'. *Pediatrics.* 102(5) November. pp. 1161-1171.

Zipoli, R. & Kennedy, M. (2005) 'Evidence-based practice among speech-language pathologists: attitudes, utilization and barriers'. *American Journal of Speech-Language Pathology.* 14 August. pp. 208-220.

Appendix A

UNIVERSITY OF HERTFORDSHIRE

ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS ('ETHICS COMMITTEE')

FORM EC6: PARTICIPANT INFORMATION SHEET

Title of study

Real-ear Measurements: Moving Evidence into Practice

Introduction

Your child is being invited to take part in a study. Before you decide whether to take part, it is important that you understand the research that is being done and what your child's involvement will include. Please take the time to read the following information carefully and discuss it with others if you wish. Do not hesitate to ask us anything that is not clear or for any further information you would like to help you make your decision. Please do take your time to decide whether or not you wish to take part. The University's regulations governing the conduct of studies involving human participants can be accessed via this link:

http://sitem.herts.ac.uk/secreg/upr/RE01.htm

Thank you for reading this.

What is the purpose of this study?

The purpose of this study is to evaluate the use of real ear measurements when fitting hearing aids compared to using manufacturers' first fit recommendations. Real-ear measurements are not outside the normal care in an Audiology Clinic and their use meets national quality guidelines for hearing aid fitting.

In addition, the barriers that may exist to implementing evidence based guidelines in clinical practice will be investigated along with facilitators that can be identified to reduce barriers.

It will be a collaborative investigation between Audiology and Education.

Do I have to take part?

It is completely up to you and your child whether you decide to take part in this study. If you and your child decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Agreeing to join the study does not mean that you or your child have to complete it. You and your child are free to withdraw at any stage without giving a reason. A decision to withdraw at any time, or a decision not to take part at all, will not affect any treatment/care that your child may receive (should this be relevant).

Are there any age or other restrictions that may prevent me from participating?

No

How long will my part in the study take?

If you decide to take part in this study, your child will be involved during their next routine appointment in Audiology (1 hour) and your next routine appointment with your Teacher of the Deaf. Your child will also be involved in a second routine appointment with your Teacher of the Deaf (1 hour).

What will happen to me if I take part?

The first thing to happen will be:

You will attend your child's scheduled hearing aid review appointment. At this appointment, real-ear measures will be carried out in the hearing aid fitting. These measures are part of normal care in an Audiology Clinic and involve making sure that your child's hearing aid settings meet his/her personalized prescription target in the ear.

Four weeks after this appointment, your child will be assessed using speech discrimination and an evaluation questionnaire at school. Your child already completes these assessments on an annual basis as part of their routine care under the Sensory Support Service. These assessments will take place at school by your child's Teacher of the Deaf. No additional time will be taken to carry out these routine tests than the usual time allocated for your child.

The numerical data from the real-ear measurements, speech tests and feedback from questionnaires will be used to evaluate the hearing aid fitting. No personal or identifiable data will be used in this evaluation.

What are the possible disadvantages, risks or side effects of taking part?

There may be changes made to your child's hearing aid amplification settings as a result of the real-ear measurements. As these changes are made to ensure prescription (amplification) targets are met, it is likely that the changes made will be beneficial to your child. In many cases the changes can be small and unnoticeable. However, there could be a period of time when your child notices the new sound and they may describe this to you. This period (known as adaptation) happens as your child gets used to listening with the new settings and can last up to 6 weeks. There will be opportunity to alter the hearing aid settings further, if necessary following the initial review appointment and after the adaptation period. Again, such follow up appointments are routine in the hearing aid fitting process and will personalize your child's hearing aid settings further.

What are the possible benefits of taking part?

Your child may hear a greater range of sounds, and/or hear speech more clearly.

How will my taking part in this study be kept confidential?

Any data collected will be anonymized and confidentiality maintained throughout the study.

What will happen to the data collected within this study?

The data collected will be used to

1. Compare the manufacturer's fit to a verified fit using real-ear measures.
2. Investigate any perceived benefit for your child of a verified fit.

All data will be anonymised at source and stored in accordance with the Data Protection Procedures of the Education Authority Northern Ireland.

All materials will be kept on a computer with encryption password.

All data will be anonymised to ensure participants cannot be identified.

Who has reviewed this study?

