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Study of FM in Real World Settings

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Introduction

There is evidence that the provision of personal FM systems is inconsistent and inequitable across the UK (RNID, 2002; FM Working Party, 2008). The provision of FM systems has traditionally been via Educational services, whereas hearing aids are provided through National Health Service provision. This situation is no longer tenable in view of the advances in hearing aid technology. Activating FM and ensuring functionality for each individual deaf child is appropriately set up is part of the programming of the hearing aid which educational professionals do not, generally, have the equipment or training to undertake. Design integrated FM receivers are increasingly commonly available and have potential advantages, but choosing these (by educational staff) is not always an option as educational staff do not select the hearing instrument which is to be fitted, or is a less attractive option because when the hearing instrument will be changed is someone else's remit (paediatric audiology staff). As a wider range of devices become available increasing the potential for connectivity (e.g. mobile phones, Ipads, MP 3 players) FM systems potential to enrich the life experience of deaf children is significantly increased, with the option of life style choices being significantly enhanced. Viewing FM systems as purely 'educational aids' to facilitate inclusive practice, as is common with the UK, is an outdated and unnecessarily limiting approach to the provision of this important technology.

The benefits of personal FM in improving speech discrimination on noise has been well documented but is limited to non UK research and currently fails to take into account developments in both hearing instruments and FM technology. Additionally the potential benefits from personal FM, reducing listening effort or fatigue have not been investigated at all. The views of deaf children, their parents, teachers and Teachers' of Deaf have not been explored or reported. Research which has been undertaken is based on a didactic teaching approach or clinical tests which fail to take into account 21st century teaching approaches in the UK which are dynamic, complex listening environments.

This study investigated the listening environments in which deaf children are being educated, it looked in detail at classroom management of FM amplification, it considered the effect FM amplification on dual task performance in quiet and noise, sought to understand the self reported experience of deaf children using FM and to provide an opportunity to explore user views-that of individual deaf children, their parents, Teachers of the Deaf and Educational Audiologists. It looked in detail at the practice of teaching in mainstream education together with measures of signal to noise rations. This challenges the approach taken in much of the research and suggests that deaf children are in a much more complex listening environment than has previously been identified.

In order to try to ensure that the methodological approach taken was rigorous and robust a detailed literature review was undertaken across a range of areas including: paediatric use of personal FM amplification; classroom acoustics, dual task paradigms, paediatric focus groups, reported class room benefit of amplification. Consideration of the literature was the baseline upon which the methodological approach was built.

<u>Classroom acoustics</u>

The importance of an acceptable acoustic environment to facilitate learning within school classrooms has been established and minimum standards that govern signal to noise ratio and reverberation times exist (British Association of Teachers of the Deaf, 2001). Children require a higher signal-to-noise ratio (SNR) than adults to enable effective speech comprehension (Ng et al., 2011) . In this context SNR refers to the level difference between the wanted teacher speech signal and all other unwanted signals in the classroom. In a learning environment it is likely that much of the speech signal will contain content which is novel to the listener. Thus, the listener is less able to draw upon contextual cues which may be available with more familiar speech topics. Background noise (and therefore SNR) has been found to affect academic performance and can have a deleterious effect upon multiple aspects of learning such as attention and behaviour (Crandell and Smaldino, 2000).

Several experimenters have examined the effect noise has upon speech reception. Blandy et al. (2005) found that normal hearing children required a SNR greater than

-4 dB to achieve a Bench, Kowal and Bamford (BKB) word test score of 71%. The detrimental effect of noise has been found to be greater in children with hearing impairment compared to those with normal hearing. Crandell (1993) found that children with mild hearing loss had unaided mean BKB scores of 53.8 % and 38.1% at -3 and -6 dB SNR respectively. Ng et al. (2011) recorded BKB scores in normal hearing and hearing impaired children focusing on the SNR required obtain a 50% score rather than tracking the 71% word score SNR threshold. However, it is possible to derive the SNR required to reach a 71% word score by examining the presented SNR performance functions. Ng found that an SNR of approximately 6 dB was required to obtain 71% word score in normal hearing children, which was 10 dB higher than Blandy's findings. The discrepancy between Ng and Blandy's findings is unclear. Nevertheless, Ng found that significantly higher SNR levels were needed to achieve 50% correct scores in hearing impaired compared to normal hearing children. Ng concluded that normal hearing children required a SNR of 5 dB greater than normal hearing adults to achieve equivalent speech test scores. Children with hearing loss require a further 4.5 dB greater SNR to obtain speech test scores equal to normal hearing children.

The importance of maintaining a high SNR ratio in classrooms, especially those that include children with hearing impairment, is clearly established (Bradley and Sato, 2008). Thus it is of importance to survey classrooms in order to determine if the required SNRs are being reached to enable an acceptable level of speech reception. It could be possible to increase speech reception in non-conforming classrooms by the use of assistive listening devices that can increase SNR at the children's ears. There is a plethora of published evidence examining the speech and noise levels in classrooms.

Sato et al. (2008) reported an average classroom SNR of 11 dB, which appears to suggest SNRs are on average near to acceptable levels. However, the reported range of classroom SNRs are wide, ranging from short term teacher speech SNRs of -19 dB to long term average of 35 dB (Markides, 1986, Pekkarinen and Viljanen, 1991). Variation of classroom SNR is to be expected due to the many different factors that can affect it, such as teacher voicing levels, and class activity. It is also important to note that a wide range of SNRs (-18 to 9 dB) were found across multiple measurement positions and activities within a single classroom (Larsen and Blair, 2008). The manner in which the speech and noise measurements were performed and the method of calculating SNRs was not standardised and could have led to the wide range reported SNR range. Thus, it is possible that the variation in SNR levels was partly, or wholly, due to the differing measurement methods and not just to the differing classroom conditions.

To date no study has aimed to specifically measure the SNR reaching the ears, or hearing aid microphones, of hearing impaired school-aged children. The overall aim of the work presented in this paper was to determine the acoustic experience of school-aged hearing-impaired children and to assess the possible benefit obtained from the use of radio aids (FM system). This paper discusses the efficacy of the alternative SNR analysis methods previously used to measure classroom SNR. In order to examine the methods a pilot analysis of a small subset of classroom recordings was performed. The overall aim of this analysis was to determine the optimum method for future use in the complete dataset.

Classroom signal-to-noise ratio measurement methods

Pearsons et al. (1977) surveyed speech signal and background noise levels in various environments including a total of twenty classrooms from two schools. They recorded classroom speech and noise from three microphones which were positioned on the teacher, at the front and back of the class. The class was instructed to continue their normal activity which included front of class teaching (lecturing), question and answer interactions and study periods without teacher/class interaction. The speech levels were calculated at 100 ms intervals during 10 second samples of the recordings. In order to visualise the distribution of the signal levels the sample levels were plotted on histograms. The speech levels were calculated from the mean level of the 100 ms intervals for each 10 second segment. The background noise levels in the classrooms were recorded during "normal activity" and during quiet periods of where the class and teacher were instructed not to speak. The mean level of speech was calculated for each sample period. The speech levels ranged between 67 and 78 dBA. The noise levels ranged between 45 to 55 dBA. The study concluded that the speech levels were on average 15 and 16 dB above the background noise levels for school one and two respectively. A secondary conclusion was that teacher speech levels increased linearly with increasing noise level, later experimenters describe this phenomenon as the Lombard effect (Junqua, 1993, Summers et al., 1988). This initial study set the founding basis from which further more sophisticated methods followed.

Markides (1986) aimed to determine classroom speech and SNR levels in schools for the deaf and special units in mainstream schools. Markides measured speech and noise levels using a sound level meter (SLM). Noise was recorded in three class situations. However, Markides did not present the measurement method in sufficient detail for it to be replicable. It is stated that the SLM was set in fast mode which normally has a 125 ms integration time (British Standards Institute, 2003). However, the duration of the measurements is unclear. In the speech measurement periods it is likely that the SLM reading fluctuated due to the modulated nature of speech. Similarly fluctuations are likely to have occurred during the noise periods. It is possible that single or multiple readings per classroom measurement period were taken and then averaged, but this information is not provided for the speech periods in two of the three class conditions. Nevertheless, Markides' method is potentially advantageous to the Pearsons et al. method as it considers three class conditions. The reported SNRs ranged between -24 dB for short duration noise, such as banging of doors and desks, to 12 dB in "quasi-stationary noise". However, in common with Pearson's work, the noise measurements were not made at time periods close to the speech. Thus, it is possible that although noise was measured in a variety of conditions, it may not have been representative of the noise during the actual speech periods.

Hodgson et al. (1999) describes an automated analysis method used to determine average speech and noise levels for long duration class recordings. Hodgson recorded university lectures using a digital tape recorder. In this paper the method utilised by Hodgson et al. (1999) shall be referred to as the "distribution fitting method". The speech and noise levels were calculated from two normal distribution curves fitted to the distribution of the levels of 200 ms segments of the recordings. The uppermost normal curve was said to be representative of the speech levels, and the lower distribution the noise. This method was advantageous as the speech and noise levels were derived from the same recording period rather than separate periods as in previously mention methods. However, since this analysis method was entirely automated the source of the signal level at each distribution point is unknown. It is possible that this method can adequately separate speech from static background noise such as ventilation and external class noise. However, it is equally possible the short duration noise from a modulated source, such as an interfering second speech signal, could mix with the upper distribution attributed to the speech source. Thus, it is likely that the method cannot correctly determine signal and noise level when both signal and noise are modulated and the SNR is insufficiently high to clearly and distinctly separate the two distributions. It is possible that the method will not give an accurate indication of SNR during periods in school classrooms where pupils interrupt or interact with the class teacher. In such situations at each time point it is unclear which sound source (teacher or child) is the signal. However, no account can be taken for this in the distribution fitting method.

