Remote Microphone Use with Pre-School Cochlear Implanted Children

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

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Abstract

Distance, noise and reverberation in the home and pre-school settings result in challenging listening environments for a young hearing impaired child. Radio aids or FM systems provide an improved signal to noise ratio, thereby enabling access to an improved listening experience. Recent studies have highlighted the benefit of FM use with pre-school hearing aid users, yet little research has been done to analyse the significance of an improved signal to noise ratio with cochlear implanted pre-school children. The aim of this study was to investigate the impact of the Cochlear™ Wireless Mini Mic on the language of two profoundly deaf pre-schoolers. A case study approach was used, using both quantitative and qualitative methods of data collection and analysis.

Two families took part in the case study. Comments from parents and staff through diary sheets and interview questions allowed for qualitative data analysis. Diary sheets also offered quantitative data on Mic use, and the Listening Evaluation questionnaire and LENA™ Developmental Snapshot (LDS) were used to show changes in language development following Mini Mic use. The Language ENvironmental Analysis tool (LENA™) allowed thorough investigation of Adult Word Counts (AWC), Child Vocalisations (CV) and Conversational Turns (CT) on specific days, with and without the Mini Mic.

The family of P2 used the Mini Mic for only one week, reporting that they did not notice any benefit. LENA™ results, however, showed higher AWC, CV and CT for almost all situations on the day the Mic was used in nursery. The family of P1 used the Mini Mic in a range of situations over the initial two month period. Parents and staff reported improved attention, focus and behaviour when using the Mini Mic, particularly in noise and at a distance. Qualitative comments were reinforced by quantitative data from the Listening Evaluation questionnaire which showed the most significant improvements were in responses to questions and commands and attention, with a 50% improvement in responses from another room. LDS scores showed a slight improvement in language development for P1 although he still remained in the ‘at risk’ category. LENA™ data showed improved word counts when the Mini Mic was used, with Conversational Turns more than doubling during directed activity time in nursery.

This study contributes to a battery of recent and ongoing research enriching our understanding of the benefits of remote microphone use with pre-school hearing impaired children.

1. Introduction

1.1 Background

Since the introduction of the Newborn Hearing Screening Programme (NHSP) in 2006, many children with a permanent childhood hearing impairment (PCHI) are identified as very young babies. Guidelines from Modernising Children's Hearing Aid Services (MCHAS) enable children identified with PCHI to have access to digital amplification within only a few months of life (Feirn 2014). A multi professional approach between Health and Education services allows for early intervention and support for families of these children.

It is widely accepted that early auditory experience is essential in laying a foundation for the acquisition of spoken language, therefore early amplification offers a hearing impaired child a linguistic advantage over a child with PCHI who is not identified until later. In addition to early amplification, the benefits of early intervention have been evidenced (Vohr et al 2008; Moeller 2000; Yoshinaga-Itano et al 1998).

Background noise, reverberation and distance from the speaker can result in adverse listening conditions, particularly for the hearing impaired child. The speaker's use of a remote microphone in the form of a radio aid or FM system enables an improved signal to noise ratio (SNR), thereby overcoming these challenges and offering improved speech perception and reduced listening effort.

Traditionally, the use of such systems has been limited, in the UK, to school age children in educational settings, due to the impracticalities of the size and weight of systems, concerns over the use of small parts and lack of funding. More discrete systems and integrated receivers, however, have allowed for significant research in recent years into the benefits of radio aids or FM systems on the language development of pre-school hearing aid users (Webster 2015; Mulla 2011; Statham & Cooper 2009).

While evidence points to the improved SNR from a radio aid having a positive impact on speech recognition, understanding and clarity, most studies to date have been with pre-school hearing aid users, with very little research being done with pre-school cochlear implanted children.

The Cochlear™ Wireless Mini Mic was introduced in 2015 to all users of the Cochlear Nucleus 6 (CP 910) cochlear implant. It uses the same 2.4GHz wireless technology as the latest radio aid systems to offer the child an improved SNR, the speaker wearing a small clip-on microphone to transmit speech to microphones in the child's speech processors.

A case study into the language development of pre-schoolers using the Mini Mic would provide insight into whether remote microphone use could produce benefits for cochlear implanted pre-schoolers similar to those of a radio aid for pre-schoolers using hearing aids. A mixed methodological approach was used in the form of two case studies.

1.2 Outline of chapters

Chapter 2 will review the literature relevant to this area of research, looking in particular at previous studies into the benefits of radio aid use with pre-school hearing aid users.

Chapter 3 will outline the methodology used, including ethics, recruitment, equipment and procedure. It will go on to describe the quantitative and qualitative methods of data collection and analysis, the results of which will then be evaluated in Chapter 4.

Chapter 5 will discuss the findings of this study, including strengths and weaknesses and make recommendations for future research.

2. Literature review

2.1 Early intervention

Research by Jusczyk (1997) suggested that infants possess innate capacities to produce speech sounds from birth. This initial ability to discriminate phonetic contrasts of any of the world's languages is reduced over time to the most relevant, following prolonged exposure to their native language. These findings were substantiated by Khul et al in 1999.

An infant born with a hearing impairment is deprived of important pre-natal auditory experiences (Lecaunet & Granierre-Deferre 1993). However, early diagnosis and appropriate amplification now offers hearing impaired babies access to speech sounds from a very early age.

Yoshinaga-Itano et al (1998) found that early identification of hearing loss, followed by early intervention, was associated with improved language development. Children with a hearing loss who were identified before 6 months of age demonstrated significantly better receptive and expressive language scores than those identified after 6 months of age, regardless of age, degree of hearing loss, method of communication or socio-economic status (Yoshinaga-Itano et al. 1998).

Similarly, in 2000, Moeller discovered that children enrolled into intervention services before 11 months of age had better vocabulary and verbal reasoning skills at age 5 than those enrolled at a later age, regardless of the degree of hearing loss. Family involvement was also found to be of significant benefit (Moeller 2000).

More recently, in 2008, Vohr found that children identified with a hearing loss who were enrolled onto intervention programmes before 3 months of age demonstrated significantly better language outcomes than those enrolled after 3 months of age (Vohr et al. 2008).

The Early Support 'Monitoring Protocol for deaf babies and children' (2008) highlights the benefits of early identification of PCHI, particularly the potential for improved language development and communication, provided that effective

early support services are put in place following diagnosis and amplification (DCSF 2008).

2.2 Challenging listening conditions

In real life situations, speech can be masked by the background noise that is invariably present, thereby affecting speech perception and understanding (Yang et al 2012). Unlike adults, children find it harder to understand speech in noisy or reverberant situations as they are less able to make use of the context, which may be unfamiliar to them (Wroblewski et al. 2012; Klatte et al. 2010; Neuman et al. 2010).

Nozza et al (1990) found that, for groups of infants and adults, speech-sound discrimination in noise varied with signal to noise ratio (SNR) and a group of infants in the study required a greater SNR than the adult group in order to produce comparable levels of performance. Bradley and Sato (2008) and Eisenberg et al (2000) also found that younger children had more difficulty understanding speech in noise than older children. Logically then, for a young child with a hearing loss, understanding speech in noise is extremely challenging. Wolfe and Schafer (2008) found that speech recognition scores in noise were 50% poorer than in quiet for cochlear implanted children. Similarly, in 2012, Yang found that speech recognition at a SNR of 10dB was only 50% for cochlear implanted children and 33% for hearing aid users.

A study by Finitzo-Hieber and Tillman in 1978, which highlighted the importance of good acoustic listening conditions in schools, found that, as well as having worse speech scores in noise, hearing impaired children also scored lower than their hearing peers when reverberation times were increased (Finitzo-Hieber & Tillman 1978). A more recent study in Essex examined the impact of reducing reverberation times in the classroom. In acoustically treated rooms, staff reported increased participation in class, improved understanding and better behaviour from the hearing impaired children. Teachers commented on preferable teaching conditions and reduced stress. Questionnaire results clearly showed that the perceived quality of the listening environment improved with the reduction in reverberation times (Canning & James 2012). In another study in 2012 on the effects of reverberation on speech recognition, Wrobleski et al

suggest that younger children require better acoustic conditions to achieve the same sentence recognition scores as older children and adults (Wrobleski et al 2012).

Bracket (1992) proposed that the optimal distance from the listener for speech discrimination is within a metre and Ross (1992) explained that for every doubling of the distance from the speaker, the acoustic intensity of the speech signal is reduced by 6dB. While a very young infant may be likely to remain within the optimal listening distance due to being held by or in close proximity to a parent or carer most of the time, once an infant becomes more mobile he/she will immediately begin moving further away thereby increasing the listening distance.

A study by Moeller et al in 2007, comparing the vocalisations of early identified hearing impaired infants with their normally hearing peers, concluded that one reason for a delay in consonant and syllable structure development could be the negative effects associated with noise, reverberation and distance in everyday settings. Maronne et al (2008) agreed that hearing aid and cochlear implant users had difficulty understanding speech in background noise, reverberation and over long distances.

2.3 Radio Aid benefit in education

For hearing impaired children, the negative effects of background noise, reverberation and distance can be overcome by the use of a radio aid or FM system (NDCS 2008). The speech signal is transmitted directly to the child's hearing aids or cochlear implant at a greater SNR than that at the hearing aid or cochlear implant's own microphone, thereby 'shortening' the distance between the speaker and the microphone and reducing the effects of background noise and reverberation (Wolfe et al. 2013; Thibodeau 2010).

Many studies have shown the benefits of improved speech perception when using a radio aid or FM system with hearing aid users at school. Crandell and Smaldino (2000) found that the use of FM technology in noise can improve speech intelligibility by as much as 20-25dB. Mulla (2011) adds that, as well as improved speech perception, the effort of listening is reduced, which in turn leads to improved concentration and attention.

Similarly, FM systems have led to better speech recognition for cochlear implant users. In 2006, Schafer and Thibodeau concluded that children with CIs had better speech recognition in noise with the use of an FM system on one or both sides than with no FM system. Wolfe and Schafer (2009: p.6) concurred:

> Personal FM systems can provide significant improvements in speech recognition in adverse listening situations for persons using cochlear implants.

2.4 Radio Aid benefit with pre-school Hearing Aid users

In 1992, Brackett compared the language of 19 profoundly deaf cochlear implant users between the ages of 2 and 7, who had access to a personal FM system, with the findings from a study by Boothroyd (1984) of the phoneme characteristic scores of 120 profoundly deaf hearing aid users. Brackett suggested that the children in his study, using the FM systems, had better levels of phoneme recognition than those in the previous study who did not have access to an FM system. His findings, however, cannot be reliably used as evidence of FM benefit for pre-school children as the 2 groups were of very different sizes, details of individual demographics were not included and participants used different amplification technologies.

Moeller et al (1996) provided a more extensive and reliable set of data through their longitudinal study of FM use in non-academic settings. Eight children between 2 – 4 years old at the beginning of the study, with mild to severe hearing loss, were divided into 2 groups. The parents of one group were provided with a personal FM system for their child and were given extensive training in its use, maintenance and care. Parents were asked to complete daily and weekly diary sheets to show where and when they had used the FM system, whether they noticed any differences in their child's auditory performance with the FM system and whether they had any problems using the FM system. Over the duration of the study, the children's spontaneous utterances increased in complexity and grammatical accuracy, but there was no statistical difference between the group using FM and the group without FM. The small sample size in this case was a major limitation. The results on the situational profile for listening in background noise and at a distance showed no

improvements with FM use. Conflicting comments from the parents, however, suggested that they had in fact noticed improved listening in adverse conditions and, overall, both parents and children who had used the FM system indicated that they found it to be beneficial, particularly in specific situations.

Gabbard (2003: p.95) suggested that:

> When the child begins to spend more and more time several feet away from their parent, often not attending directly to the parent's language model, it is appropriate to consider adding the use of FM.

In her study, parents of 9 children aged between 15-30 months with mild to profound hearing loss were asked to complete the 'FM Listening Evaluation for Children' questionnaire (Gabbard 2003) after they had used a loan FM system with their child for a period of at least 3-6 months. Scores for perceived benefit in listening performance were identical for hearing aids only and with FM. However, in their questionnaire comments parents reported benefits of FM use including improved attention in noise, improved focus on the speaker and being able to hear while being mobile. Although this study advocates the benefits of FM use, there was again little detail on the study protocol or participant demographics and no detailed data on the actual use of the FM systems. The difference between the perceived lack of benefit according to the questionnaire and the benefit indicated by parents' comments is similar to that found by Moeller et al (1996). A limitation of the quantitative data is that parents merely indicated their child's performance by choosing a number, without the option to expand on their choice more fully, as they could with their actual comments.