This study has been reviewed by:

The University of Hertfordshire Social Sciences, Arts and Humanities Ethics Committee with Delegated Authority

The UH protocol number is EDU/PGT/02156

Who can I contact if I have any questions?

If you would like further information or would like to discuss any details personally, please get in touch with me, in writing, by phone or by email:

Wendy Martin

Service for Sensory Impaired

Belvoir Park Primary School

Belvoir Drive

Belfast BTZ 7DL

02890491583

Email: wendy.martin@eani.org.uk

Supervisor: Tracy James

Although we hope it is not the case, if you have any complaints or concerns about any aspect of the way you have been approached or treated during the course of this study, please write to the University's Secretary and Registrar.

Thank you very much for reading this information and giving consideration to taking part in this study.

UNIVERSITY OF HERTFORDSHIRE

ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS
('ETHICS COMMITTEE')

FORM EC6: PARTICIPANT INFORMATION SHEET

1 **Title of study**

Real-ear Measurements: Moving Evidence into Practice

2 **Introduction**

You are being invited to take part in a study. Before you decide whether to do so, it is important that you understand the research that is being done and what your involvement will include. Please take the time to read the following information carefully and discuss it with others if you wish. Do not hesitate to ask us anything that is not clear or for any further information you would like to help you make your decision. Please do take your time to decide whether or not you wish to take part. The University's regulations governing the conduct of studies involving human participants can be accessed via this link:

http://sitem.herts.ac.uk/secreg/upr/RE01.htm

Thank you for reading this.

3 **What is the purpose of this study?**

The purpose of this study is to evaluate the use of real-ear measurements when fitting hearing aids compared to using manufacturers' first fit recommendations. Real-ear measurements are not outside the normal care in an Audiology Clinic and their use meets national quality guidelines for hearing aid fitting.

In addition, the barriers that may exist to implementing evidence based guidelines in clinical practice will be investigated along with facilitators that can be identified to reduce barriers.

It will be a collaborative investigation between Audiology and Education.

4 **Do I have to take part?**

It is completely up to you whether or not you decide to take part in this study. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Agreeing to join the study does not mean that you have to complete it. You are free to withdraw at any stage without giving a reason.

5 **Are there any age or other restrictions that may prevent me from participating?**

No

6 **How long will my part in the study take?**

If you decide to take part in this study, you will be involved for one interview session lasting approximately thirty minutes to one hour.

7 **What will happen to me if I take part?**

The first thing to happen will be you will take part in an interview session about your views on real-ear measures.

8 **What are the possible disadvantages, risks or side effects of taking part?**

None

9 **What are the possible benefits of taking part?**

A protocol for real-ear measures may be implemented.

10 **How will my taking part in this study be kept confidential?**

Any data collected will be anonymized and confidentiality maintained throughout the study.

11 **What will happen to the data collected within this study?**

The data collected will be stored electronically, in a password-protected environment, for 4 months, after which time it will be destroyed under secure conditions;

The data will be anonymised prior to storage.

12 **Will the data be required for use in further studies?**

The data will not be used in any further studies.

14 **Who has reviewed this study?**

This study has been reviewed by:

The University of Hertfordshire Social Sciences, Arts and Humanities Ethics Committee with Delegated Authority

The UH protocol number is EDU/PGT/02156

15 **Factors that might put others at risk**

Please note that if, during the study, any medical conditions or non-medical circumstances such as unlawful activity become apparent that might or had put others at risk, the University may refer the matter to the appropriate authorities.

16 **Who can I contact if I have any questions?**

If you would like further information or would like to discuss any details personally, please get in touch with me, in writing, by phone or by email:

Wendy Martin

Service for Sensory Impaired

Belvoir Park Primary School

Belvoir Drive

Belfast BTZ 7DL

02890491583

Email: wendy.martin@eani.org.uk

Supervisor: Tracy James

Although we hope it is not the case, if you have any complaints or concerns about any aspect of the way you have been approached or treated during the course of this study, please write to the University's Secretary and Registrar.

Thank you very much for reading this information and giving consideration to taking part in this study.