Sato and Bradley (2008) utilised Hodgson et al. (1999) method in 15-20 minute school class recording periods where “the teacher talked quiet frequently”. Sato and Bradley (2008) stated that there are a wide range of noise sources in a classroom and that the distribution method could not be applied to open plan classrooms due to the possibility of the contamination of the speech distribution from the adjacent class teacher. However, the presence or absence of class interaction or interruption from children during the recording periods in not given. Thus, it is possible that whilst their SNRs may represent the average situation, shorter periods of poorer SNR were missed. Moreover, it is possible that in cases of negative classroom SNR the upper distribution could mistakenly be attributed to the signal when in fact it is noise. It is important to determine the worst case SNR so that action can be taken to ensure hearing-impaired listeners are not frequently disadvantaged compared to normal hearing peers. The authors hypothesised that this method could lead to an overestimation of SNR owing to the aforementioned factors.

Shaw (2008) described an alternative method of determining classroom SNR which is known as the “Sound Assurance” method. The Sound Assurance method was designed to measure the SNR experienced by hearing-impaired children in their classrooms to assure that the acoustic environment is acceptable for speech reception. In this method classroom audio is recorded using digital sound recorders. Speech utterances, and the noise surrounding it, are manually extracted from the digital recordings by an experimenter manually marking the periods of wanted speech utterances and unwanted noise using computer audio editing software. The speech utterance segments are said to represent the recorded level of speech plus noise. That is to say the noise that is present during the noise periods is said to be equally present during the speech utterance and thus it adds to the measured speech utterance level. The speech utterance level is derived by subtracting the noise level from the speech plus noise level. Since the speech and noise periods are determined by the experimenter, in contrast to the distribution fitting method, the source of the sounds level attributed to speech is more certain.

The sound assurance method is not precisely described and thus subject to variation. The selection of time periods from the recording is entirely subjective and the number and length of speech and noise periods are entirely unspecified. In a highly dynamic classroom it is possible that insufficient speech utterances from the various conditions are selected. Thus, the SNR is subject to experimenter bias. Furthermore, it is possible that during a dynamic classroom the periods marked as noise may not be truly representative of the noise present during the speech period. Moreover, deriving the true speech levels by subtracting the noise from speech utterance measurements is questionable. Figure 1 visualises the corrected speech level vs. the surrounding noise level for a hypothetical 70 dB speech utterance period. Figure 1 demonstrates that when the noise level is close to the measured speech utterance level the derived corrected speech level is dramatically reduced. Thus, the corrected speech level can be greatly reduced by small fluctuations in noise of just a few dB. If, for example, the true speech and noise levels were both 70 dB (0 dB SNR) the speech utterance period would be measured at 73 dB and the noise period at 70 dB. However, if the noise or speech in the speech utterance period fluctuated by just 2 dB, giving a measured speech utterance period of 71 dB, the speech level would be corrected to 64.1 dB. If the fluctuation was 2.9 dB the corrected speech level would be 53.7 dB. Thus, the possibility of underestimating SNR due to small fluctuations in speech and noise levels or small measurement errors exists. Furthermore, it is equally possible that the measured noise period level is higher than the measured speech utterance period level giving an incalculable noise correction subtraction and thus it must be that that level of noise was not present during the speech. In summary, whilst the sound assurance method appears to offer a number of advantages compared to the distribution fitting method, it has some potential flaws and the method is not clearly defined. Specifically, whilst the sound assurance method appears to be appropriate for static noise, and high SNR, it should be applied with caution for modulated noise sources such as interfering child speech. To date there is no published work that examines the use of the sound assurance method. Moreover, there is no published work that has compared each method on a set of classroom recordings. It is possible to apply the sound assurance and distribution method to a single set of classroom recordings. The analysis performed in this study aimed to examine the different SNR analysis methods that could be applied to classroom recordings

Use of personal FM amplification.

The use of personal FM amplification in improving speech discrimination in noise is well documented (see for example Anderson and Goldstein, 2004: Anderson, Goldstein, Colozin & Ingelhart, 2005; Boothroyd and Ingelhart, 1998; Brackett, 1992, Crandell Samldino &Flexer, 2005; Schaffer & Thibodeau, 2003). What is less well known is how well such equipment is used as any equipment is potentially exploited or limited as its management. Whereas in the USA for what are termed Remote Microphone Hearing Assistance Technology anyone managing such technology must be familiar with regulatory requirements under the Individuals with Disabilities Act (IDEA, 2004) The IDEA requires functional evaluation of the FM system in the child's environment and that performance is monitored (De Conde Johnson, 2008).In the UK the FM working party Quality Standards 2008 recommends best practice but there is no mandatory requirement that such practice is followed.

Validation of FM performance following the fitting and verification of an FM system is an on going process. Both the FMWG Quality Standards (2008) and the American Academy of Audiology guidelines (2008) provide detailed guidance on determining candidature, orientation and training, validation and on going monitoring. A range of tools are available for use in the validation process. The Listening Inventories for Education (LIFE) were developed by Anderson and Smaldino (1997). The LIFE student questionnaire was adopted and modified to the UK educational context with the addition of line drawings. It was used as part of the paediatric Modernising Children's Hearing Aid Services programme and then underwent a revision to reflect the specific assessment of hearing aid and cochlear implants for mainstreamed children and to incorporate feedback and analysis on the importance of speechreading for many children. The LIFE-UK IHP is freely downloadable (www.hear2learn.com).

FM technology is one of the tools that has actively supported the inclusion of deaf children within the mainstream education, in the UK currently 82% of deaf children are within mainstream education (CRIDE, 2012). This means that for the majority of these deaf children FM technology is being used by mainstream staff, both teachers and learning support assistants. As the technology has become increasingly sophisticated an increasingly wide range of listening possibilities are available. However, those making daily use of the technology to deliver the curriculum have minimal training in its use.

Responsibility for this training currently lies with Teachers of the Deaf (ToDs). Where responsibility for specialist provision has been placed with individual schools, rather than Sensory Services, access to this specialist training can be limited, as can the provision of FM in the first instance. The current situation in the UK is one where funding for FM systems has become fragmented and responsibility for provision of such equipment has in some cases been passed to the host school rather than the Sensory Service.

It is within this complex social, economic and political setting that the provision and management of FM technology currently sits in the UK. It was therefore important that this study took a broad view of the use of FM amplification and of any benefit gained.

Dual task paradigms

The ability of individuals to achieve the same level of performance on listening tasks across a variety of situations does not mean individuals expend the same amount of cognitive effort. It is likely that some are required to draw on cognitive reserves to overcome difficulties (Gatehouse and Gordon, 1990). Attentional behaviour and executive function (EF) develop across childhood and adolescence. Such development would appear to be non linear with growth spurts, different components potentially having different developmental trajectories (Anderson, 2003). EF is complex and multi-layered including a collection of interrelated processes that together are responsible for purposeful goal directed behaviour (Gioia, Isquith and Guy,2001). The principle elements include:

- anticipation
- goal selection
- planning
- initiation of activity
- self regulation
- mental flexibility
- deployment of attention

- utilisation of feedback (Anderson, 2003)

Working in busy classrooms children will be required to use make increasing use of the above skills. For deaf children in mainstream settings such requirements place additional pressure on children as they are hearing a degraded auditory signal.

Attention control, cognitive flexibility, information processing and goal setting are suggested to be key components of EF. Developmental trajectories of the executive domain are summarised in Figure 1 (from Anderson, 2003).

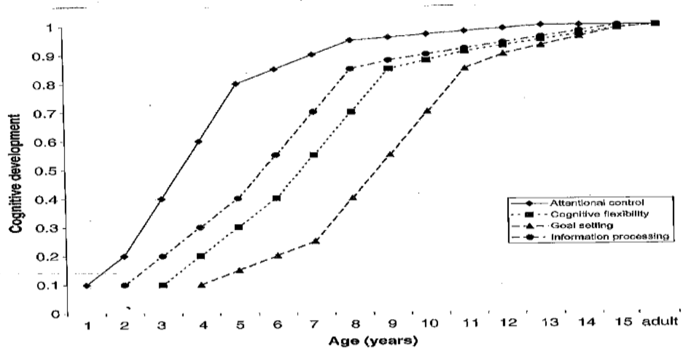


Fig. 2. Projected developmental trajectories of the executive domains.

Figure 1

There is no evidence if these skills follow a typical developmental trajectory in deaf children in either inclusive or specialist settings.

The ability to process simultaneously presented auditory and visual is one that is expected of all children in mainstream classes. Such auditory and visual information is a necessary component underlying many cognitive tasks. Word learning and effects of linguistic labels on categorization, induction and object individuation all hinge on the ability to encode and store arbitrary, auditory-visual pairings (Balaban & Waxman, 1997; Sloutsky & Fisher, 2004; Sloutsky, Lo, & Fisher, 2001; Welder & Graham, 2001; Xu, 2002). Clinical assessment of hearing aid benefit in controlled acoustic environments provide a baseline measure of benefit but fail to take into account the cognitive effort being expended by an individual child to gain a specific score. In respect of listening effort Goselin and Gagné (2010) suggest this refers to "the attention and cognitive resources required to understand speech". Hearing refers to the peripheral hearing system sensing sound, listening refers to hearing but also includes attention, and intention, an active process that involves reception and interpretation of meaning.