In 2007, Statham and Cooper provided 5 hearing aid users with FM systems for use at home and in nursery. The children were aged between 12-47 months and had moderate to profound hearing loss. The FM systems were set up by the child's Teacher of the Deaf (ToD) who also trained the families in the use and maintenance of the system. Parents were asked to fill in a daily log for the first 4 weeks. Two of the five participants withdrew due to beginning cochlear implant assessment and responses from the 3 remaining families were mixed. ToDs spent a lot of time resolving technical difficulties with compatibility of

transmitters and audio shoes and negative comments from families included reluctance to wear the hearing aids due to the extra weight and length. Overall, however, comments suggested that the FM technology provided participants with improved access to speech and an enhanced quality of family life. Families were additionally able to identify specific situations where the FM system had been particularly beneficial. Phase 2 of the project, in 2008, expanded the study to include 12 more families. Parents were advised to use the FM system in specific situations where they thought their child was having difficulty hearing and listening. Systems were set up in clinic and fitted by the Educational Audiologist in the home. Although there were still some connection problems and parents' initial reaction to the equipment was mixed, comments were generally more positive this time, reporting clearer speech and better responses. Phase 3 of the project in 2009-10 comprised 10 families who were given integrated FM systems to use that had been donated by Phonak. Parents found the integrated system cosmetically more appealing and easier to use. Previous problems with compatibility and connection were eliminated and the loss of small parts was minimised. Parents' comments were extremely positive (Statham & Cooper 2013).

The most recent studies of radio aid/FM benefit are by Mulla (2011) and Webster (2015). Seven families participated in the study by Mulla in 2011. Children's ages ranged from 11-32 months at the start of the study which took place over 6 months. Hearing loss ranged from moderate to severe with one who had a profound loss. All participants were provided with Phonak hearing aids with integrated receivers and a Phonak Inspiro FM transmitter which they were able to keep at the end of the study. Parents were given training in using and checking the FM system and were given written instructions in the care and maintenance of the equipment. They were asked to fill in daily and weekly diary sheets and to attend monthly meetings. Evidence of FM use was also collected from data logging on the FM transmitter. At the beginning and end of the study parents filled in the FMLEC questionnaire (Gabbard 2003) and the LENA™ Developmental Snapshot (LDS) was used to assess trends in language development for participants during the study.

Results of the quantitative data show that the FM technology was used for an average of 71% of the total number of days in the study and for most of that time it was perceived to be of benefit. The FM system was used in different environmental situations and FMLEC scores showed greatest improvements in noise and at distance. LDS scores that were 'within normal levels' at the beginning of the study did not show any significant improvement over time. However, some of those who were 'at risk' at the beginning had moved to 'within normal levels' by the end of the study, suggesting that pre-school hearing aided children may achieve better language development with FM technology use.

Qualitative data comprised parents' comments in the diary sheets and interview at the end of the research. Parents valued the improved access to speech, particularly in noise, at a distance and when the child is facing away from the parent, for example in a pram or car. They noted improved listening behaviours, attention, concentration and understanding. Clarity of speech and more accurate intonation were described and parents reported their child to be calmer and more confident when using the FM system. The main challenges faced were with the child pulling the microphone lead, the back of the transmitter coming loose and parents forgetting to mute the system when it wasn't needed or appropriate (Mulla 2011).

Mulla also used the Language ENvironmental Analysis (LENA™) technology to record and compare language environments with and without FM use. He found that the largest portion of the children's day was spent in environments where speech was distant or in background noise. Also of interest is his finding that, in this study, the participants had language exposure that was near the 50th percentile or better when compared to their hearing peers (Mulla 2011).

Webster has based his research on the findings of Mulla (2011). He began in 2013 with 11 families, again using an integrated FM system with the participants, who were aged between 24-30 months at the start of the study. Most participants were hearing aid users but one used a cochlear implant. Families were encouraged to use the FM in situations where they thought it might be beneficial. Parents were asked to fill out a questionnaire after 4, 8 and

12 months which included commenting on the perceived impact of the FM system for improved communication and listening in the same situations used by Mulla (2011) and also reporting back on overall usefulness. Parents' comments have been mainly positive, noting better responses and clarity of speech, improved safety and enhanced communication, particularly in noise and at a distance. All parents and supporting ToDs are comfortable with the technology which is helping to educate parents about the impact of noise and distance on their child's auditory processing skills development.

Phase 2 has added a further 12 children to the study, aged between 14-22 months. This group are using a Phonak Roger transmitter and integrated receivers. Questionnaires have been filled out at 4, 9 and 15 months after the start of Phase 2. Even though these are younger children and there have been some problems with microphone leads getting tangled when a child is picked up, most of the parents' comments to date are again very positive. Parents report that their child joins in more, is more independent, is understood more easily by others and has a wider range of words. Parents also recognise that they are calmer and are allowing their child to become more independent, for example by walking ahead with a sibling (Webster 2015).

2.5 Conclusions of the literature review & Aims of this research

Most hearing impaired children in the UK are not offered the use of an FM system until they start school, mainly due to a lack of funding. A recent audit by the Nottingham Auditory Implant Programme (NAIP, 2016) showed that children who have been fitted with cochlear implants between the ages of one and two are not being offered a radio aid until they enter full time education (Boddy 2016).

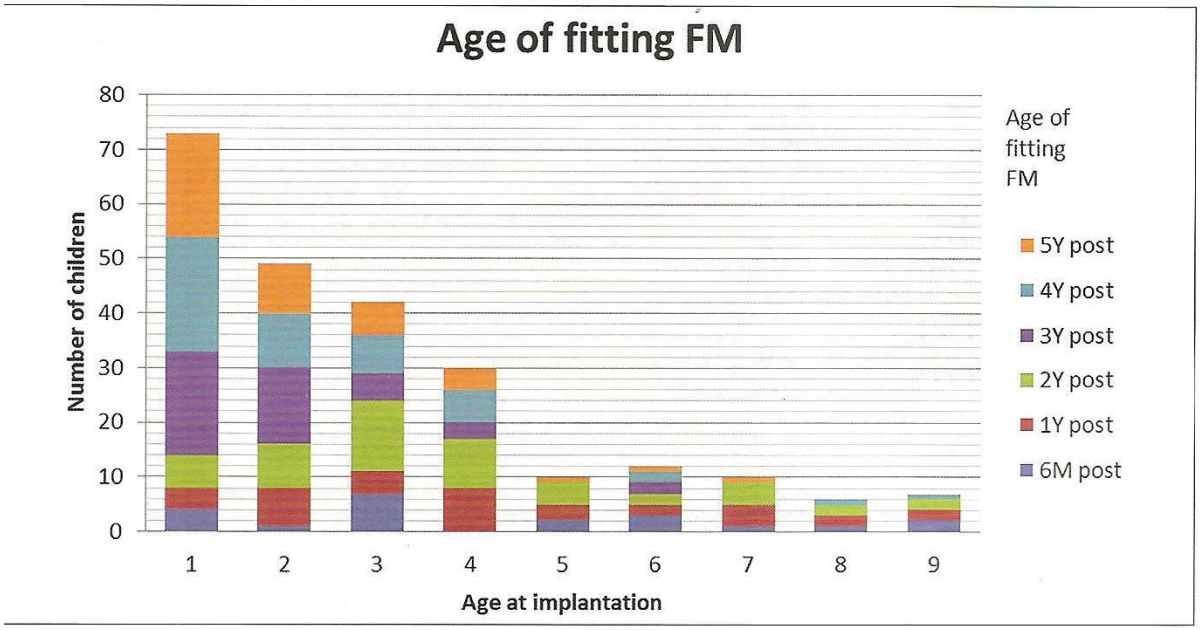


Figure 2.1. Age of fitting FM to CI users implanted between 1-2 years (Source: Boddy, C. BATOD magazine, March 2016).

Adverse listening conditions are not confined to the classroom. Early language development takes place not only in the home, but also in a variety of different situations, for example in the car, at the park, at the shops or in a restaurant, many of which are subject to background noise and high levels of reverberation.

Although previous studies have found there are many benefits of using FM technology with pre-school hearing aid users, there has been no significant research into whether radio aid use would equally benefit cochlear implanted pre-schoolers.

The introduction of the Cochlear™ Wireless Mini Mic in 2015 provides a potentially viable alternative to a radio aid system for some cochlear implanted children. This study will use an in depth case study approach, using both quantitative and qualitative data, to investigate the impact of using the Mini Mic on the language of two pre-school cochlear implant users.

3. Methodology

In selecting the appropriate methodology for a piece of research it is important to examine what the researcher wishes to know and why. Ely (2003) suggested that a researcher may choose to use a mixture of quantitative and qualitative methods of data collection, but that their choices must be explained to the reader, along with a comparative discussion of the underpinning principles of each technique.

The purpose of this research study is to investigate whether the use of the Cochlear™ Mini Mic has an impact on the language of 2 profoundly deaf pre-school children. The research design is of 2 case studies which analyse in depth the use of the Mini Mic, whether parents and nursery staff perceive it to be beneficial and whether any changes in child vocalisations are noted. The methodology used is a case study approach, using both qualitative and quantitative measures.

A case study provides a comprehensive analysis of a single or small number of units, usually real people in real situations. It allows for an in-depth study within a limited time scale (Bell 2014) and takes into account contextual conditions relevant to the subject (Yin 2013). According to Maykut and Morehouse (1994), the natural setting is where the researcher is more likely to uncover relevant findings. The advantages of a case study are that it enables the researcher to establish cause and effect and to collect data from a variety of sources to aid triangulation (Baxter & Jack 2008). Findings have the potential to influence future practice and can add strength to what is already known through prior research. The disadvantage of a case study is that it is difficult to establish reliability or generality if only a small number of cases are being examined.

Stake (1995) and Yin (2013) propose that a case study approach is based on a constructivist paradigm, which claims that truth is subjective and dependent on a person's perspective. It is therefore important that the researcher is aware of their own bias which could affect the objectivity of the research and takes care not to disregard information that may not fit in with their expectations. As Anderson (1998) reminded us, few researchers are truly unbiased and research tends to reflect the values and beliefs of the researcher. In this study, the

researcher acknowledges the hypothesis that the Cochlear™ Mini Mic may provide a profoundly deaf pre-school child with some of the benefits that have been shown by FM use with hearing aided pre-schoolers.

Triangulation is the use of both quantitative and qualitative data to establish validity (Yin 2013). It ensures the results are not merely an artefact of the method and leads to greater confidence in the reliability of the data. Tellis (1997) stated that a case study makes use of triangulation as it uses multiple sources of data, which helps to confirm the validity of the process.

3.1 Ethics: Recruitment and Participants

Recent research studies suggest that having access to an FM radio aid system has a positive impact on the language and communication of pre-school deaf children (Webster, 2015; Mulla 2011; Statham & Cooper 2009). Most studies to date have been with pre-school hearing aid users, but little is known about how remote microphone use could benefit a profoundly deaf pre-schooler fitted with cochlear implants. With the timely introduction of the Cochlear™ Wireless Mini Microphone (Mini Mic) in 2015, the researcher, as part of normal working practice, investigated the impact of its use on the language of cochlear implanted pre-school children. The participation inclusion criteria for the study were as follows:

- Child has full term, uneventful birth history and meets age appropriate motor and cognitive developmental milestones
- Child is of pre-school age (between 2 – 4 years old)
- Child is diagnosed as profoundly deaf with bilateral cochlear implants
- Cochlear implants comprise Cochlear™ Nucleus 6 sound processors (CP910)
- Child has established good use of cochlear implants
- Child attends audiology appointments at Birmingham Cochlear Implant Centre

Pre-school children with developmental delays were excluded from the study in order to limit any potential factors that might influence use of the Mini Mic, both at home and in the nursery, or have an effect on outcome measures. As this study was specifically with cochlear implanted children, those with mild to

severe hearing losses were also excluded. It was important that participants used the N6 speech processors as they are the users being offered the Mini Mic.

