The Ear Foundation
Hearing & Communicating in a Technological Era

Using radio aids with pre-school deaf children

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National Deaf Children's Society

Why use radio aids with young deaf children?

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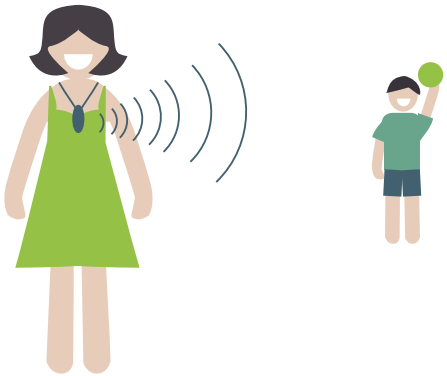
Hearing is essential for learning spoken language and the earlier a child can hear speech, the better their opportunity to learn to listen and talk. However, everyday life presents challenges for a young child with hearing loss; noise and distance from their parent when travelling in the car or buggy, walking and playing outside and even around the house make it difficult to hear speech difficult and jeopardise spoken language development.

Using a radio aid can overcome these challenges and may reduce the risk to spoken language.

Radio aid use is well-established for school-age children; however provision during these vital early years is inconsistent and inequitable.

This study asked 21 families of young deaf children about the benefits and challenges of using a radio aid in everyday life and used quantitative and qualitative measures to capture important predictors of spoken language outcomes.



Radio aids transmit a parent's voice directly to the child to overcome these daily challenges of distance and noise.

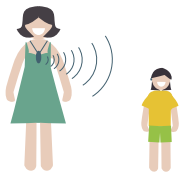
Findings

Everyday situations present a risk to learning spoken language. This study shows that using a radio aid can reduce this risk and maximise potential benefits for the child and their family by:

- Improving hearing for speech in difficult listening conditions
- Increasing the amount parents talk and interact with their child
- Having a positive impact on the family's well-being

Radio aid equipment can be challenging, but benefits largely outweigh any difficulties. Successful radio aid use requires timely and good quality information and support.

'Speech-wise she is picking up on more; she is using more language because she can hear what we are saying more. She is definitely more vocal with it, more likely to communicate'



Recommendations

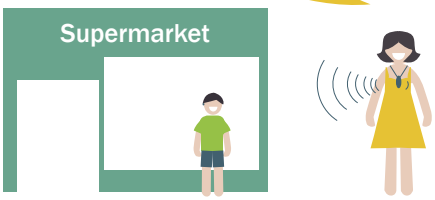
All parents of a young deaf child should be informed of the significant potential benefits of radio aids and have the opportunity and support to use this technology at home

Access to radio aids should be equitable for all pre-school children

Manufacturers should respond to the identified needs of children and families in everyday life

Professionals should be knowledgeable about managing the latest technologies

'As a parent, it is a massive, massive reassurance to walk down the street with him and know he can hear me'



Research commissioned by National Deaf Children's Society

Executive Summary

The first few years of a child's life are a time of rapid and important development. During this time the foundations for communication are laid and for all children, language and interaction with their parents is critical to success. Hearing is essential for learning spoken language and the earlier a child can hear speech, the better their opportunity to learn to listen and talk. For a baby with hearing loss, 'hearing technologies' such as hearing aids and cochlear implants can provide the necessary hearing for speech. However, crucial early speech and language development occurs in the routines of everyday life, which are full of difficult listening conditions, for example playing outside, travelling in the car or a buggy and even around the house. Using a radio aid is one way to help overcome this by transmitting the speaker's voice directly to receivers on the child's hearing technology to improve the Signal-to-Noise Ratio (SNR). Using radio aids with children in school is well-established practice; however despite encouraging research findings, provision of radio aids for babies and young children during their critical period of language development is inconsistent and inequitable.

This study conducted by The Ear Foundation recruited twenty one families to explore the benefits and challenges of radio aid use with a deaf child aged 4 years and under. Using both quantitative and qualitative measures, the study investigated potential differences in behaviours with and without radio aid use and sought parents' insights into the experience. Findings provide strong evidence for the advantages of early radio aid use and support equitable access, consistent protocols and funding.

Highlights from this study's findings include:

- Everyday listening environments present a risk to learning spoken language: using a radio aid can reduce this risk
- Using a radio aid facilitates important predictors of spoken language outcomes; improved hearing for speech and increased quantity of adult language and parent-child interaction
- Radio aid use can have a positive impact on the well-being of both children and their parents
- Successful radio aid use requires timely and good quality information and support to maximise potential benefits for the child and their family
- Radio aid equipment can be challenging, but benefits largely outweigh any difficulties

'Speech-wise she is picking up on more; she is using more language because she can hear what we are saying more. She is definitely more vocal with it, more likely to communicate'

'As a parent, it is a massive, massive reassurance to walk down the street with him and know he can hear me.'

Recommendations:

- All parents of a young deaf child should be informed of the significant potential benefits of radio aids and have the opportunity and support to use this technology at home
- Access to radio aids should be equitable for all pre-school children
- Professionals should be knowledgeable about managing the latest technologies
- Manufacturers should respond to the identified needs of children and families in everyday life

Contents

1.0 Background

Language is the foundation not only for communication, but also for learning and education, our relationships with other people and our experience of life. Hearing is a vital building block for developing spoken language and the earlier a child can hear speech, the better their opportunity to learn to listen and talk (Cole & Flexer, 2015; Sininger, Grimes & Christensen, 2010).

Hearing speech during early development is critical for spoken language

The first months and years of life are critical to the acquisition of spoken language through hearing. Learning starts early; even newborn babies have a natural interest in and ability to discriminate human speech from other sounds. As they grow, babies 'tune in' to the sounds being used in the language around them. Their brains begin to recognise, organise and learn the meaning of sounds and this forms the basis for understanding and using spoken language (Beck & Flexer, 2011).

Early diagnosis of hearing loss and early use of hearing technologies, such as hearing aids, cochlear implants and bone conducting hearing implants, have been shown to significantly benefit language development (for example Pimperton & Kennedy, 2012; Vohr, Topol et al., 2014; Yoshinaga-Itano, Sedey et al., 1998; Yoshinaga-Itano, 2000). The universal Newborn hearing screening programme (NHSP) has provided this important early advantage; most babies with hearing loss are now diagnosed and aided within a few weeks of life (Wood, Sutton & Davis, 2015).

Children learn spoken language through listening in all their daily routines and activities; in one-to-one contact, listening to others around them and importantly, listening to their own speech and vocalisations. As babies, routines such as feeding, cuddling, washing and playing, involve very close contact with their parents at an "ideal" distance for listening (Brackett, 1992). However as babies start to sit, crawl and walk, they become more independent from their parents, maybe playing a little further away in a room or moving from a car seat or buggy which faces the parent, to one which faces away; this increases the listening distance and reduces the acoustic intensity or volume of the parent's speech (Ross, 1992). Everyday activities can also be noisy; busy mealtimes with siblings, playing in the kitchen while the washing machine is on or out and about. In fact, it is suggested that babies and young children under the age of four years spend almost a quarter of their day in noisy environments (Jones and Launer, 2010). Listening in noise is more difficult than in quiet; adults with hearing loss experience greater difficulties listening to speech in noise and reverberation than adults with normal hearing (Brown, Hullar et al., 2010; Glyde, Dillon et al. 2012) and even apparently low levels of noise can interfere with young children learning to listen, particularly when they also have a hearing loss (Yang & Bradley, 2009). Children don't have the language to help them work out what someone might be saying to them or to work out where one word ends and the next one begins; and it seems that it is even harder for younger rather than older children (Bradley & Sato, 2008; Eisenberg, Shannon et al, 2000). It makes sense then to assume that for a young child with a hearing loss, understanding speech in noise or at a distance is challenging and that this has the potential to impact on their spoken language development.

Everyday life presents challenges for hearing speech and jeopardises spoken language development

The negative effects of background noise, reverberation and distance can be overcome by improving Signal to Noise Ratio (SNR) through the use of a remote microphone or frequency modulation (FM) system, commonly known as a "radio aid" (National Deaf Children's Society, 2017). A radio aid system consists of a transmitter worn by an adult or key speaker and a receiver worn by the child. The speech signal is transmitted directly to the microphone on the child's hearing aids, cochlear implants or bone conducting hearing implants, 'shortening' the distance between the speaker and the microphone and reducing the effects of background noise and reverberation (Ross, 1992, Thibodeau 2010). Many studies have shown the benefits of using a radio aid with hearing aid users in school, not only for improved speech perception (for example, Crandell & Smaldino, 2000), but also reducing the effort of listening, which in turn leads to improved concentration and attention (Mulla, 2011).

Using a radio aid can overcome challenges of noise and distance in everyday life and may reduce the risk to spoken language

Studies of younger children have suggested benefits of radio aid use in the pre-school years too (Gabbard, 2003; Moeller, Donaghy et al., 1996; Statham & Cooper, 2009; Webster, 2015). Mulla (2011) demonstrated that parents were able to make consistent use of radio aids and outcomes showed improved language, listening and overall benefits associated with the children's well being. Challenges of radio aid use with this age group were also identified, primarily with wearing the device itself; for example, children pulling at the microphone wire.

Recent technological developments in size, weight, and wireless capability have made radio aids potentially more accessible for very young children. Despite a largely strong sense of support for the potential benefits of radio aids with pre-school children, recent surveys of parents and professionals highlighted inequitable provision and inconsistencies in awareness, understanding, information and management of radio aids with this group (Allen, Ng et al, 2016).