How deaf children allocate cognitive resources has been the subject of a number of studies. Hicks and Tharpe (2002) used a speech repetition task with a light probe made up of a three light emitting diode display with assessments in quiet and with multi-speaker babble at a range of signal to noise ratios(SNR), (quiet, +10, +15, +20 dB). Reaction times for the dual task were measured, (n=14). All assessments were undertaken in a controlled clinical setting. Children's ages ranged from 5-11years, the deaf children had mild to moderate or high frequency hearing losses, the control group had normal hearing. Cortisol measures from salivary samples and self reports were used as a measure of fatigue, (n=10). In the dual task although average speech scores were good for both groups, the reaction times for the deaf children were longer. This may be a result of increased effort being expended, it is the case that whist the signal may be audible to both groups the effects of noise are more significant to deaf children. The difference in reaction time was not statistically significant. There was similarly no significant difference in reported effort ratings.

McFadden and Pittman (2008) compared a group of 8-12 year old deaf children with a normally hearing group. The children had to complete a semantic task of categorising words into sets of animal, food or people. Words were presented in quiet and in noise at a signal to noise ratio of 0 and +6dB. The secondary task was a motor task that required completion of a dot to dot puzzle. The mean performance for both tasks was similar for both groups, performance fell on the secondary task and there was unaffected by the SNR on listening effort. These studies do not consider the effects of adverse listening conditions on stress, fatigue or reaction times despite the fact that the majority of deaf children are in mainstream education, working in challenging acoustic environments. Both use relatively favourable SNR and thus findings may not be representative of children working in typical classroom settings (Arnold and Canning, 1999).

In studying the effect of stimulus bandwidth on groups of 7-14 year olds; 24 children with a sensori neural hearing loss and 32 children with normal hearing, Stelmachowicz et al., (2007) employed a dual task paradigm. The primary task was word recognition, where the signal was filtered at either 5 or 10kHz bands, the secondary task was recall of a five digit string. The recall of digits was poorer when undertaken as a dual task with word recognition. There was no statistical difference on performance between the two groups on word recognition or the two bandwidths. The study was undertaken in a clinical setting with relatively favourable SNR.

Choi et al. (2008) investigated the ability of normally hearing children aged 7-14 years in a dual task paradigm, using word recognition and serial digit recall. The study focussed on the ability of children to allocate attention to a specific task. Groups were primed to attend to either the word recognition or digit recall as the primary task. Both groups showed a decline in digit recall possibly suggesting that they were unable to direct their attention to the primary task. The SNR used was +8dB, significantly better than that likely to be experienced in classrooms.

Howard et al, (2010) aimed to use the same basic design using AB word list and serial digit recall but using SNRs that were representative of classroom environments, (quiet,-4dB, 0dB, +4db). The test was undertaken by 31 normally hearing children aged 9-12 years. There was a statistically significant effect of SNR on speech recognition and task combination. Children showed a demonstrated a clear deterioration in the secondary task performance as the SNR deteriorated. Children were reported to be “less vigilant and more relaxed in for the speech in quiet task but demonstrated increased vigilance in noise. The tests were undertaken using headphones and therefore the effect of reverberation time will not have been taken into account. Additionally the authors point out that the use of pink noise rather than multi-speaker babble may have reduced the cognitive effort required.

A study of pupil dilation during a listening task (Zekveld Kramer & Festen, 2010) demonstrated that pupil response increases with decreasing speech intelligibility. The study indicated that pupillometry –an infrared videobased tracking technology, can be used to explore cognitive load during listening. However, this is an early stage of use in research and will require further testing before it could be used in a clinical setting. This study used a young adult hearing cohort.

This study required an approach that would be appropriate for children in the age range 7-15 years. As work would be undertaken in a wide variety of settings the equipment had to be portable, easy to calibrate and have face value for range of mainstream and specialist staff that would be allowing the research to be undertaken in their settings. In discussion with a Clinical Research Psychologist concerning the most appropriate way to tackle measuring cognitive effort the Sustained Attention to Response Task [SART] approach was suggested. SART [Robertson, Manly, Andrade, et al.1997] is a simple and brief computer assisted programme for assessing sustained attention over a short period of time. SART involves withholding a key press response to a one in nine target. This approach has been shown to correlate significantly with performance on sustained attention tasks but poorly with other types of attention. The researchers suggest that SART can therefore be used to study sustained attention. This is a simple task that requires the subject to press for all numbers except 3 when the response must be withheld. Sustained attention is defined as 'the ability to self-sustain mindful conscious processing of stimuli whose repetitive , non-arousing qualities would otherwise lead to habituation and distraction to other stimuli' [Robertson et al.ibid,p 747]. This test offered a simple, accessible task where the subjects could quickly and easily have the task explained and trialled. The major caveat is that there are no norms for children. SART was developed to study attentional failures in traumatic brain injury. It has been validated for gender, age and education [Chan, 2001] but this study considered young adults rather than children. SART met the requirements of being portable, easy to calibrate and to have face value with the staff at the host schools. Additionally the fact that this is a computer based approach was felt to be particularly appropriate for young subjects. It was therefore decided to approach the dual task by employing SART with the AB word list in quiet, noise and noise with FM.

Focus groups

Deaf children -the end users of FM systems -, parents of deaf children, Teachers of the Deaf and Educational Audiologists who have a significant impact on the use of FM have significant perspectives which have rarely been heard. It is recognised under the United Nations Convention on the Rights of Children 1989, Article 12 'Parties shall assure to the child who is capable of forming his or her own views the right to express those views freely in all matters affecting the child, the views of the child being given due weight in accordance with the age and maturity of the child.' A number of studies have used focus groups with children (Gibson, 2007;Morgan et al.; 2002; Michell, 1999). Studies stress the importance of pre-meeting information that clearly explains the purpose and allows children as far as possible to make a choice about participation. Consent forms both prior to meeting and again on the day of the focus groups is recommended. The literature varies on the ideal group size with most recommendations relating to adult studies. Morgan et al., 2002 suggest that a focus group may vary from 2- 5 with larger groups being harder to focus, to transcribe and noisier, similarly very small numbers (2) may result in a serial interview with each participant spoken to in turn. All agree that the facilitator is the key to ensuring the balance of power is maintained and that all contributions are recognised. The importance of setting ground rules, of structured warm up activities, of adequate time and rest periods and the provision of opting out being available need to be taken into account. A range of activities can be used to actively involve children are suggested including role play, fantasy wishes, puzzles, visual prompts and drawing (Kennedy et al., 2001; Coad and Lewis, 2004: Veale, 2005 and NEFC, 2005).

Methodology

This was a multi-site study that aimed to represent a wide variety of educational settings, deaf children from a broad cultural, socio-economic background in order to best represent deaf children in England. Ethical approval of the study was granted by the Directorate of Children's Services. A total of fourteen educational authorities were approached as potential participants in the study. Families and deaf children were approached via educational audiologists in these authorities. The majority of children were in mainstream education, so schools also had to be contacted individually, once permission was obtained from the Head of Sensory Support Services in each area. Of the fourteen services originally approached one withdrew prior to the start of the research as a result of service re-organisation pressures, and two joined but failed to engage any families in the study, one failed to follow up because of work pressure. The 10 remaining services were closely with the research team throughout. This resulted in a group of 85 deaf children being recruited to the study. All children recruited into the study have English as their first language, had no other identified disability that affected their learning and were fitted with post aural aids and FM systems. In addition to gaining parental permission, it was necessary to gain permission from the host school for testing to be undertaken during school time.

A mixed methodological approach was taken to ensure that the study captured rich data that represented both the measurable and the reported benefits and challenges relating the use of FM amplification

For all children baseline data regarding degree of hearing loss, age of first fitting, Fitting protocol used, type of aids and FM system were requested. Additionally Speech in Noise (SPIN) data was requested on all children as recommended by the FM working group QS, 2009.

In order to meet with confidentiality issues all questionnaires were sent out for distribution to the Educational Audiologist in each area. Instructions for the Educational Audiologist and Teachers of the Deaf were included to try to ensure that the approach taken was as standardised as possible. For the LIFE Teacher Appraisal of Difficulty, a request was made for distribution to two mainstream teachers or one teacher and one Learning Support Assistant (LSA) who was familiar with the deaf child working with them at least twice a week over the last term. All documents were anonymised and were placed in a sealed envelope once completed. In addition to the questionnaire respondents were asked to comment on ease of completion, practicality and any training issues. Two copies of LIFE UK IP questionnaire were sent for each child marked with FM and without FM. The order of questionnaires was randomly generated, and made clear in the pack. It was requested that questionnaires given three days apart in order to minimise the possibility of students skewing the results. Instructions clearly stated that if this was not possible they should contact researcher by mobile phone to discuss how to approach this situation. It was requested that nil returns to be recorded if pupil had not experienced any of the situations for any perceived ‘significant’ length of time during the past term. A quiet room free from other pupils with the Teacher/TA opposite child with face towards and light source. To ensure children did not feel under any pressure to give “right” response it was requested that a shield was in place to prevent teacher/TA observing responses. In addition a cover was used to ensure only one question and reponse was visible at any time to the student.This was aimed at increasing pupil confidence to be honest and to reduce the possibility of pupils following (or otherwise) a pattern without careful consideration of each new situation. The adult administering the test was asked to avoid directing or giving any kind of overt reaction to a response, especially where they consider the pupil may be recording a response which they disagree with. They were asked to prompt is a child appeared to be off target and to simply respond with a thank you to all responses made. Children were told to mark with a cross any situations that they were unfamiliar with or unable to comment on for any reason. A request was made that the provided script to be read exactly to all pupils, with explanation to older pupils about the necessity for this because of the age range (7-16 YRS).