Two pre-school children were identified as meeting criteria and families were approached to ascertain interest. Both families were keen to take part and meetings took place with them to explain the study and answer any queries. Information sheets outlining the research were provided and consent was obtained.

Following data collection, consent was sought from parents to use the data relating to their child's use of the Mini Mic to form the main body of this research paper. Ethics approval for this step was sought from the University of Hertfordshire. Copies of these documents are included in Appendix A.

Table 3.1. Participant details

	Chronological age at start of study (months)	Chronological age at end of study (months)	Age of identification (months)	Age of implantation (months)
P1	26	29	NHSP	16
P2	41	44	NHSP	L=10 R=16

3.2 Equipment

Cochlear N6 users are entitled to the use of the Cochlear™ Mini Mic, phone clip or television streamer. Participants chose the Mini Mic as it is the most useful for a pre-school aged child and it was to be used in the study.

The Cochlear™ Mini Mic makes use of 2.4GHz wireless technology to send the speaker's voice directly to the child's processors, enabling an improved signal to noise ratio (SNR). Mini Mic and processors are paired initially by pressing a pairing button on the Mic then turning on the processor within 20 seconds and, once paired, the Mini Mic will stay paired. To use the Mini Mic, the child's processors are switched to streaming mode and the Mic turned on. Cochlear™ state that the Mini Mic has a talk time of 8.5 hours and a range of 7 metres (Cochlear™ 2015).

Figure 3.1 The Cochlear Mini Mic (Source: Cochlear, 2016).

During the distribution day, representatives from Cochlear™ explained the use of the Mini Mic to families and cochlear implants were reprogrammed for use with the Mic.

3.3 Procedure

Prior to the start of the study, the researcher met with families again to reinforce how to set up and use the Mini Mic effectively. Parents were provided with written instructions regarding the use and maintenance of the Mini Mic and were given the chance to ask questions. The Listening Evaluation questionnaire and the LENA™ Developmental Snapshot (LDS) were completed, copies of which can be found in Appendix B.

Families were then given a folder containing approximately 60 daily diary sheets and 9 weekly diary sheets, plus some spares. These were explained in detail to parents, who were given the option of either filling in the diary sheets electronically or in paper form. Both families preferred to use the paper diaries. It was agreed that parents would hand over completed diary sheets at regular intervals during the following two months. After the holidays, consent was also obtained from nursery managers to use the Mini Mic in the nursery and Key Workers were instructed on how to use the Mic. Examples of the daily and weekly diary sheets and the adapted weekly diary sheets for nursery are in Appendix B.

After the initial period of Mini Mic use, meetings took place with parents and nurseries to explain the LENA™ system in detail. Information sheets and Quick Guides on LENA™ use were distributed and there was the opportunity to ask questions or air concerns.

At the end of the study, the Listening Evaluation questionnaire and the LDS were revisited with parents of P1 and interviews were conducted with parents of P1, nursery staff and a specialist Teaching Assistant who works with P1.

Data on the use of the Mini Mic was collected using both quantitative and qualitative methods. LENA™ recordings, LDS and the Listening Evaluation questionnaire provided quantitative data, while the diary sheets provided useful quantitative data but also qualitative data in the form of parents' comments. The final interview with parents and teaching staff supplemented the qualitative data.

3.4 Quantitative data collection

Quantitative data is numerical data which can be replicated and subjected to statistical description and analysis (Bell 2014).

3.4.1 Daily Diary

Willig (2001) suggested that diary keeping is not a widely used method of data collection, due to the commitment it requires from parents. Bell (2014) advises that a reluctant subject will rarely provide usable data. The researcher was therefore mindful that the daily diary sheets in particular needed to be easy to use and take as little time as possible to complete.

Data regarding the number of hours of Mic use in different situations was recorded on daily diary sheets and parents indicated whether they felt it to be useful with a simple 'Yes' (Y) or 'No' (N). Environments listed were: 'In a quiet room, In a noisy room, Meal times, Outdoors, In the car, Shopping, Other'. Parents were advised, prior to the start of the study, to try the Mini Mic in as many different situations as possible, but not to feel they had to continue to use it in situations where they felt it was of little benefit.

3.4.2 Listening Evaluation Questionnaire

When using a questionnaire, it must be simple, clear and as specific as possible, only including questions essential to the study. Closed questions should be used, with a choice of response (Bell 2014).

A 'Listening Evaluation' questionnaire was used prior to the start of the study and again, with parents of P1, after the Mini Mic had been used for 2 months.

The researcher used the FM Listening Evaluation for Children (FMLEC) questionnaire devised by DeConde-Johnson (Gabbard 2003) as the basis for the questionnaire, also using aspects from the Parents' Evaluation of Aural/Oral Performance of Children (PEACH) (Ching & Hill 2005) to adapt it to be more relevant for this study.

Parents were asked to indicate, with a score of 3 ('Always'), 2 ('Often'), 1 ('Sometimes') or 0 ('Never'), how they perceived their child's receptive and expressive language and attention. A 4 point Likert scale was used to prevent parents opting for the middle answer, known as 'forced choice' (Bell 2014).

The questionnaire consisted of six questions:

1. Does your child respond to his name?
2. Does your child attend to the person speaking/reading/singing?
3. Does your child appropriately respond to simple (spoken) questions or commands?
4. Does your child vocalise to join in a conversation?
5. Does your child imitate sounds/words?
6. Does your child respond to environmental sounds?

For each question, parents scored their child for each of the following situations:

a) In a quiet room, within 2m,
b) In a quiet room, at 7m,
c) In a noisy room, within 2m,
d) In a noisy room, at 7m,
e) From another room,
f) Outdoors,
g) In the car.

3.4.3 LENA™ Developmental Snapshot (LDS)

The LDS is a parent survey consisting of 52 questions that assesses a child's receptive and expressive language skills. It was developed at the LENA™ Foundation in the USA by a team of researchers, speech pathologists, linguists and statisticians and can be used with children from 2 to 36+ months of age to

give an estimate of a child's developmental age as a function of chronological age (Gilkerson & Richards 2008).

The LDS indicates whether the child's development is within normal range, advanced or at risk and, for this study, was completed by parents of P1 and P2 prior to the start of the research and at the end of the study by parents of P1. The resultant graph can show development over time and in this case it was used to show progress between the child's language levels before and after using the Mini Mic.

3.4.4 Language ENvironmental Analysis (LENA™)

The success of the use of the LENA™ technology by Mulla (2011) in his research into FM use with pre-schoolers prompted the researcher to purchase a contract to use the system for this study.

In 1992, Hart and Risley's research investigated the relationship between adult communication and interaction with a child's language development. Their findings formed the basis of the development of an automated audio recording system (LENA™) which can be used to monitor the language environment of the child (Oller et al 2010). The system was developed at the University of Memphis by a team of specialists led by Professor Oller who has been involved in researching infant vocal development for the past 40 years (Oller & Eilers 1975). Recent research using the LENA™ system has investigated the effects of the quantity and quality of adult language on a child's language (Warren 2015; Diehm et al 2013) and the effect of the language environment on the language and behaviour of children (Mulla 2011; Vohr et al 2011).

Figure 3.2. LENA™ data recorder (Source: LENA™ Research Foundation, 2015).

The lightweight recorder (Figure 3.2.) fits into a specially designed T-shirt or vest and can record up to 16 hours of continuous audio data, the system developers recommending a minimum of 12 hours to give a more accurate analysis (Xu et al 2008). The LENA™ Pro software then analyses and segments the audio data, providing 4 primary reports and a composite report:

Adult Word Count (AWC) – the number of adult words spoken to or near the child,

Conversational Turns (CT) – the number of adult-child conversational interactions,

Child Vocalisations (CV) – the number of key child vocalisations,

Audio Environment – includes Meaningful speech (close and clear vocalisations), Distant and Overlapping speech, TV & ES (electronic sounds), Noise, Silence & background noise.

Each report can be viewed in monthly, daily, hourly, and 5 minute time frames.

3.4.4.1 Comparison with hearing peers

The LENA™ Natural Language Study by Gilkerson and Richards (2008) generated a database of percentiles for AWC, CV and CT for normally hearing children without language or developmental delay between the ages of 2 and 48 months. The LENA™ software v3.4.0. uses this database as a baseline to produce percentiles for users of the LENA™ system.

3.5 Quantitative data analysis

3.5.1 Daily Diary

Daily diary sheets were used to determine the number of days and hours the Mini Mic was used by P1 and P2. The percentage of days' use compared to the total number of days' participation in the study was then calculated and the number of hours where the Mini Mic was noted to be of benefit was compared to those it was deemed not to be beneficial.

The family of P2 only used the Mini Mic for one week and did not provide details of how long it was used in the different environments. Therefore only data provided in the diary sheets of P1 was analysed further. This data was

input into Microsoft Excel 2007 and the duration of time the Mini Mic was used in each situation was calculated.

3.5.2 Listening Evaluation Questionnaire

Questionnaires from the family of P1 were analysed and total scores given for each question and also for each environmental situation. Scores were compared between the initial (without Mini Mic) and final (with Mini Mic) questionnaires.

3.5.3 LENA™ Developmental Snapshot (LDS)

The LDS was completed by parents on a hard copy printout and answers and other relevant information were then input by the researcher into the LDS software (LENA™ software v3.4.0.). Parents of P1 completed the LDS before and after Mic use. The LDS was only completed by the family of P2 prior to the start of the research.

Developmental age and LDS standard scores were automatically calculated by the software and charted on a graph which categorised the child's development as 'advanced', 'within normal levels' or 'at risk'.

3.5.4 Language ENvironmental Analysis (LENA™)

After the initial 2 months of diary keeping, the family of P1 agreed to use the LENA™ data recorder over a further 8 days, 4 at home and 4 in nursery. On half of the days they used the Mini Mic and the other half were without the Mic. Days were chosen on which P1 would be doing similar activities in order to produce a better comparison.

Even though P2 had stopped using the Mini Mic, the family agreed to use the LENA™ on 2 days where P2 was primarily in nursery, one using the Mic and one without.

On the days the LENA™ was used, parents and nurseries were asked to fill in a 'LENA™ Diary Sheet' to show the activities and times for each day. A copy of the LENA™ Diary Sheet can be found in Appendix B.

Following data extraction and initial automatic analysis by the LENA™ software, the LENA™ days were further analysed by the researcher. Using the LENA™

diary sheets, a list of activities and corresponding time frames for each day was compiled (see Tables 3.2., 3.3. & 3.4.).

Table 3.2. P1 home LENA™ use

29.8.15 mins	MM activity	31.8.15 mins	No MM activity	4.9.15 mins	MM activity	2.9.15 mins	No MM activity
45	Quiet play (nanny's)	95 (60) *	Quiet play (home)	60 *	Quiet play (home)	20	Quiet play (home)
10	Car	15 *	Car	40	Quiet play	20	Car
115	Quiet play	50 *	Shops	15 *	Car	125	Quiet play
		25	Car	115(60) *	Little Ears (pre-sc group)		
		80	Quiet play (home)			15	Car
30	Car			10	Car	25	Shops
25	Party (inside)	15	Car	30	Shops	10	Car
245	Party (outside)	85 (60) *	Party (inside)	10	Car	30	Shops
				130	Indoor Play (noise)	5	Car
						15	Shops
		70	Quiet play (home)	60	Quiet play	20	Car
		30	Film	5	Car	85	TV
				50 *	Shops	55	Quiet play
				10	Car	25	Car
				120	Quiet play	70	Quiet play

Table 3.3. **P1 nursery LENA™ use**

5.10.15 mins	MM activity	12.10.15 mins	No MM activity	8.10.15 mins	MM activity	15.10.15 mins	No MM activity
45 *	Directed	110	Free play	75	Free play	45	Breakfast
20	Free play					15	Free play
5	Singing	5	Singing	10	Singing	45 *	Directed
						10 *	Story
						25	Free play
30	Snack	35	Snack	30	Snack	30	Snack
55	Free play	40	Outside	10 *	Story	30	Free play
25	Directed	10	Directed	35	Free play	35	Outside
				5	Singing	10	Story
30 *	Lunch	30 *	Lunch	30	Lunch	30	Lunch
40 *	Free play	25	Free play	30	Free play	40 *	Free play
		20	Directed				
		30 *	Outside			35	Outside
						30	Free play
		25	Snack	20	Snack	15	Snack
		60	Free play	75	Free play	20	Free play
				10	Story		
				30 *	Outside		

Table 3.4. **P2 LENA™ use**

8.9.15 mins	MM	15.9.15 mins	No MM
10	Car	10	Car
90 *	Indoor free play	90 *	Indoor free play
10	Directed activity (indoor) singing	30	Outdoor play
30	Indoor free play	50	Directed activity (indoor)
55	Directed activity (indoor)	10	Indoor free play
30 *	Outdoor play	30 *	Outdoor play
15 *	Story	10	Story
30 *	Lunch	30 *	Lunch
10	Directed activity (indoor)	30	Indoor free play
30	Indoor free play	60 *	Directed activity (indoor)
60 *	Directed activity (indoor)	35	Outdoor play (15mins directed)
30	Outdoor play	15 *	Story
5	Singing		
10	Car	10	Car
60	Play at home	60	Play at home

Activities that were the same or similar and of a similar length (*) were then chosen for direct comparison, on days with and without the Mic.