Provision of radio aids during this vital period is inconsistent and inequitable

Currently, there is relatively limited evidence for using radio aids with early identified, pre-school children; the recent technological developments provide a timely opportunity to undertake research into their use and a study exploring the real-life benefits and challenges was recommended in order to consider their use at this vital stage in language development.

1.1 Study aims

The purpose of this study was to explore the question:

What are the potential benefits and challenges of radio aid use in pre-school deaf children using any form of hearing technology?

Through regular longitudinal use of the radio aid, this study aimed to investigate everyday use of radio aids with pre-school children and provide meaningful evidence in order to:

- Understand the real-life benefits and challenges of using radio aids with young children

- Provide information to support parents in making decisions about radio aid use with their pre-school child
- Produce recommendations for professionals to support consistent policy and practice

2.0 Methodology

2.1. Procedure and Ethics

The study consisted of a series of case studies using a prospective cohort design. Both quantitative and qualitative methods were utilised to explore the experiences of families using a radio aid with their deaf [1]child in everyday life.

This research was conducted in accordance with The Ear Foundation Research policy, which follows the British Educational Research Association guidelines (2011) and was subject to both internal and external ethical review and approval. Study data were anonymised and maintained in line with the Data Protection Act (1998). Participation was voluntary, usual care was not affected and no incentive was offered for participation.

Inclusion in the study was open to families of children who met the following criteria:

- Aged 4 years or under at the start of the study
- Any degree or type of hearing loss
- Any type of hearing technology; hearing aid(s), bone conducting hearing implant(s) or cochlear implant(s)
- Not in full-time education
- Access to a radio aid system for the duration of the study[2]

Study information and invitations to participate were sent from The Ear Foundation to parents who had participated in a previous survey study about radio aids (Allen et al., 2016) whose children met the inclusion criteria. Invitations for ToDs and Educational audiologists were sent to those who had participated in the same study, circulated via the Heads of Service forum and the British Association of Teachers of the Deaf (BATOD). Professionals were asked to provide study information to other potential participants, who were invited to contact the lead researcher directly to find out more. Parents who expressed interest in participating were contacted directly by the lead researcher. All families were contacted in person to provide further explanation of the study and to answer any queries before taking consent and demographic information.

2.2. Data collection and analysis

The study used both quantitative and qualitative methods of data collection to investigate potential differences in behaviours with and without radio aid use, to explore parents' perceptions of the benefits and challenges of radio aid use with a pre-school child and provide an insight into the experience with a view to informing prospective users.

2.2.1. Daily Activity Log

Daily diary sheets were adapted from Mulla (2011) and used each day by families to record situations where they had used the radio aid. Parents were asked to record perceived benefit in each situation by circling 'Yes, No or Not Sure'. Data captured through

1 The term "deaf" is used throughout this report to refer to child/children with any degree of hearing loss as defined by the National Deaf Children's Society and Action on Hearing Loss.

2 Note: Responsibility for introducing and managing the radio aid during the study belonged to the child's local Teacher of the deaf (ToD), Educational audiologist or parent. The Ear Foundation audiologist was available for queries.

these diary sheets were inputted into Microsoft Excel 2013 and analysed to produce descriptive statistics and graphs.

2.2.2. Client Oriented Scale of Improvement (adapted)

An adapted version of the Client Oriented Scale of Improvement (COSI) questionnaire (Dillon, James et al., 1997) was used to compare perceived changes when using the radio aid in five identified situations. Parents were requested to note their child's hearing ability and the degree of change in each situation when using the radio aid. Data captured through the sheets were inputted in to Microsoft Excel 2013 and analysed to produce descriptive statistics
and graphs.

2.2.3. Listening Questionnaire

The listening questionnaire was designed to focus on any differences in listening in a range of situations and environments when using a radio aid compared to when using the hearing technology on its own. The questions were adapted from the FM Listening Evaluation for Children questionnaire (DeConde Johnson, 2003), the Early Listening Function questionnaire (Anderson, 2002) and a section was set aside for the detection of Ling 6 sounds (aa, ee, oo, mm, shh, ss) (Ling, 1989). The questionnaire was completed by parents and ToD. The completed questionnaires were inputted into Microsoft Excel and scores were analysed to produce descriptive statistics and graphs.

2.2.4. Language Environment Analysis (LENA)

The LENA digital language processor (DLP) (Figure 1) is a battery powered all-day recorder weighing less than 60 g that can be securely snapped into the chest pocket of children's specially designed clothing (www.lenafoundation.org). The device has a single microphone which remains 7-10 cm from the child's mouth whilst it is in place in the child's chest pocket. LENA records all the speech and environmental sounds which occur around the child during their normal daily activities providing information about the real-life listening and language environment.

Figure 1: LENA DLP

Families were asked to record a day without using the radio aid and a similar day with the radio aid about a week apart. A detailed diary sheet was used for each recording day.

The recordings were uploaded to the LENA software, which uses advanced speech recognition technology to analyse the audio file and work out the number of Adult Words, Child Vocalisations and Conversational Turns. Recorded and analysed data was compared with the daily diaries. Matched pairs were identified and checked for reliable comparison. Datasets were marked and matched for duration and situation. Word counts for marked datasets were inputted into Microsoft Excel 2013 and analysed to provide descriptive statistics and graphs.

2.2.5. Qualitative Interviews

Throughout the study parents completed a monthly Observation Diary; the diary consisted

of structured prompts to elicit parents' free text responses capturing changes, benefits or challenges of radio aid use in everyday situations.

At the end of the study, a semi-structured interview enabled parents to reflect on their experiences and share their personal perspectives of radio aid use. Using an Interview schedule and the parents' Observation Diaries to guide the conversation, interviews were conducted by the lead researcher face-to-face in the family home or via video or phone call where necessary. Interview transcriptions were analysed qualitatively using Thematic Network Analysis (Attride-Stirling, 2001). The interviews were transcribed and the responses were coded and organised into themes. The emergent categories were cross-checked independently by members of the research team.

2.3. Participant demographics

Participation in the study was open to children using any form of hearing technology. In total, twenty one families were recruited to participate in the study and of these, one used a Bone Conducting Hearing Implant (BCHI), two used cochlear implants (CI) and eighteen used hearing aids (HA). Thirteen families completed the study and eight families did not complete the study. Six of these eight used hearing aids and two used cochlear implants.

2.3.1 Reasons for not completing the study (n=8):

- No perceived additional benefit from using the radio aid: 3
- Inconsistent/ non-established hearing aid use: 1
- Issues with suitability and reliability of radio aid: 1
- Study required too much of the participant: 2
- Unknown reason: 1

Findings are primarily reported on those who completed the study (n=13)

2.3.2 Group demographics (n=13):

- Average age at start of study: 2;11 years (range: 1;5 years-4;2 years)
- Average age at diagnosis of hearing loss: 0;5 years (range: 0 years-2;0 years)
- Average age at start of radio aid use: 2;10 years (range: 1;4 years-4;2 years)
- Established users of radio aid prior to the study: 2 (15%)
- New users of radio aid: 11 (85%)
- Established radio aid users at end of study: 11 (85%)
- The average length of time of trial was 4 months (range: 4-6 months)

2.3.3 Individual demographics are presented in Table 1

Table 1: Individual demographics (n=13)

Participant number	Age at diagnosis (y;m)	Hearing loss[1]	Hearing technology	Age at start of RA use (y;m)	Radio aid system	Age at start of study (y;m)	Time in study (months)[2]
1	0;1	Moderate-Severe	Bilateral hearing aids	2;5	Phonak Roger Inspiro	2;4	4
2	0;0	Severe	Bilateral hearing aids	2;10	Phonak Roger Inspiro	2;11	5
3	0;2	Severe	Bilateral BCHIs	3;0	Phonak Roger Inspiro	3;2	6
5	0;1	Moderate-Severe	Bilateral hearing aids	2;10	Phonak Roger Pen	3;1	5
6	0;1	Moderate-Severe	Bilateral hearing aids	1;4	Phonak Roger Pen	1;5	5
8	0;2	Severe	Bilateral hearing aids	1;9	Phonak Roger Inspiro	2;0	5
9	0;0	Mild-Moderate	Bilateral hearing aids	2;0	Phonak Roger Pen	2;0	4
11	0;2	Moderate	Bilateral hearing aids	2;6	Phonak Roger Pen	2;8	4
12	0;9	Moderate	Bilateral hearing aids	3;5	Comfort Audio	3;6	4
13	2;0	Moderate-Severe	Bilateral hearing aids	4;2	Phonak Roger Inspiro	4;2	4
15	0;1	Moderate	Bilateral hearing aids	3;8	Phonak Roger Inspiro	3;8	5
16	0;0	Moderate-Severe	Bilateral hearing aids	3;4	Phonak Roger Inspiro	3;5	4
20	1;3	Severe	Bilateral hearing aids	3;3	Genie/ E-Clarity/ Roger pen	2;8	4

3.0 Findings

3.1 Daily activity log

Across all the participants, 468 Daily activity logs in total were completed. Across all the situations reported in the Daily Activity Log, the findings showed parents perceived clear benefits of radio aid use (Figure 2).

Figure 2. Overall perceived benefit of using radio aid in daily situations (n=468)

Parents reported using the radio aid in a wide variety of situations and activities (Table 2). For analysis, these were grouped into similar situations and activities, for example 'Pre-school group' included all types of groups involving both the parent and child in shared activities, such as singing or music. Activities involving noise and distance typically showed the greatest perceived benefit; however benefit was also perceived by some during less anticipated situations, such as during indoors 1-1 play.