UNIVERSITY OF HERTFORDSHIRE

ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS

('ETHICS COMMITTEE')

FORM EC4

CONSENT FORM FOR STUDIES INVOLVING HUMAN PARTICIPANTS

FOR USE WHERE THE PROPOSED PARTICIPANTS ARE MINORS, OR ARE OTHERWISE UNABLE TO GIVE INFORMED CONSENT ON THEIR OWN BEHALF

I, the undersigned *[please give your name here, in BLOCK CAPITALS]*

……

of *[please give contact details here, sufficient to enable the investigator to get in touch with you, such as a postal or email address]*

……

hereby freely give approval for *[please give name of participant here, in BLOCK CAPITALS]*

.....

to take part in the study entitled

Real-ear Measurements: Moving Evidence into Practice

UH Protocol number EDU/PGT/02156

1 I confirm that I have been given a Participant Information Sheet (a copy of which is attached to this form) giving particulars of the study, including its aim(s), methods and design, the names and contact details of key people and, as appropriate, the risks and potential benefits, how the information collected will be stored and for how long, and any plans for follow-up studies that might involve further approaches to participants. I have also been informed of how my personal information on this form will be stored and for how long. I have been given details of his/her involvement in the study. I have been told that in the event of any significant change to the aim(s) or design of the study I will be informed, and asked to renew my consent for him/her to participate in it.

2 I have been assured that he/she may withdraw from the study, and that I may withdraw my permission for him/her to continue to be involved in the study, at any time without disadvantage to him/her or to myself, or having to give a reason.

3 I have been told how information relating to my child (data obtained in the course of the study, and data provided by me, or by him/her, about him/herself) will be handled: how it will be kept secure, who will have access to it, and how it will or may be used.

4 I understand that participation in this study may reveal findings that could indicate that my child might require medical advice. In that event, I will be informed and advised to consult my GP.

5 I understand that if there is any revelation of unlawful activity or any indication of non-medical circumstances that would or has put others at risk, the University may refer the matter to the appropriate authorities.

6 I declare that I am an appropriate person to give consent on his/her behalf, and that I am aware of my responsibility for protecting his/her interests.

Signature of person giving consent

……Date……

Relationship to participant

.....

Signature of (principal) investigator

.....Date……..

Name of (principal) investigator

WENDY MARTIN

Name of (principal) investigator: *WENDY MARTIN Protocol number: EDU/PGT/02156*

UNIVERSITY OF HERTFORDSHIRE

ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS

('ETHICS COMMITTEE')

FORM EC3

CONSENT FORM FOR STUDIES INVOLVING HUMAN PARTICIPANTS

I, the undersigned *[please give your name here*, *in BLOCK CAPITALS]*

……..…

of *[please give contact details here, sufficient to enable the investigator to get in touch with you, such as a postal or email address]*

…..……

hereby freely agree to take part in the study entitled

Real ear Measurements: Moving Evidence into Practice

1 I confirm that I have been given a Participant Information Sheet (a copy of which is attached to this form) giving particulars of the study, including its aim(s), methods and design, the names and contact details of key people and, as appropriate, the risks and potential benefits, and any plans for follow-up studies that might involve further approaches to participants. I have been given details of my involvement in the study. I have been told that in the event of any significant change to the aim(s) or design of the study I will be informed, and asked to renew my consent to participate in it.

2 I have been assured that I may withdraw from the study at any time without disadvantage or having to give a reason.

3 I have been told how information relating to me (data obtained in the course of the study) will be handled: how it will be kept secure, who will have access to it, and how it will or may be used.

4 I understand that if there is any revelation of unlawful activity or any indication of non-medical circumstances that would or has put others at risk, the University may refer the matter to the appropriate authorities.

Signature of participant……..…Date…….……..

Signature of (principal) investigator……Date……

Name of (principal) investigator

WENDY MARTIN *Protocol number: EDU/PGT/02156*

Dear (Parent / Guardian)

MSc in Educational Audiology Dissertation Title: Real-Ear Measurements: Moving Evidence into Practice.

I write to ask for your permission to use information from your child's hearing aid review in the above project.

The aim of the study is to investigate the feasibility of suggested practice guidelines and their benefit in the fitting of hearing aids. This information will then be used to inform the implementation of Good Practice Guidelines.

The hearing aid review will be no different to a routine session. The audiologist will carry out measurements and collect some additional data on the fitting of your child's hearing aids in order to achieve a good fit to prescription targets for your child's hearing loss.

This data will then be shared with myself for the purpose of comparison in the project. Your child will also be tested for speech discrimination in school. Again this will follow the usual routine for your child and will be carried out by myself in my role as Teacher of the Deaf.

Any data collected will be anonymised to ensure that your child cannot be identified in the project. Confidentiality will be maintained at all times.