Percentiles for P1 and P2 were compared to those for hearing children on the days the LENA™ system was used.

3.6 Qualitative data collection

The quantitative methods described above provide information about how the Mini Mic was used by the 2 families, but it is important also to discover parents' views and experiences with using the Mic.

Qualitative data aims to provide an in-depth account of a subject's opinions and a detailed account of their experiences (Bell 2014).

3.6.1 Diary sheets

On the daily diary sheets, as well as recording the length of time that the Mic was used, parents could choose to add brief comments. On the weekly diary sheets they were able to record more detailed comments in answer to the following open-ended questions:

1. Have you noticed any difference in your child's communication when using the Mini Mic?
2. Have you noticed any changes in your child's behaviour when using the Mini Mic?
3. Were there any problems with using the Mini Mic?
4. Where do you feel the Mini Mic was most useful?
5. Were there any situations where you felt the Mini Mic was of little use?
6. Are there any other comments you would like to make?

The questions were based on those used by Mulla (2011) for his FM study, who in turn had used the weekly observation inventory devised by Moeller et al (1996) as his basis. This approach allowed parents to identify what they perceived to be meaningful information, rather than the researcher presenting them with pre-defined closed questions (Silverman 2005; Willig 2001). Weekly observations also allow data to be recorded in real time, avoiding problems associated with retrospective reporting, such as forgetting of details (Willig 2001).

3.6.2 Interview

An interview is one of the most important sources of case study data (Tellis 1997) and can be structured or semi-structured: using a loose structure but allowing for the respondent to talk about what they perceive to be important (Bell 2014).

The advantage of an interview is that it gives the researcher the opportunity to probe further and supplement existing data. The disadvantages are that it can be time consuming and stressful for the interviewee and is highly subjective (Bell 2014). There may be geographical constrictions and it is harder to analyse than a tick box questionnaire. It is important that the interviewer puts the respondent at ease by being polite and friendly, making good eye contact, appearing unbiased and non-judgemental and actively listening to the respondent. The interview should be conducted in a quiet environment where there are unlikely to be interruptions. Bell (2014) points out that there is always a danger of the interviewer's bias influencing responses, for example by asking leading questions to support preconceived ideas, and this must be acknowledged by the researcher.

Following analysis of the data collected for this study, a semi-structured interview was used with parents of P1 and with staff working with P1. Maykut and Morehouse (1994) proposed that the researcher does not predetermine what is important, rather uses areas of significance from data already collected to inform ongoing research. In this case, comments from the daily and weekly diary sheets were used as a basis for the interview structure, allowing parents and staff to recall events and offer opinions in more detail. Careful consideration was given to the order of questions (Bell 2014) and quantitative data was also shared with interviewees. A copy of the interview schedule can be found in Appendix B.

Willig (2001) and Smith (2003) suggested that developing a rapport is a fundamental concept of semi-structured interviewing. As the families and nursery in the study were in contact with the researcher over a 3 month period, parents and staff were relaxed and open during the interview process, which took place in the home for parents and in the nursery setting for the Specialist Teaching Assistant and nursery Key Worker.

3.7 Qualitative data analysis

Comments from diary sheets and interviews were thematically analysed and 5 main themes were identified:

1. Improved access to speech
2. Improved communication
3. Well-being and safety
4. Practicalities and technology
5. Situations with limited or no benefit

Each theme will be discussed in detail in the Results section.

4. Results

4.1 Quantitative analysis

4.1.1 Overall use

Daily diary sheets were used to establish the total length of time each participant had used the Mini Mic and from that the total hours perceived to be of benefit or little benefit was also calculated (Table 4.1.).

The family of P1 remained in the study for 8 weeks and used the Mini Mic for 75% of that time. They gave a reason for all the days that the Mini Mic was not used. On 7 occasions it was because parents had forgotten to charge it, on 5 occasions it was because P1 was not consistently wearing his processors (for example when playing at the beach on holiday) and on the remaining 2 days the family were flying and they weren't sure whether it would be appropriate to use the Mic on the plane.

The family of P2 left the study after 5 weeks and only used the Mini Mic for one week, reporting that they found it to be of little use.

	P1	P2
Days in study	56	35
Days mic used	42	7
% mic use	75	20
Total use (hours)	167;45	unknown
Average daily use (hours)	4;00	unknown
Benefit: hours (%)	119;30 (71%)	n/a
Little or no benefit: hours (%)	48;15 (29%)	n/a

Table 4.1. Overall Mini Mic use

The families had been asked to use the Mini Mic in as many different situations as possible. The following table and graph show the total number of days and hours that the Mic was used in different situations with P1.

Table 4.2. **P1 situational use**

P1 Situation	Days used	% of total days	Hours of use
quiet	21	37.5	63;30
noise	16	28.5	46;00
meal	10	18	11;30
outdoors	14	25	22;00
car	15	27	11;15
shops	10	18	08;30
other	2	36	05;00

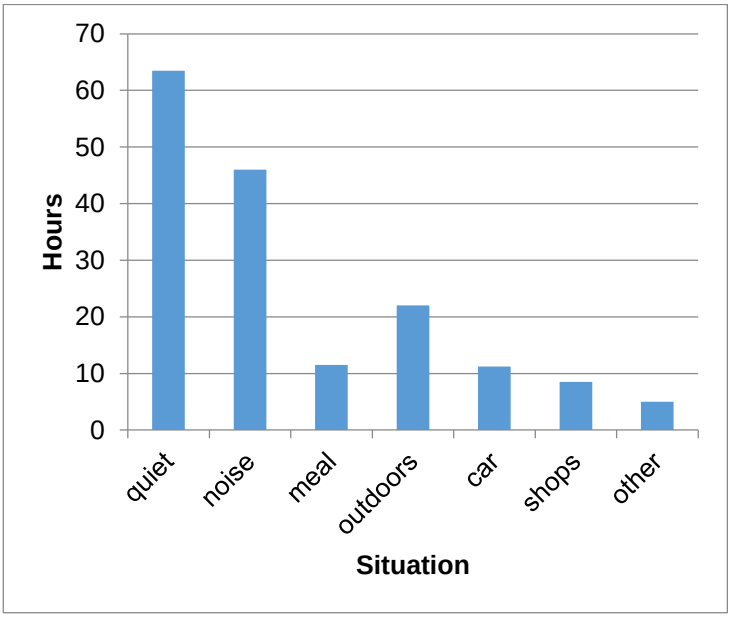


Figure 4.1. **P1 situational use**

Over the 42 days of Mini Mic use, the family of P1 used the Mini Mic primarily indoors, both in quiet and noisy environments. It was also used outdoors for a total of 22 hours, on car journeys for over 11 hours and while shopping for 8 ½

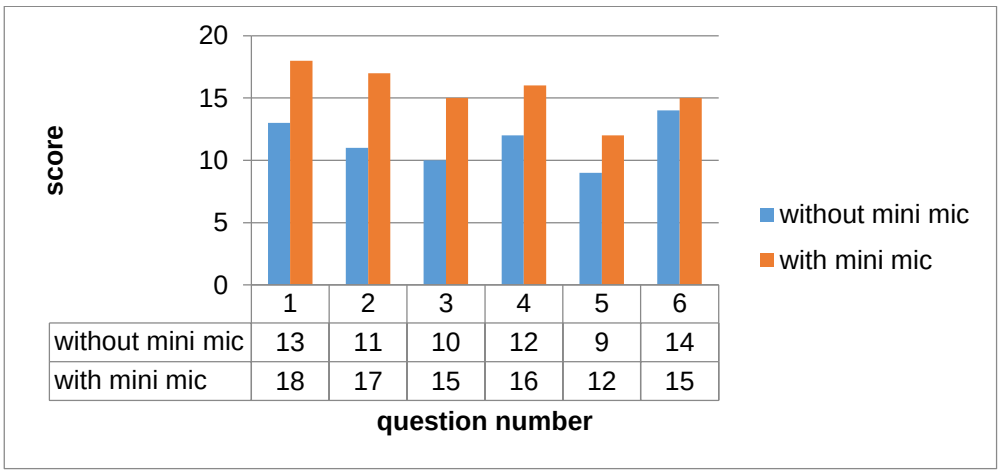
hours. The ‘other’ situations were at an outdoor market and swimming in the pool while on holiday.

4.1.2 Listening Evaluation Questionnaire

The questionnaires filled out with the family of P1 were analysed to compare family’s perceptions of their child’s language and communication with and without the Mini Mic. As stated previously, the following 6 questions were asked:

1. Does your child respond to his name?
2. Does your child attend to the person speaking/reading/singing?
3. Does your child appropriately respond to simple (spoken) questions or commands?
4. Does your child vocalise to join in a conversation?
5. Does your child imitate sounds/words?
6. Does your child respond to environmental sounds?

Scores were totalled for each question category using the formula ‘Never’ = 0, ‘Sometimes’ = 1, ‘Often’ = 2, ‘Always’ = 3. Scores for P1 improved for each of the question categories when using the Mini Mic. No comparison was possible for P2 as the family left the study before the end and did not complete the second questionnaire.



	1	2	3	4	5	6
without mini mic	13	11	10	12	9	14
with mini mic	18	17	15	16	12	15

Figure 4.2. Question category scores for P1

Percentage improvements for each question are shown in Table 4.3.

Table 4.3. **P1 % improvement**

Question	% improvement
1	28
2	35
3	33
4	25
5	25
6	7
Overall average % improvement	**26**

The greatest improvement for P1 was in response to questions and commands (question 3) and attention (question 2). There was little change in response to environmental sounds (question 6).

Scores were also totalled for each environmental situation (Figure 4.3.).

1 = in quiet at 2m

2 = in quiet at 7m

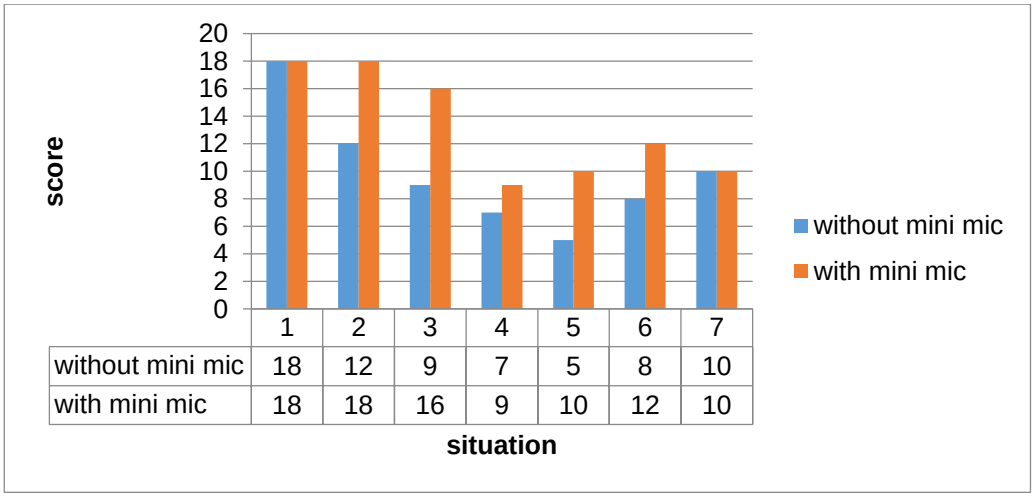
3 = in noise at 2m

4 = in noise at 7m

5 = from another room

6 = outdoors

7 = in the car



	1	2	3	4	5	6	7
without mini mic	18	12	9	7	5	8	10
with mini mic	18	18	16	9	10	12	10

Figure 4.3. **Situation scores for P1**

Percentage improvements for each situation are shown in Table 4.4.