From the total cohort a sub group of 40 children were identified by their educational audiologists, teachers of the deaf and school settings as being able to be actively involved in the study. This group included primary and secondary children with a small number in specialist provisions but the majority being in mainstream educational settings. Subjects were aged 8 to 14 and had a permanent sensory-neural hearing loss. Subjects had bilateral hearing aids provided through the National Health Service (NHS) and radio aid (FM system for classroom use) provided by the education system. The data obtained for eleven of these children has currently been analysed. Subjects included four children (two classes) who attended a special educational status primary school. Four subjects attended mainstream primary schools and three subjects attended mainstream secondary schools.

Recording Procedure

School classroom visits were made to one classroom session for each child. In two cases two of the recruited children were in the same class and therefore 9 classroom visits have been analysed. The classroom and class lesson type was uncontrolled and were chosen by the educational audiologist responsible for each child.   The classroom visited depended upon the possible available times and the cooperation of the class teachers, school timetable and head teacher. Classroom activities varied both between and within class sessions.   No attempt was made to control the type of class activity the recordings took place in. The type of classroom activity was noted throughout the duration of the class visit.

Class sessions were recorded using digital sound recorders at two positions. The first position, which shall be referred to as the “teacher recording” was a Stennheiser MKE-2013 lavalier microphone positioned at an equal distance to the radio aid microphone from the teachers’ mouths (approximately 14cm). The class teacher also used the radio aid transmitter as they would normally do so with each child. The microphone was connected to the external input of a Zoom H1N recorder worn in a small bag strapped around the teachers’ waists. The second recording position was made as close as possible to the child subjects within the classroom. The second recording, which shall be referred to as the “class recording”, was made using a Stennheiser MKE-2013 lavalier microphone connected to the external input of a Zoom H4N recorder. Where possible, the second channel input of the Zoom H4N was connected to the output of an FM radio aid receiver to enable the FM transmission to be recorded. The class recording microphone was placed on the top of the pinnae of an adult experimenter. This microphone position is close to the normal position of BTE hearing aid microphone. The adult sat as close to the child as possible and moved around the class with the child as appropriate throughout the lessons. The class recording was not placed upon the children’s own ears as it was felt this was likely to disrupt their normal learning. Moreover, if the microphone position were positioned on the child it could have interfered with their hearing aids due to the proximity of the lavelier microphone and associated wire connection to the hearing aid microphone. The recorders were calibrated at the start of each class by recording a calibration track from the output of a 94 dB SPL 1 kHz calibrator with the input level set to -24 dB on the recorder input level meter. The Zoom H1N and Zoom H4N recorded 24 bit samples at a sample rate of 44.1 kHz. The noise floor of the recorders was tested by recording silence in a sound treated room with an ambient noise level of 22.2 dBA measured on a Class 1 SLM and was found to be 33.7 dBA.

Recording times varied between classes, we aimed to record one entire class session for each child where possible. The shortest and longest recording times were 30 and 60 minutes respectively. The two recordings (class and teach) of each classroom were not precisely synchronised as two separate digital records were used without a synchronised time code signal. Cross-correlation between the segments of the two recordings revealed that the audio recordings drifted by approximately 1 ms per minute. This equates to 0.7 samples per second difference which is an error of 0.002 %. Thus, this drift was attributed to the normal variations between the oscillators recording clock generators (presumably crystal oscillators) of each device.

In some cases the class included periods of group work or work directed by other class room assistants in the room. In such cases the teacher recording microphone remained with the main class teacher and thus a recording close to the source of the teacher (instructor) sound was not available during those time periods. The recording at the teacher position enabled easy identification of teacher speech during class periods of poor SNR and provided information as to the input levels into the radio aids to determine the possible SNR advantage. The recordings were made at the child positions to enable the signal-to-noise ratio at the child's ear to be approximated.

The classroom and teacher recordings were analysed to determine the SNR of the class teacher speech near to each child's position in the class and at the teacher microphone placed near to an FM microphone to examine the possible SNR achievable from received FM stream. It was not possible to determine the precise SNR at the receiver end as it is not possible to perform SNR analysis of the received FM transmission. The transmitters utilise compression and expansion to enable wide dynamic range of signal levels to fit into the narrower FM transmission dynamic range which is limited due to transmission channel bandwidth. In the recorded received FM audio the relationship between signal level during speech and level during noise is uncertain due to the likely differing amount of gain applied to the relatively louder signal and relatively quitter noise periods. It is not possible to determine the precise SNR at the child's ear as the hearing aid mixes microphone and FM received signal. It could be possible to determine this by programming an additional hearing aid as a clone of each child's aid and analysing SNR from recordings of the hearing aid output in a coupler within the classroom. However, such an experiment would most likely lead to erroneous results due to the compression of the FM transmitter (expansion of receiver) and the compression of the hearing aid. In general the nonlinearity could lead to underestimation of SNR. This analysis and experimentation was outside the scope of the presently discussed work.

Classroom recordings were analysed using two methods. The first method was based upon the methods described by Hogdson et al. (1999) which was more recently utilised by Sato and Bradley (2008) in elementary school classrooms. The first method is the distribution fitting method described in the introduction above and detailed below. The second method was an adaptation of a manual method utilised and described by Shaw (2008) detailed below. The analysis methods were applied to both the class and teacher recordings for each class.

<u>Deriving speech level from recordings</u>

In each of the analysis methods, discussed in the introduction above, it is possible to derive an estimate of speech level by subtracting the measured sound pressure level during the noise periods from the sound pressure level found during the speech periods that contain both speech and noise. This correction method was suggested by Shaw (2008) in the Sound Assurance method. This correction method is demonstrated in Figure 2 which shows the corrected speech level versus noise levels for a measured signal and noise period of 70 dB A. Previous experimenters, such as Hodgson et al. (1999) and Sato and Bradley (2008), who examined teacher speech levels, noise levels and determined classroom SNR by use of automated distribution fitting methods, did not perform such a correction. It is therefore possible that in those aforementioned studies the SNR was overestimated. However, at favourable SNR conditions where the noise is 10 dB or greater below the speech level, the corrected speech level differs by less a small margin of less than 1 dB. However, in situations where the noise level is close to speech, the corrected speech level, and thus the SNR, can vary considerably as demonstrated in Figure 2 Corrected speech level for 70 dB signal + noise measurement vs. noise levels It is also worthy of note than when speech and noise levels are close (i.e SNR is close to 0 dB) measurement errors, due to fluctuations in speech and noise levels, can cause the situation where the sound pressure level of the measured speech and noise period is less than the sound pressure level during the noise period. In such cases it is impossible to derive speech levels, as the level of noise found surrounding the speech cannot have been present during the speech. In this present work such instances did occur and in such cases the SNR was assigned to be –10 dB for the purpose of analysis.

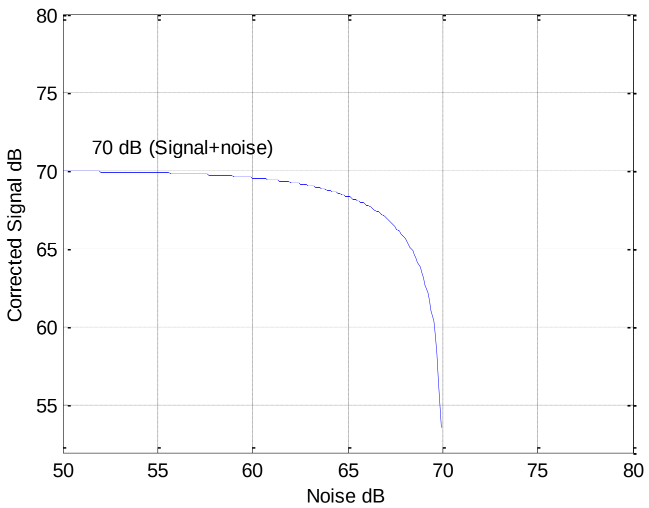


Figure 2 Corrected speech level for 70 dB signal + noise measurement vs. noise levels

All analyses were scripted in MATLAB. The digital audio samples were imported in to MATLAB and analysed using the Distribution fitting (DF) method and a Modified Sound Assurance method (MS) which are defined as follows.

<u>Distribution fitting method (DF)</u>

Two separate DF analyses were performed. The first analysis examined the SNR over the full duration of each class recording. The second analysis examined the SNR in one minute segments at ten minute intervals of the recordings. The DF method was based on the method used by Hodgson et al. (1999).   The RMS sound pressure levels in dB A were calculated for 200 ms segments within each analysis window (i.e. one minute segment or full recording time). The distribution of the sound pressure levels was plotted on a histogram and two normal distribution curves were fitted to the frequency distributions of the sound pressure levels. The upper distribution was attributed to speech and noise period and the lower to noise. The analysis was performed for the full spectrum and for 18 1/3 octave bands. Speech, noise and SNR were derived from the mean of the two normal distributions.