Table 2. Parent perception of benefit in different situations and activities

Activity	Benefit	No benefit	Not sure
Outdoors (close)	85%	8%	6%
Outdoors (at distance)	89%	5%	5%
Car	89%	1%	10%
Buggy	100%	0%	0%
Nursery (indoors)	84%	9%	7%
Nursery (outdoors)	88%	0%	13%
Indoors (1 adult)	59%	14%	27%
Indoors (>1 adult)	77%	13%	10%
Indoors (at distance)	88%	13%	0%
Pre-school group	92%	0%	8%
Meal time at home	88%	0%	13%
Shopping	91%	0%	9%
Party	89%	0%	11%
Soft play	91%	0%	9%
Eating out	100%	0%	0%
Family gathering	100%	0%	0%

3.2. Client Oriented Scale of Improvement (adapted)

At the end of the study parents were asked to consider five situations; in the car, playing outside, during preschool activity groups, shopping in a busy place and whilst out and about in a buggy. They were then asked to rate any change they noticed when using the radio aid in that situation on a 5 point scale from 'Worse' to 'Much better' and also to report on the amount they currently used the radio aid in that situation (Figure 3).

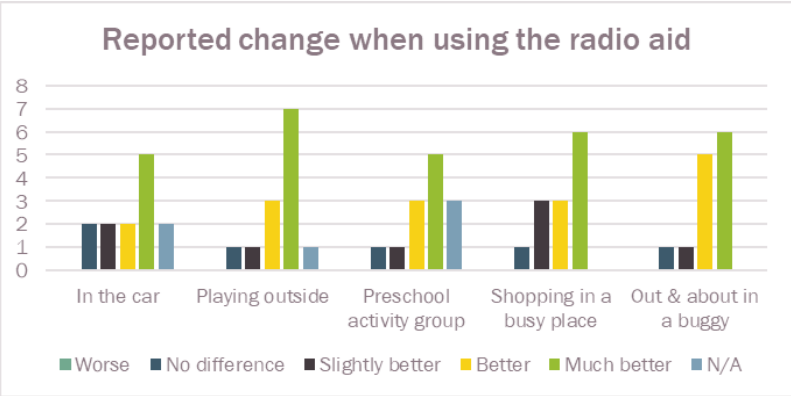


Figure 3. Reported change when using radio aid in specified situations (n=13)

Although parents were simply asked to rate 'change', they often provided more detail about what constituted that perception of change, often related to ease of communication, safety, improved child listening and responsiveness. Not all families perceived change in all situations, but none reported a situation as worse when using the radio aid. Figure 4 shows levels of current radio aid use in these situations.

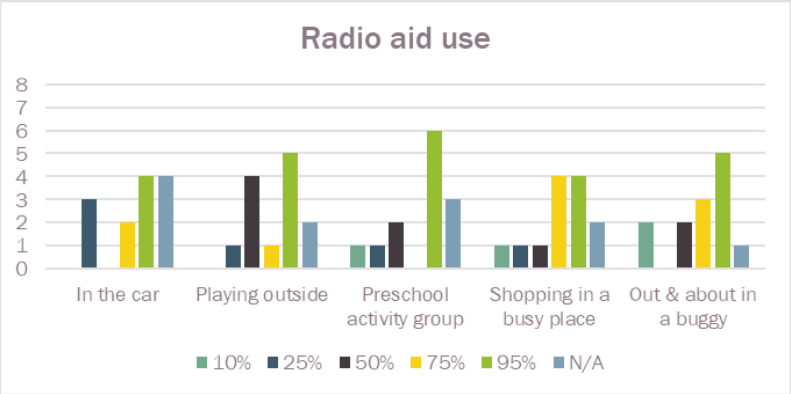


Figure 4. Levels of current radio aid use in specified situations (n=13)

By the end of the study, families seem to have decided in which situations the radio aid was useful and to what extent. Only two families no longer used the radio aid at all; having perceived little benefit, they had returned the radio aid equipment. The rest used the radio aid selectively according to individual perceived benefit.

3.3. Listening Questionnaire

Collectively, these assessments provided information about the child's listening skills. 46% (n=6) were completed by the parent and 54% (n=7) by the Teacher of the Deaf. Numbers for each measure vary due to some incomplete assessments. Results shown are based on the end of study assessment only.

3.3.1. Listening Evaluation

The child's listening for speech was assessed with and without the radio aid in four different listening conditions, Quiet, Noise, Auditory only and At distance, using a scale from 1-5 with 1 being "Seldom" and 5 "Usually". The scores showed improved listening in every situation when using the radio aid, especially in noise, auditory only and at distance (Figure 5).

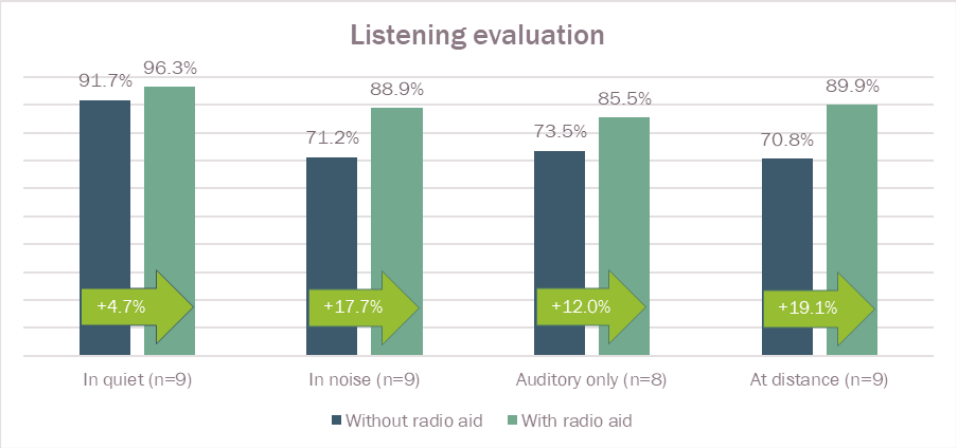


Figure 5. Changes in listening without and with radio aid in different situations

3.3.2. Listening Function (ELF)

Using a scale from 1-5 with 1 being "Seldom" and 5 "Usually", the ELF assessed whether when using the radio aid the child appeared more aware of voice and environmental sounds, readily searched for the location of the speaker's voice, used an increased amount of babbling/talking and had more interest in communicating.

Figure 6 shows that all the children were reported as being more aware of voice and able to locate someone talking when using the radio aid. Reports of changes to the child's babbling/ talking and interest in communication were mixed. There was little change to awareness of environmental sounds as might be expected.

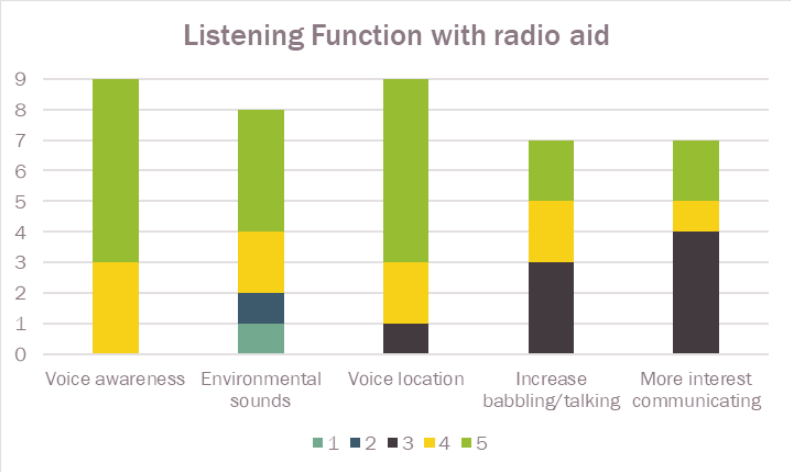


Figure 6. Listening function with radio aid

3.3.3. Ling 6 sounds

Figure 7 illustrates the number of Ling 6 sounds (aa, oo, ee, mm, shh, ss) correctly identified by the child in 'Quiet-close' (within 3 feet), in 'Quiet-at distance' (10 feet), in a 'Noisy room-close' and in a 'Noisy room-at distance' both with and without the radio aid.

Improvements can be seen in all these listening conditions when using a radio aid, most notably in quiet at distance and in noise both close and distant. Some children could already identify all sounds using only their hearing aids; however for those who did not, the gain with their radio aid ranged from 1 to 4 more sounds identified. For example, one child identified two Ling 6 sounds when using only hearing aids and six Ling 6 sounds when using the radio aid.

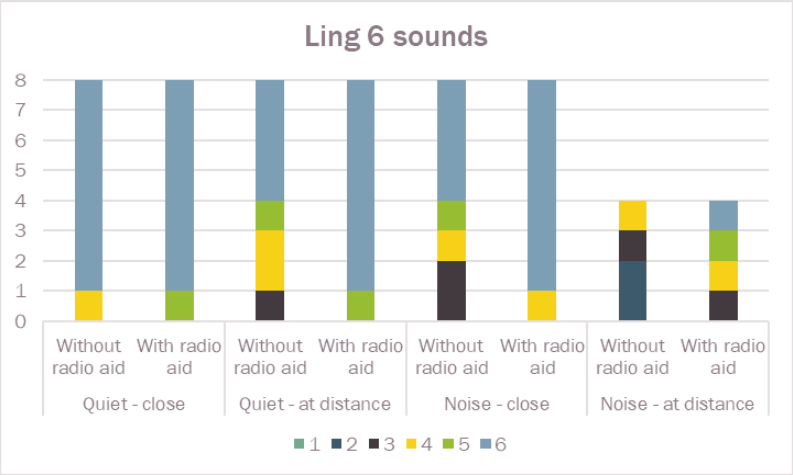


Figure 7. Ling 6 without and with radio aid in quiet and noise, close and at distance

3.4 LENA Paired recordings

Paired recordings consisted of a LENA recording on a day *without* using the radio aid and a similar day *with* the radio aid about a week apart. Thirty four pairs of similar activities were identified representing six different listening environments; in the car, indoors 1:1 with an adult, indoors with more than one person, outdoors, shopping and at nursery. LENA analysis estimates the number of Adult Words [3], Child Vocalisations [4] and Conversational Turns [5] during each identified activity.