Table 4.4. **P1 % situational improvement**

Situation	% improvement
1 in quiet at 2m	0
2 in quiet at 7m	33
3 in noise at 2m	44
4 in noise at 7m	22
5 from another room	50
6 outdoors	33
7 in the car	0
Overall average % improvement	**26**

The parents of P1 gave the same score for 'in the car' (situation 7) both with and without the Mic. All other situations were given higher scores with the Mini Mic (situation 1 – in quiet at 2m - had already scored 18/18 without the Mic and remained the same). The greatest improvement was for 'from another room' (situation 5).

4.1.3 LDS

LENA™ Developmental Snapshot results for P1 and P2 are shown in the screenshots below.

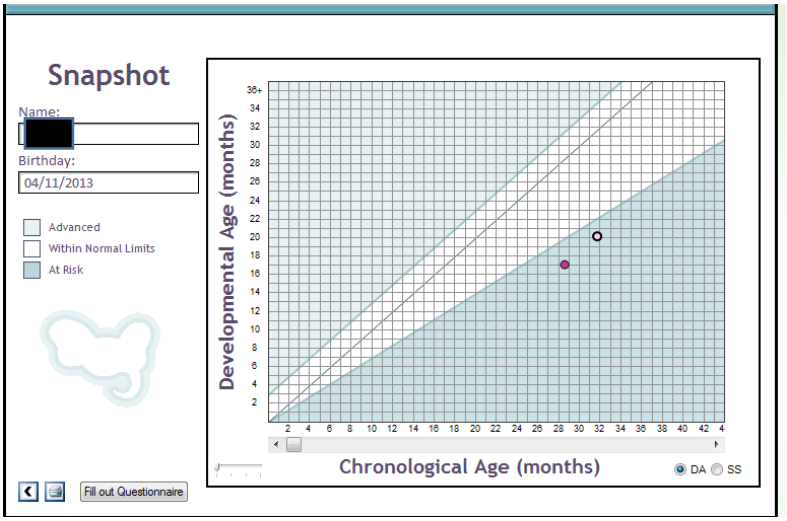


Figure 4.4. **P1 LDS standardised scores**

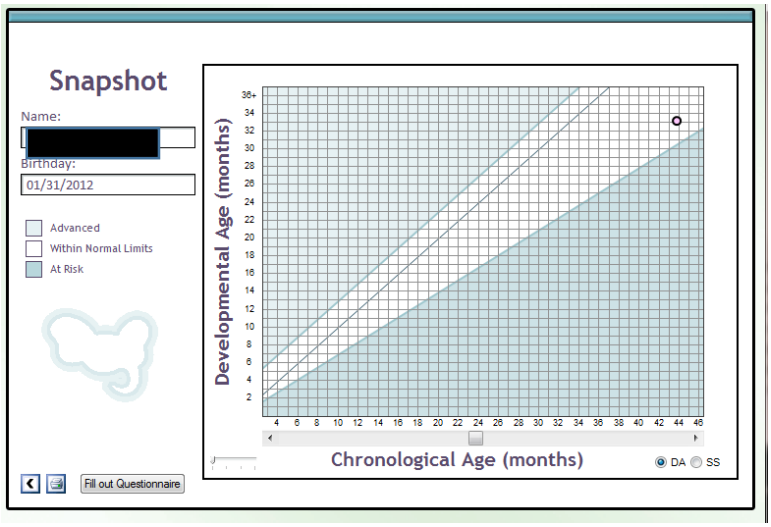


Figure 4.5. **P2 LDS standardised score**

The following table shows a comparison for P1 between LDS results before and after Mini Mic use.

Table 4.5. **LDS results, P1**

P1	**Before MM**	**After MM**
Chronological age	28 months, 21 days	31 months, 24 days
LDS Developmental age	17 months	20 months
Standard score	<65 (1st %)	66.63 (1st %)
Category	At risk	At risk

After 3 months of Mini Mic use, P1's developmental age had also increased by 3 months, although his standard score had improved slightly. As P2 left the study early, only the standardised score calculated at the beginning of the research is shown, which is within the normal range.

4.2 LENA™ analysis

4.2.1 Comparison of LENA™ word count

Using the 5 minute composite reports for the days when the LENA™ was used, the total number of Adult Words (AWC), Child Vocalisations (CV) and Conversational Turns (CT) were calculated for each of the specific situations previously identified in 3.5.4. In this way, an activity when the Mini Mic was

used could be compared with the same or similar activity when the Mic was not used (Tables 4.6., 4.7., 4.8.).

Table 4.6. **P1 home LENA™ use**

Situation	minutes	**AWC + MM**	AWC no MM	**CV + MM**	CV no MM	**CT + MM**	CT no MM
Quiet play (home)	60	**514**	478	**458**	212	**40**	28
Indoor + noise	60	**868**	405	**167**	146	**26**	14
Car	15	**138**	89	**14**	4	**1**	0
Shops	50	**2094**	68	**193**	269	**54**	7

Table 4.7. **P1 nursery LENA™ use**

Situation	minutes	**AWC + MM**	AWC no MM	**CV + MM**	CV no MM	**CT + MM**	CT no MM
Indoor free play	40	**186**	101	**167**	75	**8**	4
Directed activity (indoor)	45	**2049**	1497	**128**	96	**61**	30
Story	10	**607**	768	**32**	14	**14**	2
Outdoor play	30	**336**	344	**46**	13	**9**	1
Lunch	30	**822**	335	**49**	55	**8**	4

Table 4.8. **P2 LENA™ use**

Situation	minutes	**AWC + MM**	AWC no MM	**CV + MM**	CV no MM	**CT + MM**	CT no MM
Indoor free play	90	**1177**	544	**40**	38	**8**	0
Directed activity (indoor)	60	**4840**	1449	**144**	62	**99**	30
Story	15	**1588**	1660	**18**	36	**13**	24
Outdoor play	30	**148**	101	**44**	8	**3**	2
Lunch	30	**881**	226	**43**	27	**10**	7
Car	10	**292**	144	**84**	49	**25**	13
Play at home	60	**886**	3856	**1333**	343	**76**	73

P1's home results show increased AWC, CV and CT when using the Mini Mic for all activities with the exception of Shops where, despite many more Adult Words when using the Mic, Child Vocalisations were slightly higher without it. Conversely, Conversational Turns were greater with the Mic. In P1's nursery results, CT is greater for all activities and CV for all except lunch, which is slightly more without the Mic.

For P2, AWC, CV and CT are increased with Mini Mic use for all activities except Story, where all are greater without the Mic.

4.2.2 Comparison of percentiles with hearing peers

The raw scores for AWC, CV and CT were converted to percentiles using the LENA™ software, to enable comparison with hearing peers for the days LENA™ was used. Percentile estimates are based on 3,384 12-hour recordings from 378 families on the LENA™ normative database (LENA™ 2012). Nursery data for P1 has been excluded as the data for both with and without Mic was inconclusive.

Table 4.9. P1 % comparison with hearing peers

Date	MM?	AWC (%)	CV (%)	CT (%)
29.8.15	MM	52	85	56
31.8.15		1	36	6
2.9.15		53	51	34
4.9.15	MM	46	80	38

Table 4.10. P2 % comparison with hearing peers

Date	MM?	AWC (%)	CV (%)	CT (%)
8.10.15	MM	93	82	69
15.10.15		94	10	31

For P1, CV and CT percentiles were higher when the Mini Mic was used at home, CV being in the 80th percentile and above when using the Mic. On 3 of the 4 days, AWC is in line with hearing peers, both with and without the Mic, but significantly lower without the Mic on one of the days.

P2 percentiles for AWC are very high in comparison to hearing peers, both with and without the Mic. CV and CT percentiles are above average when the Mic was used and below average when it was not.

4.3 Qualitative analysis

Both participants had established good use of their cochlear implants before the research began and families had set expectations about the language and communication of their child using the implants. Comments in the daily and weekly diary sheets therefore addressed perceived benefits or disadvantages over and above those of the cochlear implants themselves. All quotes referenced here are verbatim.

Unfortunately the family of P2 decided after the first week that the Mini Mic wasn't beneficial to their child so they stopped using it. The diary comments from this family were negative:

> *'No difference using the Mini Mic.'*
>
> *'No particular situation have we noticed the Mini Mic to be useful.'*
>
> *'Unfortunately it was of little use.'*

Parents reported that they gave the Mini Mic to nursery for a second opinion, but they also noticed no difference using it. When interviewed prior to P2 using the LENA™ data recorder, nursery staff told the researcher that they hadn't been given the Mini Mic to use in nursery previously. The parents of P2 felt that maybe their son was too young to benefit from using the Mini Mic:

> *'We feel he is possibly too young to be grasping the Mini Mic at this stage?'*

Parents of P1, on the other hand, completed the daily and weekly diary sheets for 8 weeks and were interviewed at the end of the research to provide a more narrative account. P1's Key Worker in the nursery and a Specialist Teaching Assistant who works with P1 on a weekly basis were also interviewed about using the Mini Mic in nursery. Responses from diary sheets and interview were thematically analysed and 5 main themes were identified:

- Improved access to speech
- Improved communication
- Well-being and safety
- Practicalities and technology
- Situations with limited or no benefit

4.3.1 Improved access to speech

We know that noise, distance and reverberation are factors in a person's ability to hear and understand a speech signal. For children, a better signal to noise ratio (SNR) is important (Cole & Flexer 2011) and for hearing impaired children an even better SNR is needed. The optimal distance is between 1 – 2 metres but this can be less in noise (Madell 1992).

Parents of P1 commented that using the Mini Mic, and therefore allowing an improved signal to noise ratio, was particularly beneficial in noise, both inside and outdoors:

> '*At a social event J could hear me over lots of noise.'*
>
> *'J is responding well over noise of toys and television in background.'*
>
> *'At nanny's again, with TV on and a busy house. Still getting good responses.'*
>
> *'J's hearing and responses were much better.' [playing outside]*
>
> *'Lunch at Nanna's with other children. Good response.'*
>
> *'At Nanny's house, playing outside with young cousins and in and out of wendy house, still getting good responses from J.'*

Similarly, parents found the Mini Mic useful when their child was further away from them, for example in the park or garden, or walking to the shops:

> *'Response at distance was much better.'*
>
> *'Did hear when walking a few steps ahead.'*
>
> *'Works well at a distance.'*

'At children's centre, works at a distance in a noisy room.'

P1 was also able to use the Mini Mic when swimming in the pool on holiday as parents had bought 'aquabags' for his cochlear implant, allowing him improved access to speech in an environment where previously he might not have had any access to speech at all.

'J used aquabags to wear processors in pool. With the Mic he was able to hear us when usually he would have heard nothing.'

Even in a quiet environment at home, parents saw some benefit:

'I didn't have to repeat myself or call J more than once.'

4.3.2 Improved communication

We have seen that parents' comments suggest improved access to speech when using the Mini Mic but it is important to clarify whether the child is just 'hearing' or can 'listen' and understand what is said. Cole and Flexer (2011) call this 'attending to acoustic events with intentionality.'

In a quiet environment parents of P1 noticed improved attention, responses and understanding:

'Good responses when I was in another room.'

'If I ask him to go and get his shoes and his socks on or something like that he's definitely I think understanding better, listening.'

'Yeah it's better [behaviour]. He definitely pays more attention when I'm talking.'

'Big difference, J responded much better.'

They suggest that he was copying more words when using the Mini Mic, although they acknowledge that this could partly be developmental progress:

'Yeah he's definitely doing that a bit more [imitating] when we've got it on, and now we're sort of getting to that age aren't we where he'll start to copy everything but I think the mic's helped with that.'