Modified Sound Assurance method (MS)

The modified sound assurance method (MS) involved a manual analysis of the recordings. One minute segments of the recordings at ten minute intervals were analysed. Time positions of the speech utterances of teacher speech were marked using audio editing software. These marked positions were considered to be speech periods (speech and noise, from which speech level is derived). The time positions were imported into MATLAB which calculated the dB SPL levels within the marked speech periods. There were two types of noise considered in the one minute segments. The first noise level was calculated from all time positions within the one minute segment that were not marked as speech. The noise level was calculated in MATLAB in the same manner as the speech level. The second noise type required a further manual analysis of the recordings. The time positions of the noise during the one minute segments were marked using audio editing software, periods where a speech signal was heard that was not the class teacher but could be considered as signal were excluded from the second noise time positions. These noise positions are referred to as noise 2. Noise 2 positions, for example, excluded periods of child speech answering teacher questions to the class. MATLAB calculated full spectrum sound pressure level and sound pressure level in 18 1/3 octave bands.

Focus groups.

All parents and children initially invited to be involved in the project were asked to register their interest or otherwise in attending a focus group. Invitations to attend focus groups were sent to all families who had registered an interest at this early stage. Separate invitations were sent to parents and children. Although focus groups were planned at a variety of venues and times, including weekends response was extremely low. It became evident that parents might consider that they did not know anything significant about FM, or that their comments might not be considered to be relevant, especially where FM systems did not go home.

A new information sheet that made the importance of all contributions was then circulated. Suitable venues had to be physically accessible, to exert no pressure to respond in a particular way, to make respondents feel relaxed and feel valued. Whilst one special school setting was used all other meetings were in hotels where the facilities actively helped families and deaf children feel they were being invested in and valued. Consent forms were completed prior to attending. Prior to attending a short activity required each attendee to identify three things they liked and three they did not like. This acted as a warm up activity where all attendees including the researchers shared likes and dislikes. Posters that stated house rules were shared with the whole group to ensure attendees understood all contributions were welcomed, valued and anonymous. A further consent form was completed with the opportunity for children to complete these with the support of a ToD who remained neutral and accepted the child’s response even when this meant a session could not be audio recorded. The parent and child groups were then split and rules reiterated before recording of the session began. 14 families choose to be involved in the focus groups. Children were given the option of drawing responses, had the opportunity to talk individually about their feelings to a video camera, or to use post it notes and a special box to post thoughts anonymously. It was made absolutely clear to all children that we would not share their comments with their parent. All session were consent was given were audio/video recorded. In the session where a child did not want to be audio/video recorded field notes were taken by an observer. All recording were transcribed and thematically analysed using NVIVO 9 sort and retrieve software.

RESULTS

Of the 14 Local education authorities approached the 10 that did joint the study gained permission from parents to join the study as demonstrated in Table 1.

Table 1: Subjects joining the study by area

County	Frequency	Percent
Bolton	4	4.7
Cheshire	9	10.6
Dorset	10	11.8
Hertfordshire	9	10.6
Oxford	13	15.3
Salford	5	5.9
Somerset	10	11.8
Staffordshire	10	11.8
Surrey	5	5.9
Warwickshire	10	11.8
Total	85	100.0

Whilst the primary aim of the study was to consider mainstreamed deaf children the recruitment of 85 children included a number from Special Schools for the Deaf, Table 2.

Table 2: Spread of school provision attended by subjects

Child School type	Frequency	Percent
Primary	37	43.5
Secondary	35	41.2
Special Primary	4	4.7
Special Secondary	9	10.6
Total	85	100.0

In order to check that the study sample was representative of deaf children in England a comparison was made with CRIDE 2012 statistics, see Figure 3

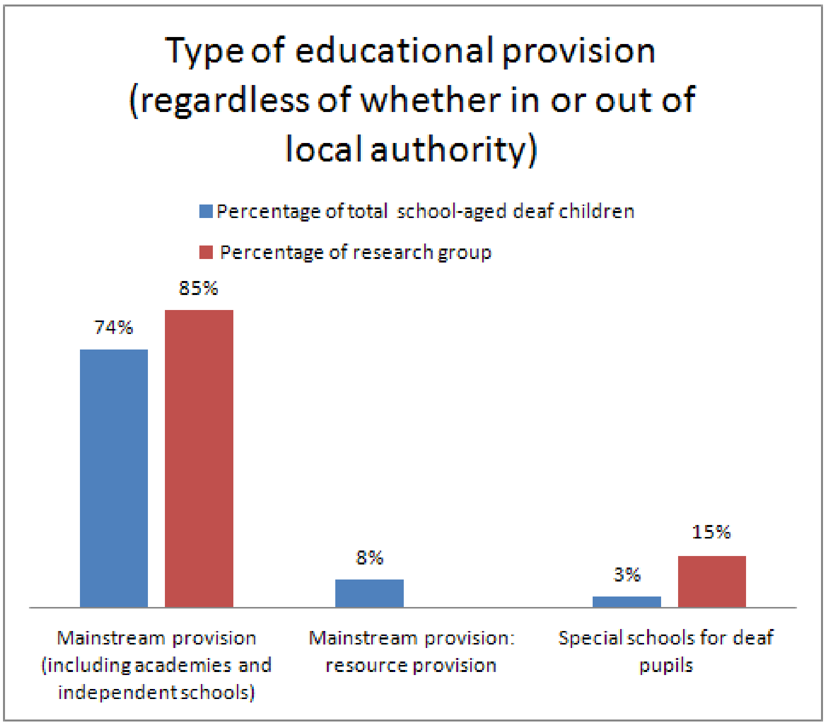


Figure 3

Educational provision of study sample compared to CRIDE 2012 data

The introduction of the Newborn Hearing Screening Programme has seen the age of identification of permanent hearing loss reduced to 8 weeks. This cohort is predates the introduction of NHSP and as illustrated Figure in this group were predominantly late identified with several children being very late identified.

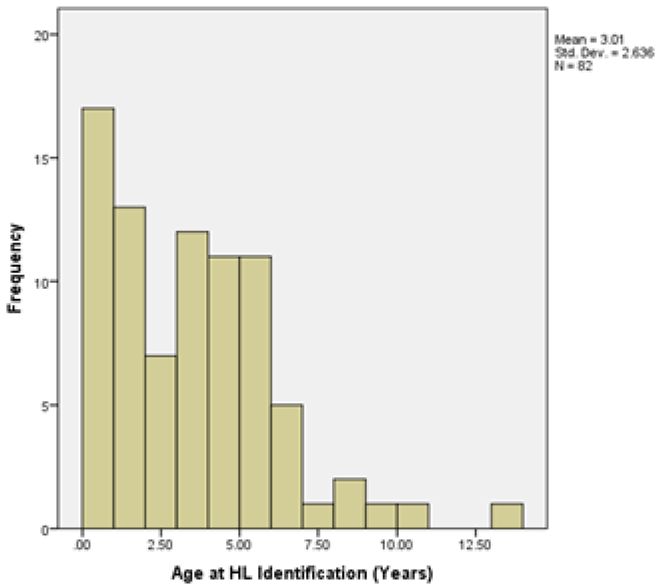


Figure 4

This is an interesting group who demonstrate a wide range of hearing loss but who are predominantly late identified. **Error! Reference source not found.**

Figure 5. Pure tone average of study group

School Type			Frequency	Percent	
Primary	Valid	Mild	13	35.1	
		Moderate	17	45.9	
		Profound	1	2.7	
		Severe	6	16.2	
		Total	37	100.0	
Secondary	Valid	Mild	7	20.0	
		Moderate	17	48.6	
		Severe	11	31.4	
		Total	35	100.0	
Special Primary	Valid	Moderate	2	50.0	
		Severe	2	50.0	
		Total	4	100.0	
Special Secondary	Valid	Moderate	5	55.6	
		Severe	4	44.4	
		Total	9	100.0	

The late identification of hearing loss was naturally also associated with late fitting of amplification, as demonstrated in Figure .

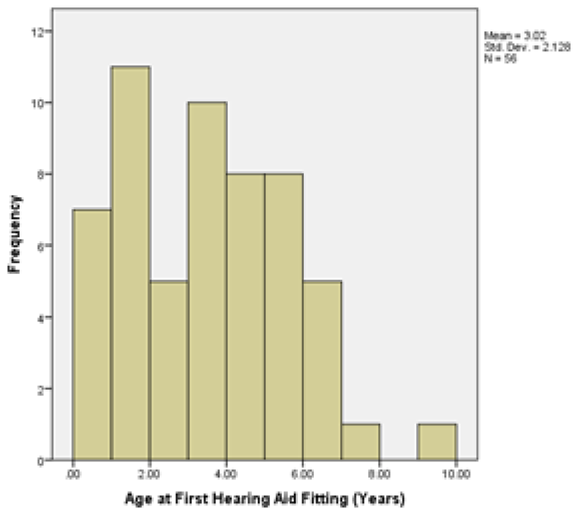


Figure 6

A wide range of hearing aids were fitted. All of these hearing aids are provided free at the point of delivery by Healthcare services,Table 2.