Table 3 presents the cumulative totals comparing the counts of Adult Words, Child Vocalisations and Conversational Turns in each listening environment. Green arrows indicate the percentage increase with radio aid use and the red arrows indicate the percentage decrease.

Listening environment (No onf pair)	Adult Word Count			Conversational Turns			Child Vocalisation		
	Without radio aid	With radio aid	%	Without radio aid	With radio aid	%	Without radio aid	With radio aid	%
Car (7)	766	1994	+160% ▲	32	78	+144% ▲	255	309	+21% ▲
Indoors: 1-1 with an adult (6)	5746	6712	+17% ▲	300	401	+34% ▲	1270	1389	+9% ▲
Indoors: more than 1 adult (7)	4828	4399	-9% ▼	302	267	-12% ▼	1205	1292	+7% ▲
Outdoors (7)	1347	2587	+92% ▲	90	169	+88% ▲	554	733	+32% ▲
Shopping (3)	626	976	+56% ▲	42	66	+57% ▲	283	317	+12% ▲
Nursery (4)	1790	1572	-12% ▼	37	21	-43% ▼	155	267	+72% ▲

Table 3. Adult word count, Conversational Turns and Child Vocalisations without and with radio aid (n=number of paired recordings per situation)

Adult words, child vocalisations and conversational turns all increased when the child was using the radio aid in the car, indoors on a 1-1 with an adult, outdoors and when shopping.

However, Indoors with more than one person and Nursery demonstrated a different pattern whereby the adult words and conversational turns decreased, and the child vocalisations increased. LENA records sounds to or near the child and these are captured as "meaningful speech". As an adult moves further away from the child or where there is

3 Adult Word Count (AWC)= estimate of the number of adult words spoken to or near the key child

4 Child Vocalisation Count (CVC)= estimate of the number of key child vocal sounds (babble and words)

5 Conversational Turn Count (CTC)=estimate of the number of adult-child or child-adult interactions (a vocal sound initiated by the child or adult to which the other responds within 5 seconds)

more than one person around the child, their speech is analysed as “distant or overlapping”. In a busy listening environment with more than one adult talking, any adult words and conversational turns may not be included in the Adult Word count or Conversational Turns count. Importantly, for a child using a radio aid, he/she should continue to hear the adult words despite the distance and noise and this may explain why the child vocalisations continue to show an increase.

4.0 Interview findings

Thematic analysis produced six main overarching themes and sub-themes related to radio aid use.

Access to speech in daily life	Communica-tion & spoken language	Well-being	Practical considerations	Engaging with the technology	Choosing the right time

4.1 Access to speech in daily life

In noise	• Out and about • Managing extreme noise
At distance	• At home • Out & about
Where using a radio aid is less useful	• When you're close to the child • When you can control the background noise • Group situations or with lots of key speakers

4.2 Communication & spoken language

Hearing & listening	• Quicker & more consistent responses • Increased respnsiveness to speech • Increased respnsiveness without visual cues
Attention	• Actively engaged • Improved concentration & focus • Increased eye contact
Language	• Maximising language opportunities • Increased spontaneous communication • Two-way interaction
Speech	• Copying speech more readily • Clearer speech intelligibility • Changes to intonation, pitch & volume
Behaviour	• Within child • In relation to others

4.3 Well-being

Emotional	• A sense of confidence for children and parents • Feelings of self-consciousness
Psychological	• Increasing independence • Reducing parental anxiety
Social	• Joining in • Increased participation • Reduced isolation

4.4 Practical considerations

Choose a simple, reliable system	• Easy to use • Reliable
Wires	• The fewer wires, the better
Batteries	• Battery safey is an issue • Battery life is affected
Size, weight & visibility	• Wearing the receivers • Wearing the transmitter & microphone
Valuable equipment	• Responsibility • Inconsistent advice from insurers

4.5 Engaging with the technology

Knowledge of radio aids and how they might help	• Awareness & understanding • Expectations
Access to the technology is essential	• Access depends on local policies • Equipment must be suitable & reliable
Develop confidence with the technology	• Getting started • Confidence that it's working • Establish a routine
Find what works	• For your child • For you

4.6 Choosing the right time

"The right time": factors to consider	• As early as possible • Child's mobility • Speech & language development • Consistency of hearing aid use • Before starting education • When it's right for you and your child

4.1 Access to speech in daily life

Parents talked about how their child could hear and respond to speech more easily using the radio aid in situations, which would be more difficult using only their hearing aids. They gave lots of specific examples of these everyday situations, which had three overarching and often overlapping factors: in noise, at a distance, and the position of the child in relation to the parent.

4.1.1 In noise

For many parents, the main aim of a radio aid was to help their child hear better in noisy everyday situations:

> *P20: If we go somewhere noisy, like in shops, he has to be in the stroller [...] so it meant I could talk to him, whereas before he couldn't really understand what I was saying because he would have the noise of the shops*

Some parents noticed a difference even in fairly quiet situations or at home:

> *P5: On a one-to-one basis, I know he can hear me and is taking in what I'm saying, rather than having to try to hear me due to any minimal background noise eg story time, playing games*

Occasionally, noisy situations can be uncomfortable or distressing for children and difficult to manage. One family described how they used the radio aid to manage this tricky situation to enable their child to still hear and be comforted by them:

> *P3: We took her to [large busy shopping centre] and it quickly became obvious that she was struggling with the noise. She insisted on having hood up to block out the background noise, but using the system we knew she was hearing us. Sometimes we use the radio aid not just as a way to guarantee that she can hear us, but as a way to 'dampen down' extreme background noise*

4.1.2 At a distance

Parents described situations both in and out of the house where they wanted their child to be able to hear them at a distance:

> *P8: Any situation where there is a distance between us and [child][...] in a café or restaurant– whenever we leave the house [...] when we go to soft play, walking, when she is in the pushchair; there is always an option to use it outside*
> *P20: If his brothers ask where I am in the house 'mummy where are you?' I could say I am here and they could locate where I was [...] I can now say to him 'mummy's in the bathroom' whereas before he just couldn't do that*

Children are often in positions where they cannot easily see the parent's face for additional visual or lip reading cues, for example in a forward facing buggy or in a car seat in the rear of a car:

> *P9: [In the car] we do it because he can hear us, and he can hear everything clearly, and because our voices are that way, so if we need to talk to him, we need to turn around, which you can't always do; so if you talk directly into that [radio aid] you don't have to turn directly to look at him for him to hear you, [it] was really good for that*

4.1.3 Where using a radio aid is less useful

A few parents felt that it was always more useful to use the radio aid; however the majority described specific times where they had tried the radio aid and found it provided little additional benefit or their child did not like to use it. Limited benefit was also reported due to deteriorating hearing levels and this was the reason for one child being withdrawn during

the study.

4.1.3.1 Using the radio aid when you're close to the child

P6: If you are going to be close to [child] for a sustained period of time, then it's not always necessary. When in close proximity it can have little use as [child] can already hear us

One of the children withdrawn from the study was under 6 months old at the start of the study; although they used a radio aid with an older child, parents felt that they did not need to use the radio aid for the younger child who was not yet mobile and largely in close proximity.

4.1.3.2 Using the radio aid when you can control the background noise

P5: I have not used the FM system a lot at home, the reason for this is we always keep any additional noise to a minimum e.g. no TV in the background

4.1.3.3 Using the radio aid in group situations or with lots of key speakers

P5: During free play when his key worker was interacting with lots of different children

Interestingly, for the other family who did not complete the study, the parent reported that the child was hearing so well using her CI, that use of a radio aid (Mini Microphone) made no difference in any situation, so they no longer used it.

4.2 Communication and spoken language

The children in the study ranged not only in age and hearing levels, but also in their developmental stages; some used age-appropriate speech and language, while others showed some delay.

4.2.1 Hearing & Listening

Despite these different levels, all the children demonstrated changes in their hearing and listening when using the radio aid:

4.2.1.1 Quicker & more consistent response to speech

P2: [child] would look up or look round for me much quicker; more often when I call her name

P16: She is more responsive, a lot more responsive when I have worn the radio aid

4.2.1.2 Increased responsiveness to speech

For those children with still limited language, parents noticed increased responsiveness through the child stilling, looking, responding appropriately or making eye contact:

P3: [child] stills which is how we know [child] has heard us

P2: At home, she was much more aware of my voice and looking round for me

For those using language, parents noticed changes such as *joining in* with songs and rhymes, *copying* words and *answering or responding appropriately*:

P16: If she was engrossed in something and wasn't responding I'd say "can you hear me?" and she always shook her head, but I could tell as she would follow instructions quite quickly

P6: She will join in and sing songs so she can definitely hear us

P3: She attempts to sign back to us across the room in response

P12: [Child] pauses, looks around or responds using words in my question

4.2.1.3 Increased responsiveness without the need for visual cues

Others showed they were listening without the need for visual cues or lip reading:

P5: [Child] noticeably responds to instructions more, rather than following what his peers are doing. At stories he can sit further away but still show he is engaged by laughing or saying words [...] He doesn't always need to turn around to listen to you either whereas without it he does rely on you being at his level facing him so he can see your lip pattern

P20: Before he would have to wait for the song and the visual clues [...] he was able to participate quicker at the same point as his peers because he was able to hear what was being asked of him rather than waiting for the other things he had been relying on

4.2.2 Attention

Both parents and nursery staff frequently commented on the child's improved attention using the radio aid.