The data collected will be stored in accordance with data protection procedures of the Education Authority.

If you agree to your child's participation, please sign and return the attached Consent Form.

Thank you very much for your help,

Yours sincerely

Mrs W Martin
Peripatetic Teacher
Service for the Sensory Impaired
Belvoir Park Primary School
Belfast
BT8 7DL

Tel: 02890 491583

Protocol Number: EDU/PGT/02156

Dear (Child)

I am writing this letter to let you know that your parents have given me permission to use your hearing aid test results in a project I am doing about the hearing aids that you use.

The aim of the project is to see how well they work and to see how this helps your hearing.

In my project I will collect and use the results of your regular hearing aid review tests. No extra or different tests or visits will be necessary and all the results will have your name taken off.

The results will only be used in the above study.

You do not have to take part if you don't want to.

If you have any questions or concerns, please ask your parents or myself and we will do our best to answer your questions.

If you agree to take part, please sign the slip below.

Thank you for your help and I am glad that you and your family are able to help with my project.

Yours sincerely

Mrs W Martin

Peripatetic Teacher
Service for the Sensory Impaired
Belvoir Park Primary School
Belfast
BT8 7DL

Tel: 02890 491583

Your Name _____

Date _____

I agree to take part in this study.

MSc in Educational Audiology

Dissertation Title: Real-Ear Measurements: Moving Evidence into Practice.

University of Hertfordshire Protocol Number: EDU/PGT/CP/02156 W. Martin 14018445

I am writing to ask you to take part in the above study by completing a questionnaire. I am currently completing my dissertation evaluating the use of real-ear measurements when fitting hearing aids compared to using the manufacturer's first fit recommendations. In addition, I wish to investigate the barriers that may exist in using these measurements in every day clinical practice, along with facilitators that can be identified to reduce barriers. I am particularly interested in the barriers and/or facilitators in using real-ear measurements with children.

This is a collaborative study between Audiology and Education. The project is intended to identify the barriers and facilitators to the use of real-ear measurements and to evaluate their benefit within the context of a busy clinical setting. It is hoped that solutions will be found to the barriers identified as the study progresses. Any information can then be shared and used as appropriate by Audiology clinics. It is also hoped that this study will strengthen links between Audiology and Education.

If you are happy to take part, confidentiality will be maintained at all times. Returned questionnaires will only be kept for the duration of the study. At the end of the study returned questionnaires will be destroyed in accordance with the Education Authority procedures. Any electronic information will be stored on an encrypted computer and deleted at the end of the study.

It is important that institutions will not be identified in this study. In order to ensure that your completed questionnaire remains anonymous, please return the completed questionnaire using the self-addressed stamped envelope provided. Please then write your name and Audiology Clinic on the self-addressed stamped postcard provided and post this **separately**. In this way, I will know you have completed and returned a questionnaire but will not be able to link a specific questionnaire to you or your place of work.

If you would prefer to complete the questionnaire electronically, please send me a request via the email address below and I can send you the questionnaire for completion. Please be aware if you choose this method, I will be able to identify you as respondent. This will still guarantee confidentiality, but not anonymity.

I am very grateful that you have taken the time to read this letter and would be grateful if you could complete and return the questionnaire and the accompanying postcard.

Please complete and return by: _____.

Thank you for your time and cooperation

Yours sincerely

Wendy Martin

Contact Details:

Mrs W Martin

Peripatetic Teacher

Service for the Sensory Impaired

Belvoir Park Primary School

Belfast BT8 7DL Tel: 02890 491583 email: wendy.martin@eani.org

University of Hertfordshire

UNIVERSITY OF HERTFORDSHIRE
SOCIAL SCIENCES, ARTS AND HUMANITIES

ETHICS APPROVAL NOTIFICATION

TO Wendy Martin

CC Tracy James

FROM Dr Timothy H Parke, Social Sciences, Arts and Humanities ECDA Chairman

DATE 22/12/15

Protocol number: **EDU/PGT/CP/02156**

Title of study: Real-Ear Measures: Moving Evidence into Practice

Your application for ethics approval has been accepted and approved by the ECDA for your School.

This approval is valid:

From: 22/12/15

To: 01/05/16

Please note:

Approval applies specifically to the research study/methodology and timings as detailed in your Form EC1. Should you amend any aspect of your research, or wish to apply for an extension to your study, you will need your supervisor's approval and must complete and submit form EC2. In cases where the amendments to the original study are deemed to be substantial, a new Form EC1 may need to be completed prior to the study being undertaken.