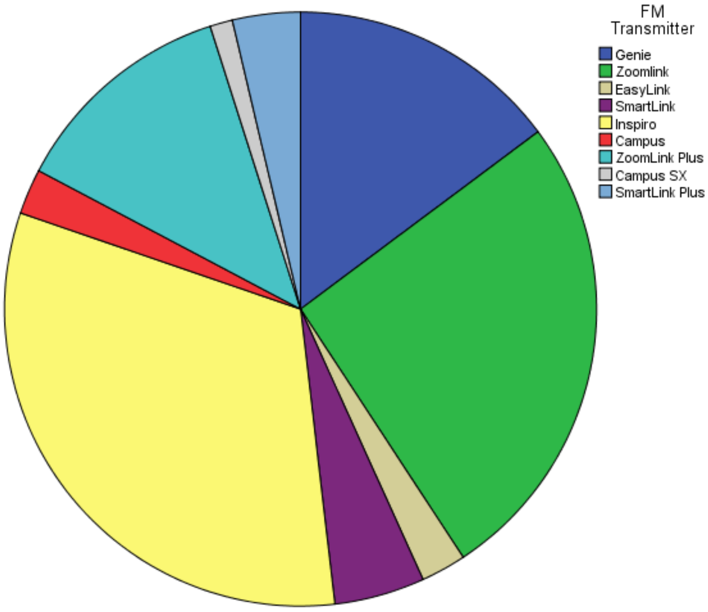
Table 2

		Frequency	Percent		
Valid	Not Aided	1	.6		
	Spirit3D	19	11.2		
	Spirit3D VC	4	2.4		
	Spirit 3P	5	2.9		
	Spirit Zest	25	14.7		
	Spirit2P	2	1.2		
	Zest P	1	.6		
	Mini Zest	1	.6		
	Prisma 2 Pro	2	1.2		
	Naida UP	4	2.4		
	Naida V SP	15	8.8		
	Niada V UP	7	4.1		
	Naida SP	19	11.2		
	Super Power	1	.6		
	Nathos Micro	12	7.1		
	Nathos SP W	2	1.2		
	Nathos Micro W	2	1.2		
	Nios Micro V	4	2.4		
	Eterna 211	4	2.4		
	Eterna 411	2	1.2		
	Eterna 411 dAZ	8	4.7		
	Eterna 311 dAZ	14	8.2		
	Eterna 211 AZ	2	1.2		
	Eterna 211 dAZ	14	8.2		
	Total	170	100.0		

The majority of children were using wireless FM. Some authorities prefer to use bodyworn FM with primary aged pupils. Such systems are easy to check and verify with personal aids and less easy to loose. There are significant cosmetic issues that parents reported were problematic for their child. Such systems may provide a good signal but such systems are heavy and cumbersome to wear. Parents felt children were clearly stigmatised when using bodyworn systems and despite the concerns of professions regarding reliability and ease and cost of loosing the wireless receiver, parents wanted their child to feel relaxed, confident and one of the class group.

A range of transmitter options were used across the study group. These are summarised in **Figure** .

Figure 7



Children used a variety of FM receivers, predominantly MLXi, MLXs but also including direct audio input shoes with lead to body worn Genie receiver. Thus the diversity of age of idenfitication, degree of hearing loss, type of personal aids and FM systems in addition to underlying aetiology, the family dynamics, the learning styleof each child make this a heterogeneous group, typical of a cohort of deaf children.

CLASSROOM STUDY

Detailed classroom observations were undertaken in 32 classrooms. This included 14 mainstream primary school classes, two special primary (school for the deaf) classes, 12 mainstream secondary school classes, and four special secondary (school for the deaf) classes. Minute by minute notes were made in association with recordings of classroom activities

Acoustic conditions.

None of the classrooms met BATOD recommended reverberation times for all frequencies. 26% of the classrooms measured met BATOD recommended levels for mean reverberation times, **Figure**

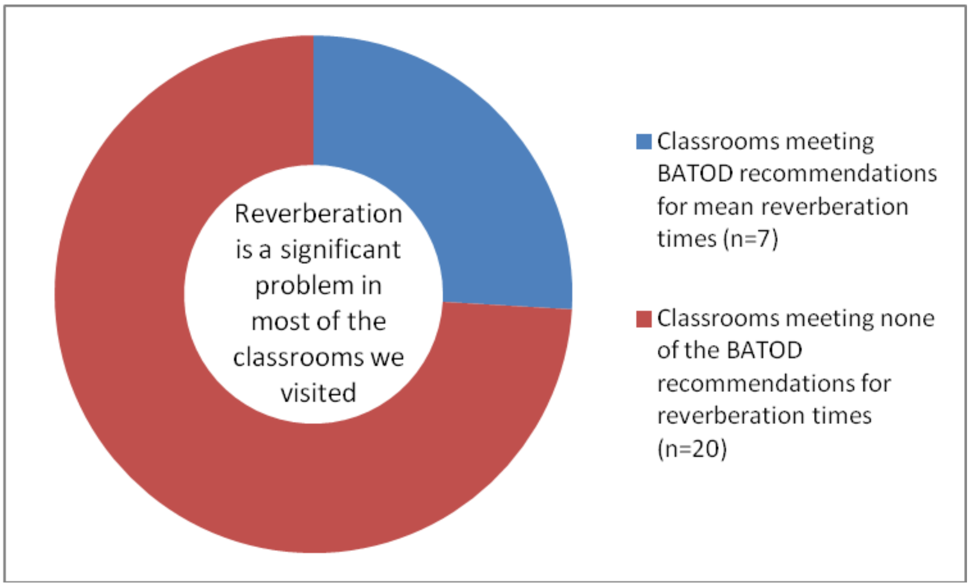


Figure 8

Teaching styles / Classroom dynamics

The study classroom observations demonstrated a trend away from the didactic teaching approaches (Figure) which enable easy use of FM systems. In order to ensure optimal use of FM teachers and pupils need to be aware of, and able to facilitate appropriate transmitter use in rapidly changing environments. Increasing use of classroom teaching assistants, pupil interaction and additional technologies such as whiteboards and computer generated learning materials increases the potential benefits of FM to users, at the same time as increasing the need for sensitivity and expertise by teachers and other users of FM transmitters.

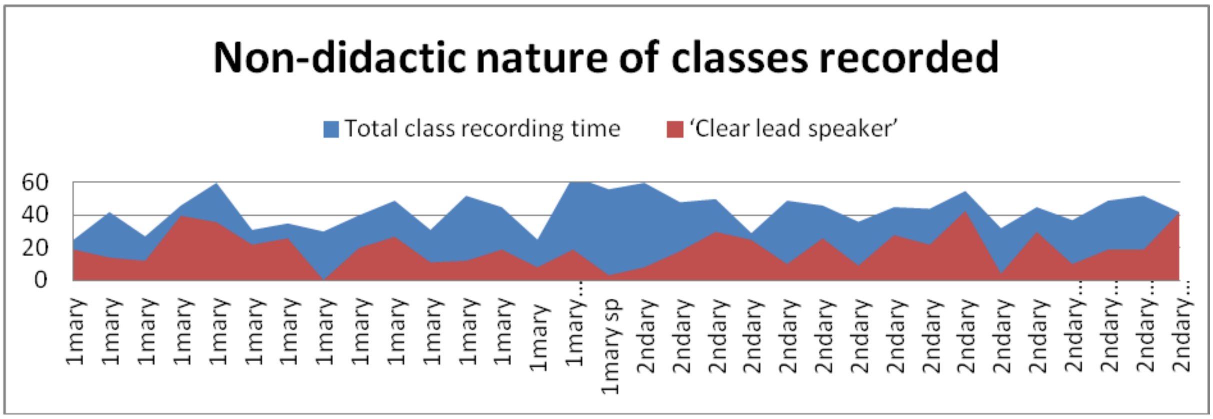


Figure 9

Classroom observations and subsequent analysis of data revealed significant concerns about the quality of sound signals children were receiving regularly and frequently throughout their lessons. There were clear examples of textbook use of FM in most settings, but also evidence that additional or refresher training in optimal use was required.

The way the data was collected prevents comment on the percentage time children experience any particular use of FM. However, it does enable comment on the relative frequency of occurrence throughout the lesson at minute intervals. (Figure).

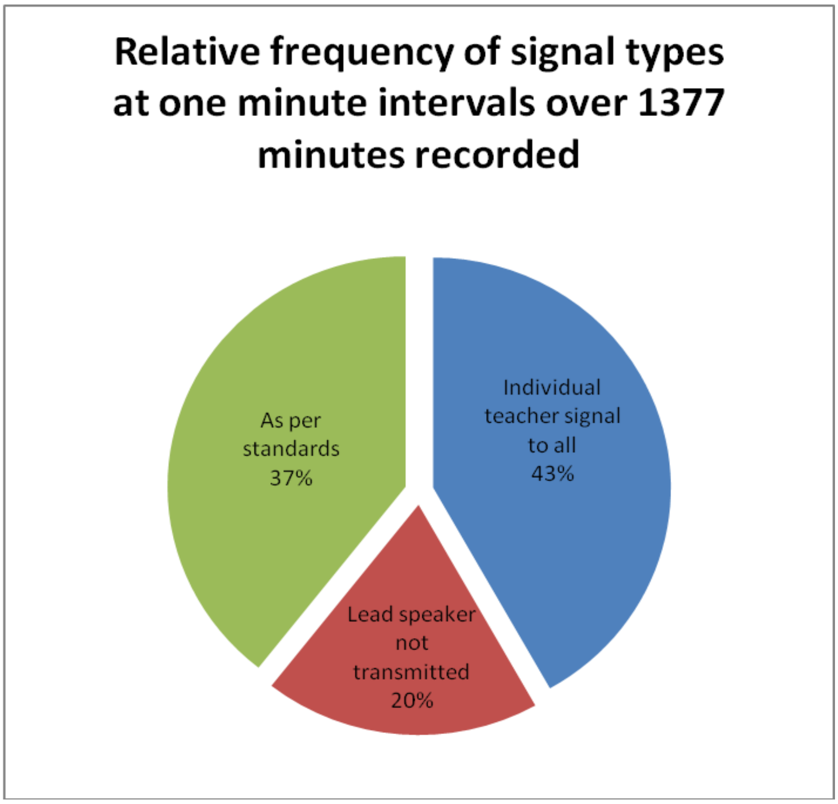


Figure 10

Key note: occurrence of an activity was made once within each one minute interval. No record of total times of activities was made.