In noise, parents noted that P1 could communicate and follow instructions in situations where he might not have been able to without the Mini Mic:

'Watching a film and eating pizza with brother in lounge, J could still understand instructions.'

'In a restaurant for Sunday dinner, although a bit restless J is still able to communicate well and able to hear me when moving through the restaurant.'

'In a restaurant, I could speak to J without raising my voice and he would listen.'

Similarly, in the car, when wearing his processors, parents were able to communicate with P1 where previously they wouldn't have been able to due to him being unable to access lip pattern and facial expression to help his understanding over the noise of the car.

'Better communication in car.'

'We were able to talk whilst we were in car.'

P1's Key Worker in the nursery commented that his communication and attention improved when she used the Mini Mic with him in quiet situations, for example story time and 1:1 work:

'He's more focused. Chats more, he's trying to communicate through babble and some recognisable words.'

'When repeating words, J a lot clearer.'

She also made use of the Mic in noisy situations, for example during free play or lunch time, when she wanted to get P1's attention:

'You can get his attention quicker.'

A Specialist Teaching Assistant who works with P1 on a weekly basis made the following observations about his improved communication:

'He is more attentive when he uses the Mic. I think he was definitely listening more.'

'His speech has become clearer, the words he was already using are definitely clearer.'

'I've got another child with an implant (implanted about the same time) on my caseload, whose language was at the same stage as J's before he started using the mini mic. J now is clearer, he's made more progress. I'd like to see her with a mini mic!'

'His listening skills are superb, he always had good listening skills but with the mic he is more attentive.'

4.3.3 Well-being and safety

Emotional and social well-being is defined by the National Institute for Health and Care Excellence (NICE) as 'being happy and confident….having good relationships with others…' (NICE 2012).

Improved access to speech had a positive effect on P1's safety as parents could call him back if he went too far from them:

'J would turn when I called him in the pet shop and supermarket.'

'Yes, walking to the shops and J likes to run ahead.'

'Walked to shop, J turned when called.'

[It's useful] 'when we've been out shopping or out in the park, when there's more background noise or wind, and when he's able to run further away.'

From a social point of view, parents found that P1 was able to join in more and play safely further from them:

[It was useful] 'at a bar on holiday, J was running around.'

4.3.4 Practicalities and technology

The family of P1 found the Mini Mic easy to use after they had been given the appropriate training prior to the start of the study:

'Yeah it was ok with the right training.'

They found the daily management straightforward but admitted forgetting to charge the Mic overnight on occasions:

'…we would have to sometimes remember to charge it, so memory…fitting it in with other things as well.'

Both the parents of P1 and his Key Worker admitted forgetting they were using the Mic and not passing it over to another speaker:

> *'Remembering to pass it round perhaps when we were out…' (Mum)*

> *'Remembering to pass it over as you forget you are wearing it.' (Key Worker)*

Parents had been advised on using the Mini Mic only when they felt it was beneficial but they commented that they were uncertain at times whether they should keep it switched on or not:

> *'…I didn't know how much it was an inconvenience if I was on the phone or talking to someone in the other room and J was sitting here.'*

The limited battery life of the Mini Mic also encouraged parents to establish in which situations it would be of the most benefit.

> *'We had to charge it every night. It lasted about 7 hours. It would last till just after lunch time which was nap time (at nursery).'*

> *'…and sometimes perhaps the battery life…perhaps leaving it off until later on in the afternoon, so thinking about it in advance.'*

4.3.5 Situations with limited or no benefit

In a quiet environment, and particularly when the child was in close proximity to the adult, the Mini Mic was perceived by parents not to make as much difference:

> *'I think when we've been at home [the mic is of little use], his understanding is so good now.'*

There were also times when P1 took his processors off:

> *'I suppose it depends on him and having his ears on sometimes. If he's poorly or unwell he doesn't always want his ears on so that limits your use.'*

4.3.6 Ongoing use and advice to other families

The family of P1 were very positive about the benefits of the Mini Mic in many environments and would advise other parents to:

> *'…just give it a go in all situations and see what you find the most useful.'*

P1's Key Worker commented on the benefits of using the Mic in nursery:

> *'I think J would benefit from using it daily, especially in 1:1 and small group sessions.'*

The Specialist TA reinforced the benefits of ongoing use, especially in nursery:

> *'I definitely think he'd benefit from continuing to use in nursery, especially story times, group activities.'*

> *'That's where language is developed, in nursery, so surely that's where they need the input. Not to have it on all the time but to use it where it's most useful which we would advise and train the nursery on.'*

After hearing the positive comments about their son's progress, parents of P1 are keen to continue using the Mini Mic in nursery.

4.4 Summary of key findings

• The parents of P2 noticed no significant difference when using the Mini Mic for only one week. On the 2 days LENA™ was used, however, results indicate improved scores for AWC, CV and CT in most situations both at home and in the nursery.
• During Story time, P2's CV and CT were higher without the Mic. However, this is to be expected as there would be little vocalisation or conversation from the children at this time.
• The family of P1 were able to establish regular Mini Mic use in a variety of listening situations and found it beneficial in most. Over 8 weeks of use, the Mic was used on 75% of the total days and, for 71% of that time, the Mic was found to be beneficial by the family. The Mic was of little benefit in quiet situations with a good SNR.

• LENA™ results for P1 show improved AWC in most situations when using the Mini Mic; CV was greater in all situations except ‘Shops’, where it was significantly greater without the Mic, and ‘Lunch’ where it was slightly greater without the Mic.
• CT scores were improved in all situations when the Mini Mic was used for both P1 and P2.
• The Listening Evaluation questionnaire for P1 showed improved question scores after Mini Mic use, the greatest improvements being for responses to questions and commands (33%) and attention (35%), with an overall average improvement of 26%.
• Situation scores were the same or greater for P1 after Mic use, with an improvement of 50% for ‘from another room’, showing the benefit of improved listening at a distance. Overall average improvement across the different listening environments was 26%.
• LDS scores before and after Mini Mic use show a slight improvement in language development for P1, although he is still categorised as ‘at risk’. P2’s score before Mic use was ‘within normal levels’.
• P2 had a higher than average exposure to adult words compared with hearing peers and higher than average scores for CV and CT when using the Mini Mic, compared to lower than average scores without the Mic. An average exposure to language at home resulted in an above average CV score for P1 when using the Mic.
• Parents of P1 valued the improved signal to noise ratio the Mini Mic allowed, which enabled their child improved access to speech, particularly in noise (both indoors and outside) and at a distance. P1 was also able to access speech in new situations, for example the swimming pool.
• Parents and staff working with P1 reported improved attention, focus and behaviour when using the Mini Mic. Understanding was improved and he was more able to follow instructions.
• Parents noticed that P1 copied more words when using the Mic and staff working with him commented on the improved clarity of his speech.

• Parents described feeling happier about P1 walking or playing further away from them as he would hear them calling him back, thus improving, not just well-being and safety, but also his opportunity to socialise with friends.
• Parents found the Mini Mic easy to use; the only problems were forgetting to charge it and remembering to pass it to a new speaker.
• Nursery staff and the Specialist TA working with P1 encouraged continued use of the Mini Mic in nursery.

5. Discussion

The aim of this study was to investigate the impact of remote microphone use (in the form of the Cochlear™ Mini Mic) on the language development of two cochlear implanted pre-school children. The researcher hoped to compare quantitative and qualitative data with existing data relating to the effects of FM technology used with pre-school hearing aid users. The family of P2 only used the Mini Mic for a short time and P2's results will be discussed first. The family and staff working with P1 consistently used the Mini Mic in situations where they found it to be beneficial and, even though this research has essentially become one case study, we have some important data from this family. The comprehensive, more extensive results from P1 will be discussed in more detail.

5.1 P2 results

Qualitative results from the family of P2 suggest that the Mini Mic did not make any noticeable difference to the language and communication of their child. However, quantitative results from the LENA™ data contradict this and show significantly improved AWC, CV and CT in most situations when the Mic was used, particularly in nursery. Parents stopped using the Mic after one week which is probably not a long enough time to notice any differences in their child's communication. The child had good language levels initially, which may mean that any changes in vocalisations or conversational turns were not so obvious.

The 2 home situations that were analysed on the LENA™ days were 'car' and 'play at home'. For 'car' AWC, CV and CT were all almost doubled when the Mic was used during the car journey home from nursery. For 'play at home', even though AWC was significantly lower (about 25%) when using the Mic, CV was about 25% higher, indicating a huge increase in child vocalisations when the Mic was used. CT were slightly higher when the Mic was used. The difference in Adult Word Count could suggest that the adult words when the Mic wasn't being used weren't directed towards the child.

In nursery, the only situation in which word counts weren't increased with Mic use was Story time. As this is a time when children are encouraged to sit quietly and listen to the story, we might expect that P2's CV and CT ought to be less

when the Mic is used, as he is able to concentrate more easily and pay attention to the story.

It is important to note that the 2 days of P2 LENA™ use were not during the week of Mic use at the start of the study, but were completed at a later date. We cannot be sure that the Mic was in fact used at all at the beginning of the study as parents told the researcher they had given it to nursery to use, yet nursery staff informed the researcher that it had not been used in nursery before the day when it was used with the LENA™ recorder. Parents' argument that maybe P2 is too young to be benefitting from the Mini Mic doesn't make sense as the technology is all integrated into the child's processors. It seems apparent that, for some reason, even though initially keen to take part in the study, parents of P2 decided against using the Mini Mic. This is disappointing as we can see that on the only day we know for sure that the Mini Mic was used, Child Vocalisations and Conversational Turns were increased significantly.

5.2 P1 Mic use

Of the previous research outlined in the Literature Review exploring FM use with pre-school children, Brackett (1992) and Gabbard (2003) did not report any data on the daily usage of the FM technology. Statham and Cooper (2009) state that families used a daily log but do not supply the data from this. Webster (2015) has concentrated on qualitative feedback from parents and as yet no specific data on usage has been published. Moeller et al (1996) offered a brief overview of data on FM use from the daily logs completed by parents over an 18 month period in their study. They found that 5 of the 6 participants used the FM device for 40-60% of their waking day and one for 20%, in the home. It is not clear, however, what they meant by 'home setting' and whether this included outdoor use.

Mulla (2011) provides a more detailed insight into the daily use of FM technology, investigating both the duration and frequency of use and also the different listening situations in which it was used by the child. Five participants established regular use. For these five, the FM was used for between 69%-95% of the total days they were in the study. The average duration of daily use

ranged from 2 hours 29 minutes to 4 hours 12 minutes. In this study P1 used the Mini Mic for 75% of the total days, with an average daily duration of 4 hours which could indicate the ease of using the Mini Mic compared to the FM system: the parent or carer merely needs to pair the Mic then clip it on, whereas the FM transmitter is more bulky and maybe not so easy or comfortable to use.

In Mulla's study, all participants reported a high percentage of benefit (97%). In this study P1 results indicate the Mini Mic was felt to be beneficial 71% of the time. There are two possible reasons for this: in Mulla's study, parents valued the Mic as having 'benefit', 'no benefit' or 'not sure'. In this study, parents chose only between 'benefit' or 'little or no benefit'. Another suggestion is that the families in Mulla's study were able to recognise quite quickly where the FM was beneficial and only used it in those situations. In this study, the family of P1 have tried to use it in many different situations but have perhaps continued to use it in some environments even though it wasn't making a difference. Results show that the Mic was in fact used more in 'quiet' situations than any other, even though parents' comments suggest it is of little benefit in a quiet environment. This could also be due to the fact that it's just easier to keep the Mic on all the time, rather than turning it on and off. For ongoing future use parents and nursery staff would need further training in identifying where the Mic is of most benefit and limiting its use to those situations.

5.2.1 Listening environments

The daily diary sheets used by P1 included data recorded by parents on the situations during the day when the Mini Mic was used and whether they found it to be beneficial. The different situations were 'in quiet, in noise, outdoors, meal, car, shops, other'. Of the previous studies into FM use, only Mulla (2011) and Webster (2015) provide data of this kind.

Mulla (2011) found that, from his 5 settings of 'home, nursery, car, shopping, outdoors', the FM system was used the most at home and in nursery, within which there were additional sub settings, for example reading, circle time, play time. Webster (2015) has concentrated on the following situations: 'in the car, whilst shopping, in the pram/buggy, going for a walk outdoors, in the nursery, in

the playground/park, at mealtimes'. Data to 2014 shows a more equal usage between the 7 situations.