Should adverse circumstances arise during this study such as physical reaction/harm, mental/emotional harm, intrusion of privacy or breach of confidentiality this must be reported to the approving Committee immediately. Failure to report adverse circumstance/s would be considered misconduct.

Ensure you quote the UH protocol number and the name of the approving Committee on all paperwork, including recruitment advertisements/online requests, for this study.

Students must include this Approval Notification with their submission.

Appendix B Audiologist Data Collection Questionnaire and Interview

MSc Educational Audiology. Title: Real-Ear Measurements: Moving Evidence into Practice

University of Hertfordshire Ethics Protocol Number: EDU/PGT/CP/02156 W. Martin 14018455

Survey Questionnaire:

The purpose of this study is to evaluate the use of real-ear measurements when fitting hearing aids compared to using manufacturers' first fit recommendations.

In addition, the barriers that may exist to implementing evidence based guidelines in clinical practice will be investigated along with facilitators that can be identified to reduce barriers.

Confidentiality and anonymity will be maintained at all times.

Questions

1. Please write your qualification(s) here.

2. When did you qualify?

3. <u>Sources of knowledge</u>

In this section, please think about the sources of knowledge you use for audiology appointments and procedures, e.g. for fitting hearing aids to individuals.

For example:

If you always use the information you gained from your training, score this statement 5.

If you never use articles published in Audiology Journals, score this statement 1.

Please rate each of the following statements on the sources of knowledge you use to conduct audiology appointment / procedures.

Use a scale of 1 – 5, where 1 means never used and 5 means always used.

		1	2	3	4	5
1	Information that I learn about each patient/client as an individual	□	□	□	□	□
2	My intuition about what seems to be 'right' for the patient/client	□	□	□	□	□
3	My personal experience of caring for patients/clients over time	□	□	□	□	□
4	What has worked for me for years	□	□	□	□	□
5	The way that I have always done it	□	□	□	□	□
6	Information my fellow audiologists share	□	□	□	□	□
7	Information more experienced clinical audiologists share	□	□	□	□	□
8	What doctors discuss with me	□	□	□	□	□
9	Information that I learn about from manufacturers' representatives	□	□	□	□	□
10	Information I get from product literature	□	□	□	□	□
11	Information I learned from my training	□	□	□	□	□
12	Information I get from attending in-service training conferences	□	□	□	□	□
13	Information I get from local policy and protocols	□	□	□	□	□
14	Information I get from national policy initiatives/guidelines	□	□	□	□	□
15	Information I get from audit reports	□	□	□	□	□
16	Articles published in audiology journals	□	□	□	□	□
17	Articles published in other research journals	□	□	□	□	□
18	Articles published in non-peer reviewed journals	□	□	□	□	□
19	Information in textbooks	□	□	□	□	□
20	Information that I get from the internet	□	□	□	□	□
21	Information that I get from media (TV)	□	□	□	□	□

Note: 5-point Likert scale: 1 (never use) to 5 (always use).

4. <u>Barriers to changing practice based on 'best evidence'.</u>

In this section, please think about changing your practice in Audiology Clinics based on evidence, such as Guidelines published by Modernising Children's Hearing Aid Services (MCHAS) or British Society of Audiology (BSA).

If you felt you wanted to change practice or protocols in the Audiology clinic based on evidence, for example, to include real-ear measurements (if you don't already do so), are there any barriers to changing practice?

Please rate each of the following statements relating to barriers to changing practice.

Use a scale of 1 – 4, where 1 means disagree strongly and 4 means agree strongly.

		1	2	3	4
1	I do not feel confident about beginning to change my practice	□	□	□	□
2	The culture of my team is not receptive to changing practice	□	□	□	□
3	I lack the authority in the workplace to change practice	□	□	□	□
4	There are insufficient equipment resources to change practice	□	□	□	□
5	There is insufficient time at work to implement changes in practice	□	□	□	□
6	There are insufficient financial resources to change practice	□	□	□	□
7	I feel that our practice lacks a leader with knowledge in 'best evidence' to change practice	□	□	□	□
8	Staff lack the knowledge required to change any practice	□	□	□	□
9	Staff lack the training required to change practice	□	□	□	□
10	There is a lack of managerial support	□	□	□	□
11	There is insufficient time at work to read research	□	□	□	□

Note: 4-point Likert scale: 1 (disagree strongly) to 4 (agree strongly).