Considering all settings together over the 1377 minutes recorded :
every 2.52 minutes the key signal was transmitted according to FM quality standards, every 2.37 minutes a signal intended for an individual child other than the FM user was transmitted to the FM user (the mute facility was not activated), every 5.3 minutes a signal intended for the FM user was not transmitted via FM (the transmitter was not shared).The numbers of special school lessons observed is too small to support significant generalisation.

Figure and Figure demonstrate the range of FM use in the mainstream primary and secondary classrooms observed.

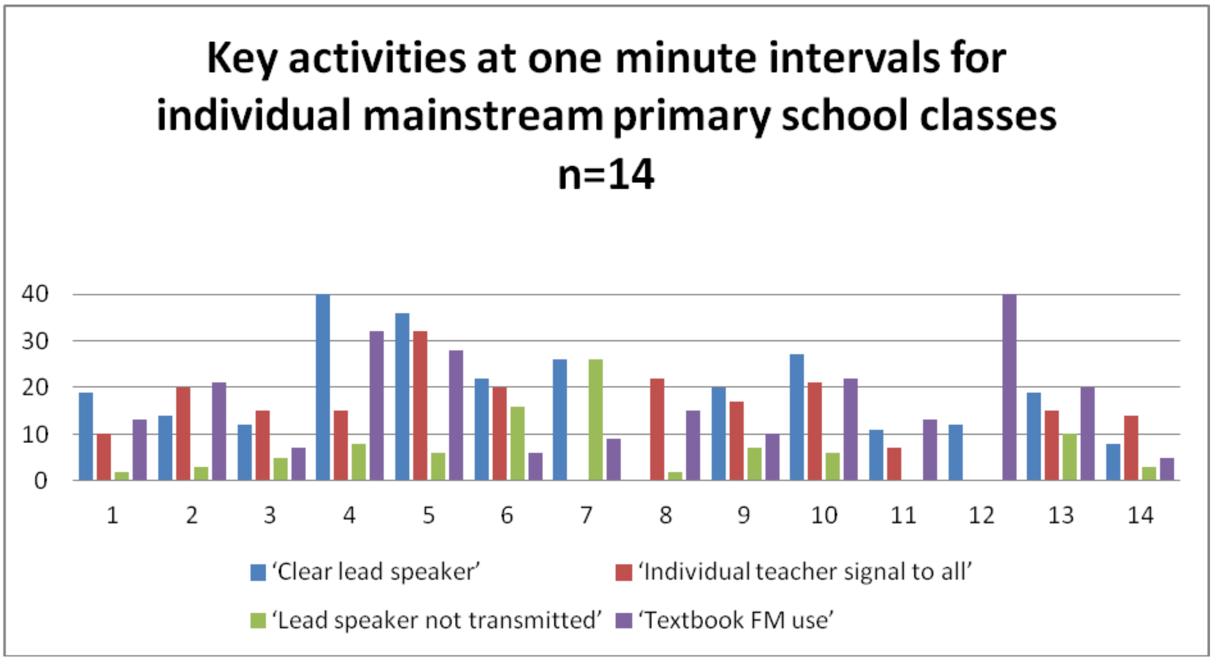


Figure 11

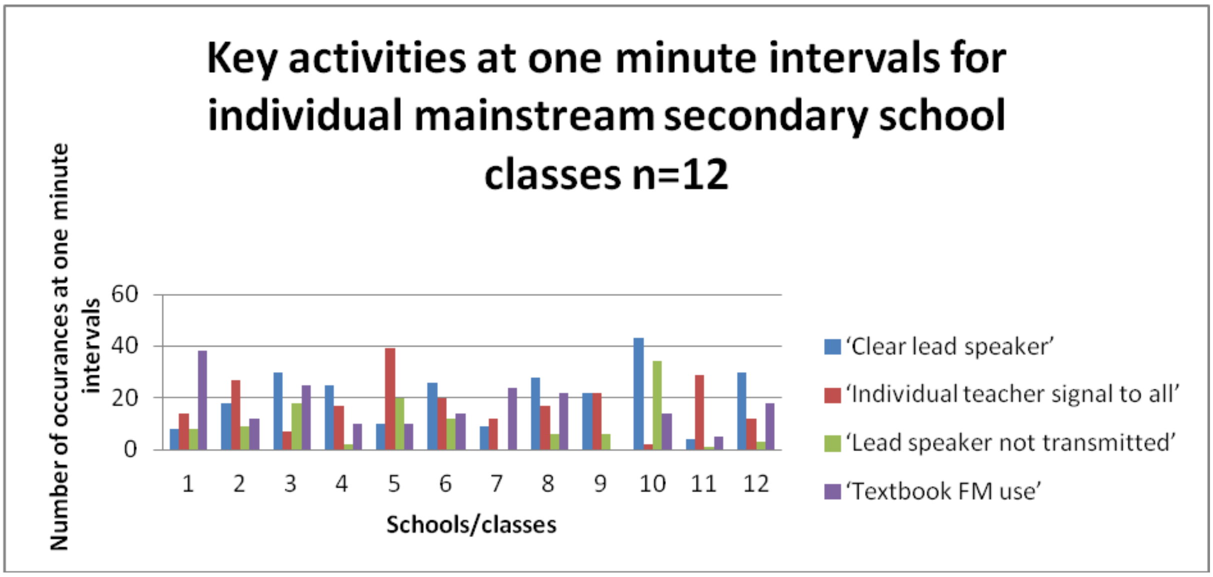


Figure 12

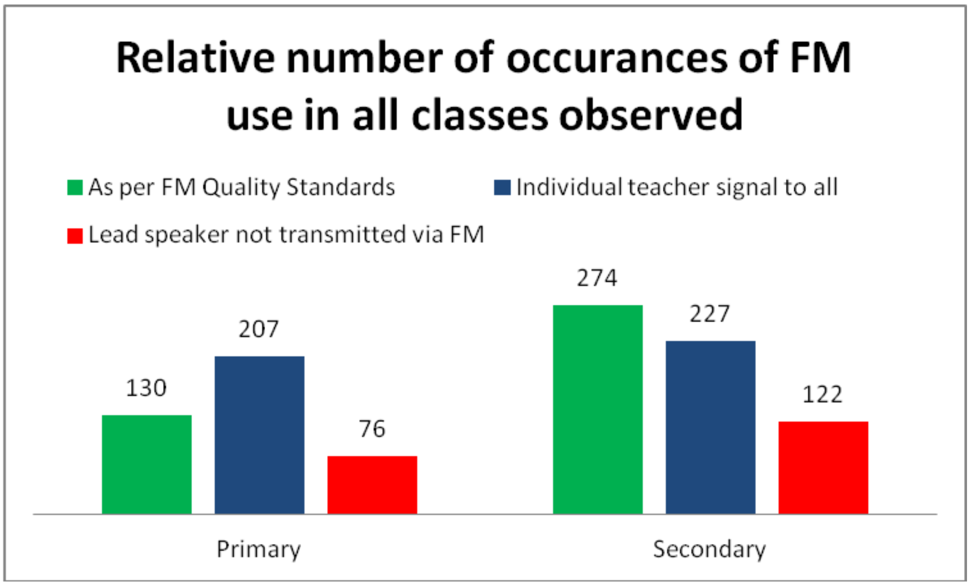


Figure 13

It is clear from these observations that whilst FM is often used appropriately, there are very significant training needs for the teachers and pupils studied with regard to its full and appropriate use. None of the pupils exposed to these listening conditions commented that it was unusual, although pupils who attended the focus groups commented on these unhelpful uses of FM, and pupil responses to the LIFE –R questionnaires implied that these conditions may be prevalent in their classes.

With 438,000 teaching staff, 219,800 teaching assistants and 28,500 deaf children in English schools (DfE 2012), it is not feasible to expect the around 665 qualified visiting teachers of the deaf employed in England (CRIDE 2012) to undertake this training effectively. An alternative approach to training is required in order to ensure pupils using FM obtain optimal benefits from it. A national training programme for all mainstream teachers and teaching assistants in appropriate use of FM would release time for teachers of the deaf to engage more fully in assessments of benefit and 'fine-tuning' of FM use.

SART

A summary of a preliminary analysis is as follows.

The classroom activity was highly dynamic. Sato and Bradley (2008) performed DF method analysis on long periods (approximately 20 minute recordings) where the teacher talked from the front of class. In this present work it was noted that long periods where the teacher talked from the front of class did not occur. The noted classroom activities are shown in **Table** Table 3.

Table 3 Logged teacher classroom activity classification for classrooms in one minute segments separated by 10 minutes. C teaching talking to class, I teacher talking to individual, G group work, Q children answer questions to whole class, S children and teacher singing.

Time / Class	0	10	20	30	40	50	60
1	C	I	I	I	IC	I	C
2	CQ	CQ	I	CQ	CIQ	CQ	
3	CQ	C	CG	C	C	IG	IG
4	IC	C	C	ICG	I	IG	C
5	CQ	CQ	IG	C			
6	CQ	CQ	CQ	CG	CG	CQ	CIQ
7	CQ	CIG	CIG	G	G	CI	
8	C	CQ	CQ	CQ	CQ		
9	IC	IG	IC	C	S		

The sound pressure levels for the MS and DF methods are shown in table 4. for the full spectrum analysis of each time period of each class recording.