4.2.2.1 Actively engaged

They reported that the child seemed more actively engaged in activities and communication:

P16: The radio aid has helped in the sense that she will play- I'm not saying that she will sit and play for 10 minutes- but she is more engaged

P5: [Child] is so much more engaged [...] on specific tasks, whereas without it, his concentration and engagement is very limited

4.2.2.2 Improved concentration and focus

They described the child being more focussed and less distracted by other children or things going on around them:

> *P12: That's the biggest thing for us, him being more focussed*
> *P15: He's a lot more switched on; he used to get a bit bored and fidgety but now he's straight there, switched on, wants to listen. Now he comes home and tells me all about the story*

4.2.2.3 Increased eye contact

Children were reported to be watching others and demonstrating improved eye contact:

> *P15: Gain eye contact more often in general conversations directed at the whole class*

4.2.3 Spoken language

This study took place over 4-6 months, so few specific developments in communication were anticipated. However, important changes were noted, which parents often attributed specifically to radio use:

4.2.3.1 Maximising language opportunities

Parents spoke about how they made more out of everyday opportunities for communication in situations where otherwise their child had limited access to hearing speech and learning language.

> *P8: We are of the school of thought that we need to bombard her with as much language as possible and in circumstances where it is difficult to do that [...] we don't want to just accept that is dead time; we want to be able to still put the language into her ears*
> *P6: Normally at distance you wouldn't be talking to her. It gives that opportunity to continue to talk. We are trying to feed in as much as we can*

4.2.3.2 Increased spontaneous communication

> *P6: Speech-wise she is picking up on more, she is using more language because she can hear what we are saying more. She is definitely more vocal with it on, more likely to communicate*

4.2.3.4 Two-way interaction

> *P5: I think the first time I had it on, I was in the car with him, I actually had a normal conversation with him. It was so bizarre!*
> *P15: You can get a nice conversation out of him now when he's outside when it's really noisy and stuff [...] it's amazing, generally get a nice conversation out of him in the car now*

4.2.4 Speech

Speech and voice were not specifically assessed due to the short duration of this study; however parents noticed changes to important aspects of speech development, which are likely to be facilitated by improved access to hearing in a wider range of situations.

4.2.4.1 Copying more readily

> *P5: He copies words and phrases straight away and would appear he's being able to get the right sounds out*
> *P5: [Child] is definitely getting more and clearer access to sounds since having the*

radio aid. He is becoming more consistent in trying to relay a sentence. He copies words and phrases straight away and would appear he's being able to get the right sounds out. He wouldn't automatically copy [...] before when you would ask him to say something or a phrase, he wouldn't' even attempt to do it, but now he will actually try and say it straight away. It's really good.

4.2.4.2. Clearer speech intelligibility

P8: We feel her speech has gotten clearer over the last month of using the [radio] aid [...] She has been developing anyway, but she is better with articulation and sounds definitely.

P2: I did find at times it helped her to say certain words clearer [...] she would generally repeat it back correctly

4.2.4.3 Changes to intonation, pitch and volume

P16: Pitch seems to have moderated

P5: Less shouting

4.2.5 Behaviour

Parents reported changes in their child's behaviour both within-child and also in relation to others.

P5: He seems to be less angry and frustrated, probably because he hasn't got to try as hard to listen. It seems to have given him more confidence to interact

P20: It changed his behaviour in that he was able to participate quicker at the same point as the rest of his peers

P6: She's been more co-operative when asking her to do things

4.3 Well-being

Throughout their narratives, parents frequently reflected on issues of well-being; these included Emotional, Psychological and Social well-being.

4.3.1 Emotional well-being

Emotional well-being can be defined as "being happy and confident" (NICE, 2012).

4.3.1.1 A sense of confidence for children & parents

All families used the words "confident" and "confidence" throughout both interviews and diary entries both for themselves and their child and associated largely positive emotions with radio aid use. They also variously described their child as being more "alert, engaged, calmer" and less "angry, frustrated or anxious", for example:

> *P5: He panics and is worried when we go anywhere different, it takes him a while to feel at ease. In that respect it (radio aid) is a massive help*

This sense of being happy and confident was also apparent in the parents themselves

> *P16: I think it has made me more relaxed. For a parent it does help if you are happier and not stressed.*
>
> *P5: I feel personally as a parent a lot more confident when we are out.*

4.3.1.2 Feelings of self-consciousness

However, despite the generally positive reports, some parents described how their difficulties with the radio aid equipment impacted negatively on both the child's and their own well-being through feelings of self-consciousness:

> *P12: it made his hearing aids heavier and more noticeable [...] so for him, more people became aware that he has hearing aids; if we went to a café, there would be more kids looking*
>
> *P20: He got pointed at in classes [...] it was just awful [...] I am not embarrassed. I just don't want the extra attention. I just don't want other people looking at us*

4.3.2 Psychological well-being

Psychological well-being is described as "the ability to be autonomous" (NICE, 2012).

4.3.2.1 Increasing independence

Parents often described feeling more able to allow their child greater independence*:*

> *P12: It gives him that little bit more freedom [...] a little bit more independence. With the radio aid he was able to hold my hand and walk through town, he now has that independence about him*
>
> *P16: I was always worried about her doing things outside of the home and (radio aid) has given me more peace of mind*

4.3.2.2 Reducing parental anxiety

Many parents felt less anxious knowing that their child could hear them at a distance for safety, comfort and reassurance:

> *P6: Ball pools, soft play, before I wouldn't let her go in as I was so frightened of her not being able to hear me [...] I don't have to do that now*
>
> *P5: It is a massive, massive reassurance to walk down the street with him and know that he can hear me*

4.3.3 Social well-being

Social well-being is about "having good relationships with others" (NICE, 2012).

4.3.3.1 Joining in

Many diary entries, both from parents and pre-school group or nursery staff commented on the child "joining in more":

> *P15: Nursery say he's interacting much more with the other children and a lot with the adults*
>
> *P5: Definitely grown in confidence [...] wanting to communicate with both staff and peers*

4.3.3.2 Increased participation

In interviews, many parents reported that using the radio aid gave their child greater opportunity to take part in distant, busy or noisy situations/ activities with other people because they could listen for reassurance or direction whilst still being part of the larger group:

> *P8: If she is not being included because she can't access all the sounds and language and stuff that she needs, then (hearing aid) is not as effective as it could be [...] (radio aid) is a tool that could enable her to be more easily integrated with the other kids in a very noisy environment*

One grandmother reported on the new-found delights of playing Hide and Seek using a radio aid*:*

P20: When you are playing Hide and Seek, you build up the anticipation. A hearing child would be very excited and giggling [...] Before he would hide and he had no idea where (Grandma) was until she got there, so just building up the anticipation made the game more exciting, which all of his (hearing) brothers would experience. He hadn't experienced that before (using the radio aid)

4.3.3.3 Reduced isolation

A consequence of increased participation is reduced isolation; some parents commented on this:

> *P6: It stops her being insular and on her own. Over that distance, if there was background noise, she wouldn't hear us talking without it. It's nice for her to know that we are around her*
>
> *P20: Because he was sat in the back of the car, he couldn't hear or see our face, so he was almost completely isolated [...] out initial response (to the radio aid in the car) was that it was fabulous!*

4.4 Practical considerations

In this study, a variety of radio aid makes and models were used by families; one family (P20) tried three radio aid systems during the course of the study including two systems with wired receivers, so had a range of experiences to draw upon. Parents openly shared both positive and negative feedback about the practical considerations of using a radio aid with a pre-school child.

4.4.1 Choose a simple and reliable system

Parents valued simple systems that are easy to set up and explain to others, reliable and easy to check that they are working correctly:

> *P13: It was basically switch it on and it connects automatically. It's literally on, done*
> *P20: it is easy to use, the touch screen is easy to follow, really easy to use [...]. It just comes in and out of range, so I don't have to worry that it is switched off*

4.4.2 The fewer wires, the better

As described, a variety of radio aid systems were used in this study; some systems involve wires more than others.

> *P8: Having been given the one we have got with the cable and everything it isn't quite as easy- the cable can get tangled up*

4.4.3 Batteries

4.4.3.1 Battery safety is an issue

The most significant and recurrent concern was the lack of a locking battery compartment when the receivers are in place on the child's hearing aids. In fact for a few families, this affected the amount of use they made of the radio aid.

> *P8: We don't have the safety catch now [...] we have a bit of a worry about the batteries because it is very easy to open and take the battery out, which at nursery with her friends, is a little bit dangerous. We take them off in the car [...] if they were locked we would feel more confident leaving them in [...] that has been the biggest drawback*
> *P6: There hasn't been a problem with it apart from the worry of the batteries [...]. If they could make a way to secure the batteries that would be the biggest improvement*

4.4.3.2 Battery life is affected

Using a radio aid takes more energy from the hearing aid batteries.