5. Additional barriers to finding, reviewing and/or using evidence in practice.

Please use this space to identify any additional barriers to the development of provision based on evidence in your practice.

6. Additional factors which would facilitate the development of provision based on evidence in your practice.

Please use this space to identify any factors which you believe would <u>facilitate</u> the development of provision based on evidence in your setting.

7. Do you use published guidelines to guide hearing aid fittings for children?

If yes, which guidelines do you use?

8. Please indicate how you verify hearing aid fittings for children.

Please tick the methods you use for each age group:

a.	Functional gain – sound field aided thresholds	0 – 36 months	☐
b.	Real-ear measures (individually measured)	0 – 36 months	☐
c.	Functional gain – sound field aided thresholds	3 – 5 years	☐
d.	Real-ear measures (individually measured)	3 – 5 years	☐
e.	Functional gain – sound field aided thresholds	5 -16 years	☐
f.	Real-ear measures (individually measured)	5 -16 years	☐

9. Please rate the relative contribution of the following factors in improving outcomes for children with hearing loss.

If you wish, add any other factors which you feel improve outcomes.

	1 = not at all, 2 = a little, 3 = quite a lot, 4 = very much	**1**	**2**	**3**	**4**
1	Parental support and involvement	☐	☐	☐	☐
2	Individually measured real ear measurements to facilitate fitting close to prescription targets (including RECD)	☐	☐	☐	☐
3	Use of evidence based prescription to generate targets (DSL , NAL)	☐	☐	☐	☐
4	Support from other services e.g. Teachers of the Deaf	☐	☐	☐	☐
5	Early identification of hearing loss and early fitting of amplification	☐	☐	☐	☐
6	Well trained paediatric audiologists	☐	☐	☐	☐
7	Good multi agency working	☐	☐	☐	☐
8	Use of published guidelines such as MCHAS / BSA to guide fitting of hearing aids to children	☐	☐	☐	☐

Thank you for taking the time to fill in this questionnaire.

Contact details:

Wendy Martin

Email: wendy.martin@eani.org.uk Telephone: 02890491583

Address: Service for Sensory Impaired Belvoir Park Primary School Belvoir Drive Belfast BT8 7DL

Interview Schedule

1. Do you think/how do you think Paediatric Audiology has changed in Northern Ireland since:
    a. The roll out of digital hearing aids
    b. The roll out of newborn hearing screening.
2. What were the training implications e.g. was there any training support available for digital hearing aids, fitting hearing aids to very young babies?
3. Was funding available for changes?
4. Quality Standards for Paediatric Audiology have not been introduced in Northern Ireland. Do you think Quality Standards should be introduced?
5. Quality Standards for Paediatric Audiology from the NDCS and other guidelines (MCHAS) include REMS for young children. Do you have a view on REMs for children? Do you think carrying out REMS would significantly change outcomes for children?
5. What do you think are the barriers to carrying out REMs with infants and young children?
6. Can you tell me about the barriers in:
    a. Yourself
    b. The context you work in?
7. What might overcome these barriers?
8. What might your motivation be to implement REMs with children?
9. How might you maintain the implementation of REMs if they were to be introduced?
10. How do you or are you able to keep up to date with technological developments?
11. How do you feel about change?
12. What, if anything would change or improve outcomes for children with hearing loss and their families?

All Interview Responses in Themes:

Time

'We need longer appointment times.'

'You feel like you are rushing but you are afraid you have forgotten about for example a referral on to sensory support services.'

'We could do real-ear measures on children if we had time to do it.'

'Time, you need so much time – even to talk to parents as well as the technological aspects of fitting.'

'We don't have control over appointments so we can't really plan. The hospital service is Consultant led – if it was Audiology led, we could use the time better.'

'Trust culture is to get through it. There has to be a balance with appointments and waiting lists. We are being squeezed to meet targets – this involves adult work.'

'Appointment bookings are solid.'

'Time for study or continual professional development is not prioritised. There should or could be time built in for CPD and effective practice. People have lives so we can't always do this at home.'

'Any time to look at research is not valued.'

'Administration time is given but this is busy time – we have to do routine work they could be done by Band 5's.'

Training Needs

'The sales reps can make a difference if they provide decent training.'