In this study the Mic was used by P1 primarily in 'quiet' (mainly the home environment) and 'noise' (including nursery and home environments) and the language development in each of these environments is studied in more detail in the next section. Significant amounts of use also occurred outdoors, in the car and at mealtimes.

The Listening Evaluation questionnaire in this study evaluated the language of P1 in 6 main situations: in quiet at a short distance, in quiet at a greater distance, in noise at a short distance, in noise at a greater distance, from another room, in the car and while shopping. In previous studies, Moeller et al (1996) used their own listening profile to illustrate changes in listening skills. They found improvements amongst the FM group for 'multiple talkers' and 'clarification requests' but little improvement for listening in noise and at a distance. Gabbard (2003) reported no difference in listening evaluation between hearing aids and FM systems; however, parents' comments contradicted this and highlighted improvements with the FM. Statham and Cooper (2009) and Mulla (2011) found that, from the periods of greatest use (home and nursery), the most noticeable improvements were in noise and at a distance.

The questionnaire used in this study was developed from the FMLEC used by Gabbard (2003), which Mulla (2011) had previously adapted for his research. Significant improvements were found in most situations when the Mic was used, particularly at a distance (from another room). These findings are reinforced by parents' comments which suggest the greatest improvements were in noise and at a distance. The scores for 'in the car' remained the same, but we know that P1's processors tend to fall off sometimes in the car so this could be an indication of why the score hasn't changed. The score for 'in quiet' has also stayed the same. As P1 would be able to hear well in quiet anyway, we wouldn't expect much of a change here. It is interesting to note that there is little change in response to environmental sounds. This indicates that when the Mini Mic was being used it didn't impede on the processor's microphone. The

child could still hear sounds around him, the Mini Mic only kicking in when someone is talking.

5.3 Language development of pre-school children

As in Mulla's research (2011), for the purpose of this study the LENA™ Developmental Snapshot (LDS) was used as a measure of language development compared with normative samples of typically developing hearing children. Mulla (2011) found that, after six months, significant improvement was shown for those children who began the study in the 'at risk' category. In this study, after 3 months of Mini Mic use, P1 remained in the 'at risk' category, although his standard score had improved slightly. It is difficult to know whether greater improvement would have been indicated with prolonged Mic use but we should note that 3 months is probably too short a time to observe any significant improvements using this measure.

In agreement with Statham and Cooper (2009), Mulla (2011) and Webster (2015) both quantitative and qualitative data from this case study show that established regular use of the Mini Mic led to perceived improvements in the child's access to speech and his responses, particularly in noise and at a distance. From the Listening Evaluation questionnaire, we can see that parents identified improvements in all question categories, most notably in P1's response to questions and commands and in attention. In diary and interview comments parents also reported improved clarity of speech, more imitation of words and an improved understanding.

The LENA™ data forms a large part of this research. In his study using LENA™, Mulla (2011) suggested that, although an important indicator of the child's acoustic environment, the LENA™ system was not sensitive enough to fully detect the potential benefits of FM use. In this study the researcher has been able to produce a very detailed account of activities and listening environments on days when LENA™ was used at home and in nursery, using the LENA™ software and also the LENA™ diary filled in by parents and nursery staff. From the list of activities, the researcher selected activities that were the same or very similar and the same length of time, in order to compare AWC, CV and CT with and without the Mic.

Studies have shown that, for hearing children, a greater frequency of adult words leads to increased vocalisation and conversational turns (Warren 2015; Diehm 2013; Hart & Risley 1992). Significantly, in this study, AWC increased when the Mini Mic was used. This in turn led to increased CV and CT for most activities. One exception was ‘at the shops’ where CV increased without the Mic. AWC and CT, however, were higher with the Mic which indicates that the vocalisations without the Mic were not part of a meaningful conversation. This could be a similar scenario at lunch time in the nursery, where CT was increased with Mic use but CV was not. Also of interest at home is the increase in all word counts for ‘in the car’ (CV increasing from 4 vocalisations to 14), even though parental perceptions in the Listening Evaluation were that it hadn’t made a difference.

In nursery, word counts were increased with the Mini Mic for almost all activities (we would expect the AWC for story to depend on the word count of the actual story). The directed activity time is probably the most significant to look at here as this is a time of learning and language development in the nursery. Results show that AWC and CV increased by over 30% when using the Mic and CT doubled. This is a significant finding as we can assume that in this situation vocalisations and conversational turns are more contextual and of a richer quality and this therefore suggests that the child has a far greater access to meaningful language when using the Mini Mic. CV and CT scores for indoor and outdoor play were also both significantly improved with the Mic.

5.3.1 Well-being

The NICE guidelines (2012) propose that Early Support practitioners should focus on the social and emotional, as well as educational, development of a young child. Fredrickson and Joiner (2002) suggest that positive emotions broaden the scopes of attention and cognition and by consequence this leads to improved emotional well-being.

In his study, Mulla (2011) suggested that FM use resulted in reduced listening effort, with parents reporting that their children were calmer and more confident. Parents taking part in the research by Webster (2015) reported that their children joined in more and were more independent. One of the parents in

Webster's study also pointed out that they themselves felt calmer and were able to allow their child more independence.

In this study an improved SNR resulted in improved communication and attention and parents reported improved understanding as a result. We can assume that, as the child does not have to concentrate as much, he will also be less tired, thus leading to improved well-being. Mini Mic use also allowed P1 greater independence and the opportunity to take part in activities he would previously have been unable to access.

5.3.2 Comparison of percentiles with hearing peers

Literature suggests that hearing impaired children may have less exposure to language than normally hearing children (Cole & Flexer 2011). In Mulla's research he found that, contrary to this, the children in his study experienced language exposure near to the 50th percentile (Mulla 2011).

In this study, P2 was exposed to an above average AWC both with and without the Mini Mic, which could be explained by his good level of language and communication. P1 has a lower level of language and was exposed to fewer adult words in nursery and an average AWC at home. However, the AWC for P1 increased with Mic use, particularly at home, which in turn led to significantly more vocalisations and conversational turns.

5.4 Practicalities of the Mini Mic

The problems with tangled microphone leads and the back coming off the transmitter that Mulla (2011) and Webster (2015) came across in their studies were not issues in this study, due to the small size of the Mini Mic and lack of wires. Other challenges in previous studies included remembering to charge the transmitter and to mute when not needed. In this study, parents also admitted forgetting to charge the Mic and appreciated that when on the telephone they sometimes forgot to mute it. We know that overhearing allows a hearing impaired child access to incidental language that normally hearing children would naturally acquire (Floor & Akhtar 2006; Akhtar 2005). However, if this were to happen too often it would not be good for the child as the competing speech would mask other sounds and possibly his own voice during play.

As in previous studies, parents were comfortable with the technology and happy with the training they had received.

5.5 Conclusions

5.5.1 Strengths and limitations

The use of both quantitative and qualitative data in this case study offers a comprehensive insight into the potential benefits of a cochlear implanted pre-schooler having access to the Cochlear™ Mini Mic. It complements and augments previous research into the benefits of FM use with hearing aided pre-schoolers.

The use of the LENA™ technology allowed the collection of data that would normally have been beyond the scope of this research, enabling the researcher to present a very detailed analysis of the findings.

The main limitation to this study was the small sample size, made even smaller by the withdrawal of one of the participants. It is very difficult to make generalisations based on these results and they should rather be used to strengthen the findings of previous research.

5.5.2 Implications for the future

Further research into the benefits of the Cochlear™ Mini Mic with a larger sample size would strengthen these findings. The Mini Mic is currently offered at no cost to Cochlear™ N6 users and is therefore a viable alternative where the argument against FM use is due to lack of funding. Some CI Services have begun to hand out the Mini Mic to families at the child's initial CI fitting, although a lack of follow up could result in the device not being used. An alternative would be to hand the Mic over to the child's ToD who would then assess the appropriate time to introduce the system. Professionals from Education and Health would need to work closely together to ensure the appropriate training and duty of care is provided to families and nurseries.

The LENA™ system has been shown to be instrumental in supporting an in-depth analysis of language data and would be a beneficial tool in further research studies with hearing impaired children. It is also a useful counselling

tool for families as it can be used to illustrate variations in the language environment of the child and relationships between adult and child word counts.

In conclusion, this case study offers a unique insight into the potential benefits of using the Cochlear™ Mini Mic with pre-schoolers and provides a basis for further research in this area. It contributes to a battery of recent and ongoing research enriching our understanding of the benefits of remote microphone use with pre-school hearing impaired children.

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Appendix A

EC6: PARTICIPANT INFORMATION SHEET

UNIVERSITY OF HERTFORDSHIRE

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

Remote Microphone Use with Pre-School Cochlear Implanted Children

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.

What is the purpose of this study?
Recent research studies suggest that having access to an FM radio aid system has a positive impact on the language and communication of pre-school deaf children (Moeller et al, 1996; Statham & Cooper, 2009; Mulla, 2011; Webster, ongoing).
Most studies to date have been with pre-school hearing aid users. This study will investigate the effects of the Cochlear mini mic on two cochlear implanted pre-school children.

I would like your consent to use the data related to your child's use of the mini mic to form the main body of my dissertation with the University of Hertfordshire.

Do I have to take part?
It is completely up to you whether or not you decide to grant permission for me to use the data relating to your child's Mini Mic use.
If you do decide to grant permission you will be given this information sheet to keep and be asked to sign a consent form. Agreeing to allow me to use the data does not mean that you can't change your mind. You are free to withdraw your permission at any stage without giving a reason. A decision to withdraw permission at any time will not affect any support that your child receives.

How long will my part in the study take?
You won't be required to take any time out as the data is already present on our casefiles. You may be asked for permission in the future to use the previously collected data to complement further research.

What will happen to me if I take part?
Your child's data will be anonymized, analysed and reported on to provide an insight into the use of the mini mic.

What are the possible disadvantages, risks or side effects of taking part?
No risks.

What are the possible benefits of taking part?
I will share my findings with you and your child's nursery so you will be able to see any benefits to using the mini mic.

How will my taking part in this study be kept confidential?
All data will be anonymised before being used in the dissertation.

What will happen to the data collected within this study?
The data will be anoymised and stored in accordance with the data protection procedures of IDS Warwickshire. All material will be kept on a computer with security password or within a locked cupboard. Any data transferred will be made anonymous.

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/CP/02140

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:

Claire Sunderland
Specialist Teacher
Hearing Team, Lancaster House
Easter Way, Ash Green
Coventry, CV7 9HP
T: [redacted]
M: [redacted]
[redacted]

Supervisor:
Dr Imran Mulla
[redacted]

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.

EC3: CONSENT FORM FOR STUDIES INVOLVING HUMAN PARTICIPANTS

UNIVERSITY OF HERTFORDSHIRE

ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS

('ETHICS COMMITTEE')

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

Remote Microphone Use with Pre-School Cochlear Implanted Children

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), 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.

2 I have been assured that I am free to withdraw my permission at any stage without disadvantage or having to give a reason.

3 I have been told how information relating to my child (data previously obtained) will be handled: how it will be kept secure, who will have access to it, and how it will be used.

4 I have been told that I may at some time in the future be contacted again in connection with this or another study.

Signature of participant……..…Date…….