> *P16: With the radio aid, it uses up the batteries really quickly so if she wasn't wearing the radio aid, we could go about 2 weeks, but with the radio aid I am changing them weekly. Whereas I get them free at the clinic, I have actually been buying them because I have been getting through them so quickly*

4.4.4 Size, weight & visibility

4.4.4.1 Wearing the receivers

Most parents reported no issues with their child wearing the extra receivers on their hearing aids and many parents chose to leave them on all the time; however it was a problem for some:

> *P2: The extra piece on her HA was heavy and would cause her HA to come unstuck from behind her ears when playing [...] She has been asking me more frequently to help her stick her HA back [...] so that is why I did not want to just leave them on. This has happened at home, when we've been out and also in the car. This has*

sometimes put me off wanting to use the FM

P12: It made his hearing aids heavier and obviously much more noticeable

4.4.4.2 Wearing the transmitter and microphone

Regardless of device, parents described their issues with wearing the transmitter and microphone:

P5: My only problem with the radio aid, I find it annoying! Having also a one year old and having to continually pick them up, the system can be knocked around

P3: We were quite conscious of it, when we first had it, and it was a really bit weird, when I was in a shop, and anybody noticed it, they maybe thought I was a secret shopper or something.

P2: I feel the whole FM receiver has too much to it for everyday/ all day use in terms of wires, ear piece and receiver and sometimes I would find it stressful using it because of this [...] I would have to take her HAs out and clip the piece on which when I'm a busy Mum is not very easy to do or quick. If it could be built into her HA without extra pieces clipped onto them and used without wires and bulky pack, it would be better/ easier as I know it would benefit her

They also shared concerns around wearing the equipment to make their child's listening experience pleasant and effective:

P1: You can't wear a necklace, I can't wear a scarf, it gets in the way

P1: If it's windy I don't [use it], I don't think she likes the wind.

4.4.5 Valuable equipment

4.4.5.1 Responsibility

Several parents referred to the value of the equipment and the responsibility of this:

P15: Sometimes I worry a bit [...] I think because they're quite expensive, I don't want him to take it out and throw it, it's kind of hard to judge that sometimes

4.4.5.2 Inconsistent advice from insurers

Parents were given differing advice about liability and insurance for the radio aid:

P8: We were told that we needed to speak to our insurer to make sure it is covered, so we are covered

P20: I spoke to my insurers and they wouldn't let me insure it because it wasn't mine, I didn't own it

4.5 Engaging with the technology

Engaging with or "buying-in" to the radio aid appears to be important for not only for trying it out, but also for continued use. Several factors emerged as important for engaging with the technology.

4.5.1 Knowledge of radio aids and how they might help

4.5.1.1 Awareness & understanding

Several parents had not heard about radio aids before joining the study; of those who had heard of them, their local ToD or organisations such as the National Deaf Children's Society or The Ear Foundation had been the source of information. Several thought that radio aids were just for use once a child started school:

> *P5: The radio aid, as I understood it, was only what they had at school [...] It was obviously something that was available, but we didn't really know a lot about them*

Most parents had a concept of what the radio aid would do, look like and what it was used for:

> *P8: Obviously the radio aid doesn't amplify, just makes your voice closer to her hearing aid*

4.5.1.2 Expectations

It seemed important that parents have realistic expectations of what the radio aid might offer as well as how to manage it; difficulties can arise when there isn't a clear understanding or expectation:

> *P9: There needs to be, it can't be a 'this is going to fix everything', it needs to be a 'this is going to help' [...]. I'm disappointed by my own expectation, not what it's actually delivered*
>
> *P2: I did not really know that much about it [...] I don't think I knew properly. I suppose I was thinking I'd just use it every day for all situations but then when I was using it, I did not find it very easy to use [...] And because I didn't really see it working really, really well for her [...] the benefit didn't seem huge enough, it just didn't outweigh, I just found it more stressful*

4.5.2 Access to the technology is essential

4.5.2.1 Access depends on local policies

Families in the study accessed their radio aids from their Local Authority Teacher of the Deaf or private providers. Some families considered taking part in the study, but were unable to access a radio aid because of local Education or Cochlear Implant service criteria/ protocols:

> *P8: It was a bit of a battle to get it. I think [...] she was 1½ coming towards 2. When we did get it, it wouldn't work with the first lot of hearing aids and we didn't start using it until September.*

4.5.2.2 Equipment must be suitable and reliable

Access to a suitable radio aid was also an issue, with problems such as reliability and wired systems:

> *P20: LOADS (of difficulties)! The wired system is MASSIVELY unsuitable for home use and those who do anything other than sit still.[...] They all have their pros and cons but for us as a family, without a doubt, the wireless one is best*

4.5.3 Develop confidence with the technology

Learning to use new technology can be challenging; parents in this study encouraged others to persevere and develop confidence over time.

4.5.3.1 Getting started

Parents valued the support of the professional in setting up and learning to use the device:

> *P15: My ToD had already set it up for me, and all I had to do was switch it on, and that was it. It was very easy*

4.5.3.2 Confidence in it working

Understandably parents need to know how to tell if the radio aid is working for their child:

> *P8: We were a bit reticent of using it at first [...] Once we got comfortable with it and we were confident that it was working all the time then it was pretty easy [...] Keep on using it until you are confident that it is working in the way you expect it to and then you won't be worrying about it*

4.5.3.3 Establish a routine

Most families admitted that it took a bit of time to use the radio aid consistently, but found it helped to establish a routine:

> *P5: There have been many occasions when I have walked out this door and got to the end of the street and thought I have forgotten his radio aid [...] but it is just getting into that routine*
>
> *P3: It lives in my handbag or her bag so if we go out somewhere it's already in the bag [...] everything get's put on charge every night anyway, it's just habit. Because it would be a nightmare if we ended up somewhere the next day and needed it and it was dead*

4.5.4 Find what works for you & your child

When asked about their top tips for using a radio aid, many parents encouraged an experimental approach to find out what works best for you and your child. The children themselves frequently demonstrated their preference and control even when they had little or no language, for example by choosing not to listen or indicating when they wanted or didn't want to use it.

> *P12: It's about not worrying about when and where; it's about just trialling it at different places and what works for you as an individual and not being fazed by it [...] Literally trial and error, when we went out, we'd just try it and if he liked it, we'd carry on and if he didn't like it, we switched it off, we'd wait a bit and then try again later [...] It is also knowing your child [...] If your child doesn't like it, try it again in a different setting*
>
> *P3: We are in general noticing that she is becoming aware of the system and in busy situations has indicated she wants it on. If at home we forget we are wearing it and it is still on she will come to us and try to turn it off*

4.6 Choosing the right time

All those who had tried the radio aid with their own child, were in favour of other children with hearing loss using a radio aid. Thinking about when would be the "right time" for children to start using it; parents came up with a range of things to consider.

4.6.1 As early as possible

P6: It would be nice to get a radio aid with the hearing aids initially really [...] I think the sooner the better really

4.6.2 The child's mobility

P1: As soon as they get mobile, as soon as they start running around and walking and going places that is an ideal age for them to have it [...] when they're becoming a bit more active, that's when it should be introduced. And I think every child should have one because they're really good

P3: Once they're older and you're worried about them going off walking, the safety part is really important.

4.6.3 Speech & language development

Some parents described the importance of early access to speech for spoken language development and the value of increasing that access through using a radio aid:

P3: But the whole thing [...] about making sure they can hear you clearly, for that speech development [...] at that age is really important.

4.6.4 Consistency of hearing aid use

Establishing consistent hearing aid use in a young child is a challenge experienced by most parents, often made worse when the child suffers repeated ear infections or has other medical or developmental needs. This study identified that when hearing aid use is inconsistent it can be a barrier to getting started with a radio aid, yet other studies have found radio aid use helped to establish hearing aid use (e.g. Mulla, 2011):

P12: I would say if a child was wearing hearing aids consistently, I think that is the time to introduce it.

4.6.5 Before starting education

Even parents, who reported that their main purpose for a radio aid was to use in nursery or school, felt that it was important for the child to become familiar with it before they started in education. They did not like the idea of introducing something new, like a radio aid, during times of change or uncertainty:

P1: Definitely before starting nursery so it's not a new thing when starting nursery as well

P16: I do think they should be offered them at nursery and also use it at home rather than keep it at the school, as it benefits children

4.6.6 When it's the right time for you and your child

When they had been happy with their radio aid experience, parents often described the "right time" as the one that they had experienced. Those who had wanted to have one sooner described that as the right time:

P5: I would have introduced it a lot sooner knowing how he copes with his hearing loss as it is now

Subsequently, they often reflected on this and suggested that earlier could be better; this usually came with a caveat suggesting that the "right time" is the one which is right for you

and your baby.

> *P20: Don't just sign up for it just as you have heard your baby is deaf, because you are going to need a couple of months to getting used to putting in the hearing aids and maintaining them [...] maybe get familiar and confident with their hearing aids and when you are alright with their hearing aids and confident with that then look into a radio aid*

However, early awareness and knowledge of radio aids was perceived as very important:

> *P12: It should be available as an option. The more you know, and the more options there are the better. If you start to close doors and you don't have them available to you and not presented those options, the doors are closed*

They recognise that all children and families are different and how, when and where a radio aid "works best" may differ.