'There was no training for earmoulds and fitting hearing aids to babies except from manufacturers.'

'There was some training on Practice Navigator from Siemens and on real-ear measures, but staff didn't know what they were on about.'

'We get training through hearing aid companies, training in their software and their hearing aids…there wasn't enough money to put into training.'

'It is very difficult to keep up to date with technology and developments. All training comes from manufacturers.'

'The training I got for real-ear measures was with adults. I was given a sheet of information, then I did one on another audiologist. You need someone experienced there to ask questions when needed.'

The things that stop us are….training.'

For newborn screening, new skills had to be learned….. we had to implement digital hearing aids sooner than we would have liked from a training point of view due to pressure from RNID. There was no training except from manufacturers.'

Training is needed, without training we are forced to read around a lot. But lack of training creates a pressure.'

Quality Standards and MCHAS

'We are the poor relations, MCHAS didn't reach Northern Ireland.'

'I know MCHAS training was available in England, but the funding wasn't available here.'

'*There is more publicity for adults and they are more demanding.'*

'Most staff didn't engage with real-ear measures before the standards for adults came in. To REM seemed more hassle than it was worth.'

'QS have driven REMs for adults because the QS introduced peer review, therefore people from Scotland have come to peer review.'

'QS for children would drive implementation and maintenance of REMs'

'QS should be implemented so that these 0-3 children can be verified. I would like to see everyone doing the same.'

Confidence

'The things that stop us are … low confidence levels. Getting the child to cooperate is stressful, kids can smell fear.'

'You can be nervous – no confidence, because it's new and you would need training. It's getting over that hurdle of doing the first two or three and just getting on with it.'

'Confidence is a huge one. Doing fittings with babies, the wriggly nature of babies. Parents are watching intently and there are parents' stress levels as well.'

'I have a script that I am comfortable with. If I have to do something new, if you get knocked off your script in appointments, it can be difficult.'

'Doing REMs at my hospital stalled. We thought, sure, you're going to adjust it anyway because the patient won't like it. I think we may have been looking for an excuse not to do it. Now, minds are changed because confidence has grown, we know how to do it and we are more convinced that it's better to use a verified baseline. I can counsel the patient better because I understand it. I'm more confident to leave the fitting as fitting to targets, I trust it more.'

'Existing staff that had been around for a long time felt uncomfortable doing REMs.'

Resources

'The set-up has been for adults.'

'There is hassle because of the equipment, you have to go from screen to screen, mute at this point, close screens down in the right order. This makes it awkward and very irritating.'

'If equipment is hard to use, you're not going to use it.'

'One thing to improve outcomes would be more trained and experienced staff. There is only one audiologist working here with children. What happens if _____ goes off sick?'

Benefit of REMs

'In an ideal world we should do REMs with children….it is more important in children than in adults.'

'We're doing pretty well without REMs, our audiologists listen to other disciplines like teachers of the deaf, you need good team work.'

'If I'm being honest, REMs are essential for 0-3 years, although a lot of children are headed for implants.'

'The 0-3's are the most important group and the mild to severe group.'

'None of our children are disadvantaged because of not doing real-ear measures. I would rather programme to aided thresholds, I rely on aided VRA.'

'Doing REMs at my hospital stalled. We thought, sure, you're going to adjust it anyway because the patient won't like it. I think we may have been looking for an excuse not to do it. Now, minds are changed because confidence has grown, we know how to do it and we are more convinced that it's better to use a verified baseline. I can counsel the patient better because I understand it. I'm more confident to leave the fitting as fitting to targets, I trust it more.'

Opinion on REMs

'We are good enough rather than best practice.'

'Is there actually enough improved outcomes to merit REMs, I'm not sure.'

'REMS make you want to match to an unrealistic target because you can never match precisely. It is more important how the child responds to hearing aids.'

'We really should be doing this, REMs and RECDs.'

'If we're not doing REMs for whatever the reason, at least there is communication between teachers, speech and language therapists, paediatricians to build up the bigger picture.'

Attitude to Change

'*I am OK with change. As an audiologist you have to be open to change.'*

'Change is hard when you've been doing something for years.'

'Change is good if I can see the benefits of it and if I'm given the time to investigate it.'

'I'm an early adopter. I get quite excited if there's a value to it. It's always difficult to make a change unless you can see the physical results of doing something different, this then motivates you.'