Signature of (principal)
investigator……Date……

Name of (principal) investigator *[in BLOCK CAPITALS please]*

CLAIRE SUNDERLAND

Protocol number: EDU/PGT/CP/02140

Appendix B

Listening & Communication Evaluation

Name: Date of Birth:

Completed by: Date:

Typical responses using cochlear implant (CI) only, without visual clues				
	Never 0	Sometimes 1	Often 2	Always 3
1. Does your child respond to his name?				
a) In a quiet room, within 2m				
b) In a quiet room, at 7m				
c) In a noisy room, within 2m				
d) In a noisy room, at 7m				
e) From another room				
f) Outdoors				
g) In the car				
2. Does your child attend to the person speaking/reading/singing?				
a) In a quiet room, within 2m				
b) In a quiet room, at 7m				
c) In a noisy room, within 2m				
d) In a noisy room, at 7m				
e) From another room				
f) Outdoors				
g) In the car				
3. Does your child appropriately respond to simple (spoken) questions or commands?				
a) In a quiet room, within 2m				
b) In a quiet room, at 7m				
c) In a noisy room, within 2m				
d) In a noisy room, at 7m				
e) From another room				
f) Outdoors				
g) In the car				

Typical responses using cochlear implant (CI) only				
	Never 0	Sometimes 1	Often 2	Always 3
4. Does your child vocalise to join in a conversation?				
a) In a quiet room, within 2m				
b) In a quiet room, at 7m				
c) In a noisy room, within 2m				
d) In a noisy room, at 7m				
e) From another room				
f) Outdoors				
g) In the car				
5. Does your child imitate sounds/words?				
a) In a quiet room, within 2m				
b) In a quiet room, at 7m				
c) In a noisy room, within 2m				
d) In a noisy room, at 7m				
e) From another room				
f) Outdoors				
g) In the car				
6. Does your child respond to environmental sounds?				
a) In a quiet room, within 2m				
b) In a quiet room, at 7m				
c) In a noisy room, within 2m				
d) In a noisy room, at 7m				
e) From another room				
f) Outdoors				
g) In the car				

Adapted from: DeConde Johnson, C. (2003), Mulla, I. (2011), PEACH (2005).

Results of initial evaluation:

Results	**1**	**2**	**3**	**4**	**5**	**6**	
a)							/18
b)							/18
c)							/18
d)							/18
e)							/18
f)							/18
g)							/18
	/21	/21	/21	/21	/21	/21	

Adapted from: DeConde Johnson, C. (2003), Mulla, I. (2011), PEACH (2005).

LENA™ Developmental Snapshot

Developmental Snapshot

Questionnaire

[redacted] 22-Apr-16

1.	When you talk to your child, does he/she look in the direction of your voice? For example: Does your child turn his/her head and/or move his/her eyes to look for you?	Yes ☐ Not Yet ☐
2.	Does your child vocalize or make sounds in response to your smile or voice?	Yes ☐ Not Yet ☐
3.	Does your child have different cries to indicate different needs? For example: Does your child's "hungry cry" sound different from the cry he/she makes when tired?	Yes ☐ Not Yet ☐
4.	Does your child express pleasure or displeasure by using sounds other than crying or laughing? For example: Does your child make "happy" sounds or sounds of frustration?	Yes ☐ Not Yet ☐
5.	Does your child bring toys or objects to his/her mouth? For example: Does your child mouth objects or place objects in his/her mouth?	Yes ☐ Not Yet ☐
6.	Does your child laugh?	Yes ☐ Not Yet ☐
7.	Does your child engage in "vocal play" by producing a wide variety of sounds? For example: Does your child produce sounds that range from very high pitch (squeals) to very low pitch (growls) and does he/she produce "raspberries" by putting lips tightly together and blowing air to produce a vibrating play-like sound?	Yes ☐ Not Yet ☐
8.	Does your child produce two or more vowel sounds, such as /ah/ or /ooh/ ?	Yes ☐ Not Yet ☐
9.	Does your child recognize his/her name (or nickname)? For example: When you say your child's name (or nickname) does it interrupt his/her activity such that he/she stops and looks toward you?	Yes ☐ Not Yet ☐
10.	Does your child shout or use vocalizations/make sounds to get your attention?	Yes ☐ Not Yet ☐
11.	Does your child imitate sounds you or others make?	Yes ☐ Not Yet ☐
12.	Does your child repeat two similar sounds together (not necessarily referring to a specific object or person)? For example: Does your child say things like "bababa" or "dadada"?	Yes ☐ Not Yet ☐
13.	When you say things to your child such as "want up?" or "bye-bye" does your child respond by lifting his/her arms or waving?	Yes ☐ Not Yet ☐
14.	Does your child put different sounds together? For example: Does your child say things such as "bah-dah", "ah-bee-tah" or "ah-mee-ga"?	Yes ☐ Not Yet ☐
15.	Does your child vocalize while gesturing to let you know what he/she wants? For example: Does your child point or motion toward a desired object while vocalizing?	Yes ☐ Not Yet ☐
16.	Does your child say any word besides "mama" or "dada"? For example: A "word" can be an attempt at a real word such as "ba" for "ball" or "wawa" for "water".	Yes ☐ Not Yet ☐
17.	Does your child give you an object when you ask for it? For example: If you say "Give me your shoes " or "Give me the ball", does your child respond correctly?	Yes ☐ Not Yet ☐
18.	Does your child follow simple 1-step directions? For example: If you say "Go get your shoes" or "Put your toy on the bed", will your child respond correctly?	Yes ☐ Not Yet ☐
19.	When you name different objects, does your child point to them? For example: If you say "Where is the ball?" or "See the truck?", will your child point to the correct object?	Yes ☐ Not Yet ☐
20.	Can you tell by the way your child's voice sounds that he/she is asking a question? For example: When your child is babbling but you can't make out the words, can you still tell that he/she is trying to ask a question by a rise in pitch at the end of the babbles?	Yes ☐ Not Yet ☐
21.	Does your child identify basic body parts on himself/herself? For example: Can your child point to his/her nose, eyes, mouth, toes, and hair?	Yes ☐ Not Yet ☐
22.	Does your child say at least 10 meaningful words that you consistently recognize? The words don't necessarily have to be pronounced perfectly. For example: If your child consistently uses "ba" for "bottle", this counts as a word.	Yes ☐ Not Yet ☐
23.	Does your child point to objects named in books? For example: If you say something like "Show me the cat", does your child point to the correct picture?	Yes ☐ Not Yet ☐
24.	Does your child spontaneously repeat words that he/she has heard in conversation?	Yes ☐ Not Yet ☐
25.	Does your child follow 2-step directions? For example: If you say something like "Go get your shoes and put them on the table" or "Go get your coat and give it to your grandma", will he/she respond correctly?	Yes ☐ Not Yet ☐
26.	Does your child understand the meaning of at least four action words without the use of gestures? For example: If you say "jump" or "throw" without demonstrating the action, will he/she respond correctly?	Yes ☐ Not Yet ☐

27.	Does your child understand "what", "where", and "who" questions?	Yes ☐ Not Yet ☐
28.	Does your child name familiar objects in a room?	Yes ☐ Not Yet ☐
29.	When you point to pictures in a book, does your child name them?	Yes ☐ Not Yet ☐
30.	Does your child understand "location" words such as "in", "on", and "out"?	Yes ☐ Not Yet ☐
31.	Does your child combine two or more words together to form simple phrases? For example: Does your child say things like "want ball" or "mommy sit"?	Yes ☐ Not Yet ☐
32.	Does your child have at least a 50 word spoken vocabulary?	Yes ☐ Not Yet ☐
33.	Does your child understand the concept of "one"? For example: If you point to a group of blocks and ask your child to hand you "one", will your child respond correctly?	Yes ☐ Not Yet ☐
34.	Does your child follow 3-step directions without getting distracted? For example: If you say something like "Go to your room, get your bear and bring it to me", will your child respond correctly?	Yes ☐ Not Yet ☐
35.	Does your child say "I", "me", and "you"?	Yes ☐ Not Yet ☐

36.	Does your child understand color words? For example: If you say something like "Point to the red one", will he/she correctly identify the object?	Yes ☐ Not Yet ☐
37.	Is your child starting to use size concepts? For example: Does your child say things like "big" and "little"?	Yes ☐ Not Yet ☐
38.	Is your child using sentences that are four words in length?	Yes ☐ Not Yet ☐
39.	Is your child adding "-s" to words to indicate "more than one"? For example: Does your child say "cats" for more than one cat, or "spoons" for more than one spoon?	Yes ☐ Not Yet ☐
40.	Can your child tell you what to do with simple objects? For example: If you say something like "Here is a toothbrush, what do we do with a toothbrush?", will he/she tell you what it is used for?	Yes ☐ Not Yet ☐
41.	Is your child adding "-ing" to the end of verbs to indicate ongoing action? For example: Does your child use words like "eating", "jumping", and "running"?	Yes ☐ Not Yet ☐
42.	Does your child use the words "a", "an", and "the"? For example: Does your child say things like "a bed", "an apple", and "the ball"?	Yes ☐ Not Yet ☐
43.	Can your child name common shapes such as circle, triangle, square, and star?	Yes ☐ Not Yet ☐

44.	Does your child understand concepts like "least", "most", and "first"?	Yes ☐ Not Yet ☐
45.	Does your child understand concepts like "tall", "short", and "long"?	Yes ☐ Not Yet ☐
46.	Does your child use the plural pronouns "we", "they", "them", and "us"?	Yes ☐ Not Yet ☐
47.	Is your child adding "-ed" to the end of verbs to indicate an action that happened in the past? For example: Does your child say things like "jumped" or "played"?	Yes ☐ Not Yet ☐
48.	Does your child spontaneously produce sentences that are 10 or more words in length?	Yes ☐ Not Yet ☐
49.	Can your child name items that belong to a common category? For example: If you say something like "Tell me three fruits you like" or "Tell me the names of three animals", will your child respond correctly?	Yes ☐ Not Yet ☐
50.	Can your child retell a story or event with a beginning, middle, and end without using pictures? For example: Does your child tell a complete story (beginning, middle and end) so you understand the story and what your child is expressing/explaining?	Yes ☐ Not Yet ☐
51.	If you name an object, can your child describe two things about the object? For example: If you say "Tell me two things about a bike.", will your child respond correctly?	Yes ☐ Not Yet ☐
52.	Does your child ask you about the meanings of words and then use the word in a sentence?	Yes ☐ Not Yet ☐

Daily Diary

Date:	From	To	Useful? (Y/N)	Comments
In a quiet room 				
In a noisy room 				
Meal times 				
Outdoors 				
In the car 				
Shopping 				
Other 				

Weekly diary

WEEKLY DIARY Mini mic use

Have you noticed any difference in your child's communication when using the mini mic?

……
……
……
……

Have you noticed any changes in your child's behaviour when using the mini mic?

……
……
……
……

Were there any problems with using the mini mic?

……
……
……
……

Where do you feel the mini mic was most useful?

……
……
……
……

Were there any situations where you felt the mini mic was of little use?

……
……
……
……

Are there any other comments you would like to make?

……
……
……
……

Diary – nursery

[redacted] - Mini mic use

Did you find the mini mic useful in these situations?

Situation	Useful? Y/N
Quiet environment (eg. story time) 	
Noisy environment (eg. free play) 	
Meal times 	
Outdoor play 	

Have you noticed any difference in [redacted]'s communication when using the mini mic?

……
……

Have you noticed any changes in [redacted]'s behaviour when using the mini mic?

……
……

Were there any problems with using the mini mic?

……
……

Where do you feel the mini mic was most useful?

……
……

Were there any situations where you felt the mini mic was of little use?

……
……

Are there any other comments you would like to make?

……
……

Thank you for your time!

LENA™ Diary sheet

LENA DIARY

Date		**Mini mic?** Y / N
From	**To**	**Activity**

Interview schedule

1. Introduction
2. How was your experience of using the mini mic with J?
3. What were the main challenges of using the mini mic?
4. Were there any times or environments where you found the mini mic particularly useful?
5. Were there any times or environments where you found the mini mic of little use?
6. Were there any drivers that prompted you to make more use of the mini mic?
7. Were there any barriers that stopped you from using the mini mic?
    a. In any specific environments?
    b. At any specific times?
8. Have you noticed any difference in J's communication when using the mini mic compared to using the CI alone?
    a. Response to name
    b. Attention
    c. Response to question/command
    d. Conversation
    e. Imitating sounds/words
    f. Response to environmental sounds
9. Have you noticed any difference in J's behaviour when using the mini mic?
10. What was your experience of physically using the mini mic?
11. How confident were you with the technology?
12. What basic daily management did you implement for the mini mic?
13. Were there any problems with using the mini mic?
14. Looking back, was there any information you would have liked prior to being given the mini mic?
15. Overall did you find the mini mic useful?
16. Do you feel you will make use of the mini mic in the future with J?
    a. Main environments
17. Do you have any advice or suggestions for parents who may be thinking of using a mini mic with their child?
18. How was the participation in the study?
    a. Diary keeping? Able to keep up with actual use?
    b. Number of questionnaires/interviews?
    c. LENA use?