> *P5: It might not be the right thing for everybody. I guess every child is different, hearing loss is different, different reasons, other things to consider. I know it won't be necessarily helpful for everybody, because everybody is different*

5.0 Discussion

The first few years of a child's life are a time of rapid and important development. During this time the foundations for communication are laid and for all children, language and interaction with their parents is critical to success. Hearing is an essential component of successful spoken language development and for deaf children, early and consistent experience of sound through appropriate amplification has been repeatedly shown as the major factor in developing spoken language (for example, Ching, 2015).

5.1 Everyday listening environments present a risk to learning spoken language: using a radio aid can reduce this risk

Learning occurs in all the routines and interactions of everyday life (for example, Beck and Flexer, 2011); however this study clearly illustrates that the life of a young deaf child is full of difficult listening situations which jeopardise language development, for example in the car, out and about, in a buggy or at social events such as parties and meals out.

Previous studies have reported improved listening responses with radio aid use in these challenging conditions (Gabbard, 2003; Moeller et al., 1996; Mulla and McCracken, 2014; Statham & Cooper, 2009; Webster, 2015). Both quantitative and qualitative findings from this study add to this evidence base for pre-school children, demonstrating that using a radio aid significantly improves a young child's listening for speech in noise, at distance and without visual cues. Improved listening was also observed and reported in quieter situations, such as during parent-child interaction at home. Concerns have previously been raised about a child's ability to develop sound localisation skills when using a radio aid; however this study suggests that young children are often more aware of people talking and able to locate the speaker with radio aid use.

Continued use of a radio aid over time indicates the benefit parents perceive for their child, having tried a range of situations and eliminated those which they did not find useful. End-of-study reports show the majority of parents found many situations were better or much better when using the radio aid and for the situations in which they found benefit, the majority used the radio aid 50-95% of the time.

Using a radio aid seems to be of benefit in the challenging listening conditions of daily life and may lessen their risk to spoken language development.

5.2 Using a radio aid facilitates important predictors of spoken language outcomes

Improved listening for speech with radio aid use is well-documented; however the link with spoken language outcomes has been inconclusive (Moeller, 1996; Mulla, 2011; Mulla & McCracken, 2014). This study provides a new and fascinating insight into how improving hearing for speech or audibility through radio aid use may help a young child to develop spoken language.

Hart & Risley (1995) demonstrated that the amount of language spoken by a parent to their child within the first three years of life partially predicts the child's language and academic achievement at 9 and 10 years. Deaf children receive a reduced amount of

language in difficult listening situations; to compensate for this, they require not only improved audibility, but also a greater quantity of linguistic input (Van Dam, Ambrose et al., 2012). This study substantiates existing evidence that using a radio aid improves audibility in noise and at distance, thereby providing the child with more of what parents are saying to them. In addition, it also suggests that when using the radio aid in some situations, adults used more words, increasing the important quantity of language. By recognising that their child can hear them when using the radio aid in challenging listening situations, this study also suggests that parents make more of everyday opportunities for language.

Parent-child interaction is also vital to language development (for example Zimmerman, Gilkerson et al., 2009; DesJardin & Eisenberg, 2007); however a child's reduced linguistic ability and lack of responsiveness can cause two-way conversations to break down. This study demonstrates that not only do parents report their child as responding more quickly and consistently to speech when using the radio aid, but also shows an increase in conversational turns in some situations. This suggests that when using a radio aid a young child is more responsive, which encourages parents to keep the conversation going, thereby increasing parent-child interaction as well as the quantity of linguistic input.

Demonstrating the increase in these predictive factors is a new and important finding and suggests radio aid use can be a contributory factor to successful language outcomes.

5.3 Radio aid equipment can be challenging

To achieve any benefits of radio aid use, the technology needs to be in place and used with confidence. However, this study highlights several issues with the equipment.

As long ago as 1996, Moeller reported the challenges of using radio aids, with parents reporting equipment as "bulky", "cumbersome", "visible" and feelings of self-consciousness. There have been many technological advances over the twenty years since that study but similar difficulties continue to be reported by parents. Unlike the Moeller (1996) study, parents in this study reported few issues of poor reliability or need for repair, perhaps reflecting the more modern technology. However the current families still complained of physical difficulties, bulky and uncomfortable equipment. Issues of wire entanglement and visibility continue to be a challenge, not only because they interfere with the physical activity of the child and adult, but also because they make both feel self-conscious. Parents are also extremely anxious about the safety of the devices, particularly the batteries. These issues impact on the well-being of the parent and can even reduce the amount of use of the radio aid, limiting benefit for the child. Integrated wireless devices are likely to address some of these issues, but currently their provision is limited.

Despite the challenges of equipment, most parents in the study persevered with using their radio aid suggesting that they perceived enough benefit from it to outweigh the difficulties.

5.4 Successful radio aid use requires timely and good quality information and support to maximise potential benefits for both child and family

Importantly this study highlights the impact of radio aid use on parents and children for their social, emotional and psychological well-being, the "building block for healthy

behaviours and educational attainment" (NICE, 2012).

Self-efficacy, the confidence and belief in one's ability to perform a task, is linked to successful outcomes; Meyer, Hickson et al. (2014) demonstrated this link in relation to hearing aid use and it could reasonably be assumed that the same would apply to using radio aids. Like Mulla (2011), most parents in this study showed confidence in managing a radio aid in daily life. Families also demonstrated self-efficacy through actively engaging with the radio aid, experimenting with what worked for them, persevering through difficulties and making decisions and choices.

Self-efficacy is improved by being well-informed, having a clear understanding of the purpose, benefits and challenges of the task, appropriate expectations and receiving both practical and emotional support (Meyer et al. 2014). This study highlighted that where there was uncertainty or a lack of confidence in the equipment and its benefit for the child; this had a negative impact on well-being and was linked with less consistent use.

Findings also showed that using a radio aid will be a different experience for every family. Best practice guidance supports self-efficacy by recommending that "professionals promote the process wherein families gain the necessary knowledge, information and experiences to make fully informed decisions [...] in response to the child's or family's changing abilities, needs, progress and emotional well-being" (Moeller, Carr et al, 2013) and that information provided to families should be" unbiased, comprehensive, clear accessible and accurate" (National Deaf Children's Society, 2017).

Whilst provision of radio aids to pre-school children may be focussed on improving listening and spoken language outcomes, successful use requires effective and positive support through well-informed choice and genuine collaboration between parents and professionals with up-to-date knowledge and skills.

5.5 Early radio aid use may improve outcomes and reduce disadvantage

Current legislation has a clear focus on early intervention and improving outcomes. There is no clear understanding of what 'early' means in relation to radio aid use; however the National Deaf Children's Society Quality Standards (2017) recommend that "every deaf child should be considered as a potential candidate for provision with a personal radio aid as part of their amplification package, at first hearing aid fitting". In this study, the parents largely supported 'early' use and whilst their views on the most appropriate time to introduce a radio aid varied, they all agreed that a radio aid should be introduced before the child starts full-time school. Regardless of age, once they became aware of radio aids and the potential to use one, all the parents were keen to try it and all would recommend that other families try a radio aid with their pre-school child.

The Equality Act (2010) requires local authorities and education settings in Great Britain to make reasonable adjustments to ensure children with hearing loss are not disadvantaged; this includes a duty to provide "auxiliary aids" when needed and to make proactive reasonable adjustments before the child is substantially disadvantaged. Despite these recommendations, access to radio aid use at home is not equitable across the UK and there are inconsistent criteria and protocols for radio aid provision (Allen et al., 2016).

This study provides strong evidence for the advantages of early radio aid use supporting

the introduction of consistent protocols and provision.

5.6 Using a radio aid in nursery requires careful management

Radio aids are widely used in schools and the benefits have been reported for many years (for example Ross, 1992). Although nurseries are noisy environments and there are clear reasons for improving SNR, the dynamics of the nursery setting are different to those often experienced in a classroom. In this study, radio aid use was largely reported as beneficial in group activities where the child was primarily listening to only one key speaker, such as the group leader. However, less benefit was perceived in group situations with more than one key speaker or where the adult was quickly changing between conversations with more than one child. Adult word count and Conversational turns also decreased in these situations; as previously explained this result may be due to the limits of LENA's recording distance.

Overhearing speech is beneficial for language learning and research has highlighted children as young as 16 months of age can learn language by overhearing two adults conversing without any form of scaffolding (Floor and Akhtar, 2006). Although this can be positive when the child is playing on their own and a parent/ key speaker is wearing the radio aid transmitter; in nursery settings and group play, the dominant speech signal coming from the radio aid can inadvertently mask out important speech from peers or other nursery staff.

Similar to parents, any staff who use a radio aid need information and practical guidance to understand and implement it effectively and appropriately.

6.0 Conclusion

This study shows clear and quantifiable benefits of radio aid use with pre-school children. The findings substantiate existing knowledge about the challenging listening environments of young deaf children and the benefits of improved SNR in noise and at distance. These findings demonstrate that radio aid use facilitates the important predictors of improved language outcomes, audibility, parent-child interaction and quantity of words. They also provide a new insight into the impact of radio aid use for these children and their families and provide a substantial evidence base for informing professional practice and commissioning decisions.

7.0 Recommendations

- **All parents of a young deaf child should be informed of the significant potential benefits of radio aids and have the opportunity and support to use the technology at home**
  Parents with a newly diagnosed deaf baby need to understand the importance of hearing speech to the development of spoken language and the challenges of everyday listening environments. Introducing radio aids as a tool in their child's hearing management raises their awareness and gives them options to consider. Evidence-based information helps parents to have appropriate expectations of the potential uses and benefits of radio aids.
- **Access to radio aids should be equitable for all pre-school children**
  Recognising the long-term benefits of early intervention for language and communication and the subsequent impact on educational achievement, this current evidence supports early introduction and equitable access to radio aids for pre-school children. To ensure equity for all deaf children who would benefit; consistent criteria and protocols need to be developed and implemented and UK Governments and local authorities should ensure adequate funding is provided.
- **Professionals should be knowledgeable about managing the latest technologies**
  Technology changes rapidly. Teachers of the Deaf and Audiologists need to remain up-to-date on the latest technologies available and how best to fit them.
  Teachers of the Deaf and Audiologists need knowledge of the latest evidence-based information in order to support the introduction and use of radio aids with pre-school children.
- **Manufacturers should respond to the identified needs of children and families in everyday life**
  Parent experience of using radio aids with young children continues to indicate issues and concerns with the equipment, which limit its access and use. Manufacturers of radio aid equipment need to understand and address these important real-life concerns about the technology.

8.0 List of Figures & Tables

Figures

Tables

9.0 References

Allen, S., Ng, Z.Y., Mulla, I.M. & Archbold, S. (2016). Pre-school children and FM/RM systems. (The Ear Foundation confidential report to the National Deaf Children's Society).

Allen, S., Ng, Z.Y., Mulla, I.M. & Archbold, S. (2016). Using Remote Microphone technology with young children: the real-life experience of families in the UK, British Academy of Audiology, 10-11 November 2016, Glasgow, UK.

Anderson, K. L. (2002). Early Listening Function: Discovery tool for parents and caregivers of infants and toddlers.

Attride-Stirling, J. (2001). Thematic networks: an analytic tool for qualitative research. *Qualitative research*, *1*(3), 385-405.

Beck, D. L., & Flexer, C. (2011). Listening is where hearing meets brain. *Children and Adults. Hearing Science*, *18*(2), 30-35.

Brackett, D. (Ed.). (1992). *Effects of early FM use on speech perception. In M. Ross (Ed.) FM auditory training systems: Characteristics, Selection and Use*. Timomium, MD: York Press.

Bradley, J. S., & Sato, H. (2008). The intelligibility of speech in elementary school classrooms. *The Journal of the Acoustical Society of America*, *123*(4), 2078-2086.

British Educational Research Association (2011). Ethical guidelines for educational research.

Brown, R. F., Hullar, T. E., Cadieux, J. H., & Chole, R. A. (2010). Residual hearing preservation after pediatric cochlear implantation. *Otology & Neurotology: Official Publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, *31*(8), 1221.

Ching, T. Y. C. (2015). Is early intervention effective in improving spoken language outcomes of children with congenital hearing loss? *American journal of audiology*, *24*(3), 345-348.

Cole, E. B., & Flexer, C. (2015). *Children with hearing loss: Developing listening and talking, birth to six*. Plural Publishing.

Crandell, C. C., & Smaldino, J. J. (2000). Classroom acoustics for children with normal hearing and with hearing impairment. *Language, speech, and hearing services in schools*, *31*(4), 362-370.

DeConde Johnson (2003). FM Listening Evaluation Checklist. Revised from Gabbard (2003).

DesJardin, J. L., & Eisenberg, L. S. (2007). Maternal contributions: Supporting language development in young children with cochlear implants. *Ear and hearing*, *28*(4), 456-469.

Dillon, H., James, A. & Ginis, J. (1997). Client Oriented Scale of Improvement (COSI) and its relationship to several other measures of benefit and satisfaction provided by hearing aids. *J Am Acad Audiol 8*:27-43.

Eisenberg, L. S., Shannon, R. V., Martinez, A. S., Wygonski, J., & Boothroyd, A. (2000). Speech recognition with reduced spectral cues as a function of age. *Journal of the Acoustical Society of America, 107*(5 I), 2704-2710.

Equality and Human Rights Commission. Equality Act. 2010. Available at: www.legislation.gov.uk/ukpga/2010/15/contents (Accessed: 15.5.2017).

Floor, P., & Akhtar, N. (2006). Can 18-Month-Old Infants Learn Words by Listening In on Conversations? *Infancy*, *9*(3), 327-339.

Gabbard, S. A. (2003). *The Use of FM Technology in Infants and Young Children. In Fabry D & Johnson CD Achieving Clear Communication Employing Sound Solutions.* Stafa: Phonak AG.

Glyde, H, C. S, Dillon, H., Hickson, L. and Seeto, M. (2012). The effects of hearing impairment and aging on spatial processing. *Ear and Hearing 34* (1), pg 15-28.

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Paul H Brookes Publishing.

Jones, C., Launer, S., Seewald, R. C., & Bamford, J. M. (2010). Pediatric fittings in 2010: The sound foundations cuper project. In *A sound foundation through early amplification 1020: Proceedings of the Fifth International Conference* (pp. 187-192).

Klatte, M., Lachmann, T., & Meis, M. (2010). Effects of noise and reverberation on speech perception and listening comprehension of children and adults in a classroom-like setting. *Noise and Health*, *12*(49), 270.

Ling, D. (1989). Foundations of spoken language for hearing impaired children. Washington, DC: Alexander Graham Bell Association for the Deaf.

Meyer, C., Hickson, L., & Fletcher, A. (2014). Identifying the barriers and facilitators to optimal hearing aid self-efficacy. *International journal of audiology*, *53*(sup1), S28-S37.

Moeller, M. P., Donaghy, K. F., Beauchaine, K. L., Lewis, D. E., & Stelmachowicz, P. G. (1996). Longitudinal study of FM system use in non-academic settings: Effects on language development. *Ear and hearing*, *17*(1), 28-41.

Moeller, M. P., Carr, G., Seaver, L., Stredler-Brown, A., & Holzinger, D. (2013). Best practices in family-centered early intervention for children who are deaf or hard of hearing: An international consensus statement. *Journal of Deaf Studies and Deaf Education*, *18*(4), 429-445.

Mulla, I. (2011). 'Pre-school use of FM amplification technology', PhD thesis, The University of Manchester. Availible at: https://www.escholar.manchester.ac.uk/uk-ac-man-scw:138160 (Accessed: 30.06.2017)

Mulla, I., & McCracken, W. (2014). Frequency Modulation for Preschoolers with Hearing Loss. In *Seminars in Hearing* (Vol. 35, No. 03, pp. 206-216). Thieme Medical Publishers.

National Deaf Childrens Society (2017). *Quality Standards for the use of personal radio aids.* Available at: http://www.National Deaf Children's Society.org.uk/document.rm?id=9697 (Accessed: 15.5.2017).

National Institute for Health and Care Excellence (NICE) (2012). *Social and emotional well-being: early years.* Public Health Guideline [PH40]. Available at: https://www.nice.org.uk/guidance/qs128/chapter/List-of-quality-statements (Accessed: 15.5.2017).

National Insitute for Health and Care Excellence. (2016). Early years: promoting health and wellbeing in under 5s. Quality Standard (QS128).

Pimperton, H., & Kennedy, C. R. (2012). The impact of early identification of permanent childhood hearing impairment on speech and language outcomes. *Archives of disease in childhood*, archdischild-2011.

Ross, M. (1992). *FM Auditory Training Systems Characteristics, Selection and Use*. Timonium: York Press.

Sininger, Y. S., Grimes, A., & Christensen, E. (2010). Auditory development in early amplified children: Factors influencing auditory-based communication outcomes in children with hearing loss. *Ear and hearing*, *31*(2), 166.

Statham, C., & Cooper, H. (2009). Our experiences of introducing FM systems in the early years. *BATOD Association Magazine (January)*, 18-20.

Thibodeau, L. (2010). Benefits of adaptive FM systems on speech recognition in noise for listeners who use hearing aids. *American Journal of Audiology*, *19*(1), 36-45.

VanDam, M., Ambrose, S. E., & Moeller, M. P. (2012). Quantity of parental language in the home environments of hard-of-hearing 2-year-olds. *Journal of deaf studies and deaf education*, *17*(4), 402-420.

Vohr, B. R., Topol, D., Watson, V., St Pierre, L., & Tucker, R. (2014). The importance of language in the home for school-age children with permanent hearing loss. *Acta Paediatrica*, *103*(1), 62-69.

Webster, G. (2015). FM+. *BATOD Association Magazine (March)*, 31-33.

Wood, S. A., Sutton, G. J., & Davis, A. C. (2015). Performance and characteristics of the Newborn Hearing Screening Programme in England: The first seven years. *International journal of audiology*, *54*(6), 353-358.

Yang, W., & Bradley, J. S. (2009). Effects of room acoustics on the intelligibility of speech in classrooms for young children. *The Journal of the Acoustical*

Society of America, *125*(2), 922-933.

Yoshinaga-Itano, C., Sedey, A. L., Coulter, D. K., & Mehl, A. L. (1998). Language of early-and later-identified children with hearing loss. *Pediatrics*, *102*(5), 1161-1171.

Yoshinaga-Itano, C. (2000). Successful outcomes for deaf and hard-of-hearing children. In *Seminars in Hearing* (Vol. 21, No. 04, pp. 309-326). Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA.

Zimmerman, F. J., Gilkerson, J., Richards, J. A., Christakis, D. A., Xu, D., Gray, S., & Yapanel, U. (2009). Teaching by listening: The importance of adult-child conversations to language development. *Pediatrics*, *124*(1), 342-349.

(Footnotes)

1 As reported by parents and Teachers of the deaf.

2 The time in study is based on the start date of the first assessment (mostly Daily Activity Log) and last assessment (Listening evaluation).