Classroom analysis. Speech, noise and SNR in 1 minute segments at 10 minute intervals

Table 4

Classroom Recording Analysis

			Teacher Mic DF Speech dB A	Teacher Mic DF noise dB A	Teacher Mic DF SNR dB	Class Mic DF Speech dB A	Class Mic DF noise dB A	Class Mic DF SNR dB	Teacher Mic MS Speech dB A	Teacher Mic MS noise dB A	Teacher Mic MS Speech 2 dB A	Teacher Mic MS noise2 dB A	Teacher Mic MS SNR dB	Teacher Mic MS SNR 2 dB	Class Mic MS Speech dB A	Class Mic MS noise dB A	Class Mic MS Speech 2 dB A	Class Mic MS noise 2 dB A	Class Mic MS SNR dB	Class Mic MS SNR 2 dB
Class ID	1.00	1	87.09	68.28	18.81	72.30	60.64	11.67	86.70	71.09	86.81	54.51	15.60	32.30	72.17	70.26	74.32	48.04	1.91	26.28
		2	67.37	44.58	22.78	72.06	57.81	14.25	77.04	65.35	77.32	48.70	11.69	28.62	63.15	73.15	71.04	50.51	-10.00	20.53
		3	75.14	54.03	21.10	64.36	58.44	5.93	79.40	73.27	80.34	51.87	6.13	28.47	67.59	62.13	68.51	54.39	5.46	14.12
		4	80.07	59.99	20.09	67.60	50.64	16.96	76.98	62.87	77.14	52.12	14.12	25.01	68.74	69.67	72.12	56.82	-.93	15.30
		5	71.85	48.75	23.09	66.69	48.09	18.60	80.58	69.99	80.94	50.67	10.59	30.27	68.19	78.19	72.31	52.18	-10.00	20.13
		6	78.53	50.02	28.51	68.03	47.29	20.74	87.19	68.32	87.25	49.99	18.87	37.25	67.03	71.79	73.02	49.12	-4.76	23.90
	2.00	1	69.32	41.90	27.42	58.26	44.41	13.85	79.74	65.84	79.91	46.40	13.90	33.51	41.33	60.02	58.29	55.37	-18.69	2.92
		2	74.09	48.78	25.31	60.43	40.90	19.53	77.21	73.29	78.69	47.93	3.92	30.75	53.89	63.89	63.13	44.05	-10.00	19.08
		3	70.35	50.09	20.26	60.05	45.12	14.93	75.13	69.96	76.07	63.00	5.17	13.07	55.93	61.41	62.17	51.11	-5.48	11.06
		4	71.44	48.44	23.00	56.96	40.78	16.18	74.54	71.67	76.29	58.05	2.87	18.23	54.21	58.11	59.22	48.79	-3.90	10.42
		5	78.33	60.46	17.87	61.44	54.43	7.01	79.70	66.65	79.87	59.21	13.05	20.66	54.14	64.14	61.09	57.30	-10.00	3.79
		6	58.97	45.73	13.24	57.52	42.13	15.40	77.45	62.21	.	.	15.23	.	57.22	59.91	.	.	-2.69	.
	3.00	1	53.48	57.61	-4.12	73.83	52.55	21.28	71.60	62.45	72.02	55.01	9.16	17.01	62.27	72.27	50.94	54.97	-10.00	-4.03
		2	75.23	52.46	22.77	57.57	51.02	6.55	77.48	52.03	77.48	52.03	25.45	25.45	56.96	50.19	56.96	50.19	6.77	6.77
		3	71.90	74.10	-2.20	70.43	65.45	4.98	74.83	78.14	74.83	78.14	-3.31	-3.31	62.25	72.25	62.25	72.25	-10.00	-10.00
		4	81.57	59.85	21.72	59.23	47.93	11.30	82.04	59.76	82.05	58.48	22.28	23.57	60.33	51.64	60.61	48.60	8.69	12.02
		5	81.66	65.40	16.26	60.33	64.54	-4.21	84.33	65.34	84.33	65.34	19.00	19.00	67.74	62.13	67.74	62.13	5.61	5.61
		6	68.83	74.31	-5.48	70.32	65.35	4.97	82.46	73.40	82.46	73.40	9.06	9.06	54.05	69.97	54.05	69.97	-15.92	-15.92
		7	76.01	72.63	3.38	68.76	70.80	-2.04	77.25	76.29	78.46	74.05	.95	4.41	63.60	73.60	63.60	71.99	-10.00	-8.39
	4.00	1	76.32	65.64	10.69	71.61	60.60	11.01	81.34	68.07	81.41	66.02	13.26	15.39	58.12	67.38	66.63	61.80	-9.26	4.83
		2	70.28	47.62	22.66	65.37	45.40	19.98	74.60	54.96	74.60	54.96	19.64	19.64	69.93	51.66	69.93	51.66	18.26	18.26
		3	82.61	64.56	18.06	72.29	63.83	8.46	87.20	69.08	.	.	18.13	.	65.48	68.31	.	.	-2.83	.
		4	84.20	64.94	19.26	74.09	64.96	9.13	86.40	66.77	86.40	66.65	19.63	19.75	69.31	66.09	69.28	66.16	3.23	3.12
		5	72.32	65.75	6.57	76.47	65.71	10.77	76.02	67.10	76.16	65.79	8.92	10.38	61.67	71.67	70.50	64.51	-10.00	6.00
		6	75.55	65.46	10.10	68.83	58.60	10.23	77.83	74.46	78.84	70.81	3.37	8.03	66.07	69.52	67.63	68.58	-3.45	-.95
		7	85.82	66.56	19.26	70.19	65.09	5.10	87.31	67.78	87.31	67.75	19.53	19.56	70.93	67.34	70.45	68.28	3.59	2.17
	5.00	1	76.45	53.11	23.34	57.64	46.99	10.65	76.80	62.44	76.78	63.00	14.36	13.77	53.06	61.09	51.85	61.85	-8.04	-10.00
		2	79.70	54.70	25.00	67.30	58.36	8.95	85.05	63.10	85.03	65.21	21.95	19.82	65.73	63.36	64.01	65.30	2.37	-1.29
		3	72.19	76.64	-4.45	78.26	67.69	10.57	85.43	78.33	85.47	78.15	7.11	7.32	75.20	79.23	78.24	77.00	-4.02	1.24
		4	92.12	72.27	19.85	80.44	64.69	15.75	87.23	71.61	87.28	68.80	15.62	18.49	64.07	74.07	65.75	69.40	-10.00	-3.66
	6.00	1	86.63	66.50	20.13	65.49	66.77	-1.29	91.56	70.14	91.57	68.69	21.43	22.88	75.01	65.75	75.16	64.26	9.25	10.90
		2	84.18	49.12	35.06	68.39	49.26	19.12	90.32	60.64	90.33	53.77	29.68	36.56	74.92	53.96	74.93	50.50	20.96	24.43
		3	86.65	59.27	27.38	67.55	47.76	19.79	89.94	64.39	.	.	25.55	.	73.75	57.65	.	.	16.10	.
		4	90.80	69.95	20.85	72.05	65.24	6.81	91.19	71.46	.	.	19.73	.	77.96	71.89	.	.	6.06	.
		5	84.30	60.04	24.26	62.04	49.98	12.06	84.88	60.82	84.89	53.56	24.06	31.33	69.01	61.79	69.59	55.81	7.23	13.78
		6	67.11	73.41	-6.29	76.03	65.81	10.22	92.76	77.53	.	.	15.23	.	80.20	76.86	.	.	3.34	.
	7.00	1	84.24	56.04	28.20	64.33	55.44	8.89	88.21	61.21	88.21	61.08	27.01	27.14	65.01	60.30	65.17	59.81	4.71	5.36
		2	75.46	60.85	14.61	70.01	60.29	9.73	88.48	65.26	88.48	65.25	23.22	23.23	66.34	72.02	65.91	72.13	-5.68	-6.22
		3	80.78	60.22	20.56	67.09	54.70	12.38	85.57	64.82	85.57	64.31	20.75	21.26	50.89	69.88	56.80	69.72	-18.99	-12.92
		4	63.49	55.60	7.89	73.73	67.20	6.53	70.69	62.41	70.89	60.71	8.28	10.18	63.80	73.80	45.88	73.32	-10.00	-27.44
		5	67.56	54.51	13.04	71.64	56.99	14.65	88.15	68.80	.	.	19.35	.	63.66	73.66	.	.	-10.00	.
		6	90.65	68.90	21.75	80.85	71.12	9.73	96.51	72.89	.	.	23.62	.	80.41	73.80	.	.	6.61	.
	8.00	1	87.76	55.84	31.92	67.07	48.09	18.98	93.67	57.91	.	.	35.76	.	74.00	57.05	.	.	16.94	.
		2	85.76	53.50	32.26	65.53	49.42	16.11	92.58	60.31	92.58	57.86	32.27	34.71	71.85	58.68	71.94	56.20	13.17	15.74
		3	82.28	62.20	20.08	57.53	62.60	-5.07	85.80	64.66	.	.	21.14	.	69.15	65.03	.	.	4.13	.
		4	81.82	57.53	24.29	79.08	63.12	15.96	95.73	65.74	95.73	64.60	29.98	31.13	75.96	65.43	76.04	64.39	10.53	11.65
		5	96.66	73.73	22.92	78.11	59.52	18.59	100.81	79.46	100.80	80.10	21.34	20.70	81.67	80.18	81.00	80.98	1.49	.03
	9.00	1	84.81	67.16	17.65	69.60	60.52	9.08	87.21	69.31	87.28	57.02	17.90	30.26	71.39	69.91	73.60	57.93	1.48	15.68
		2	72.65	74.07	-1.42	75.01	69.14	5.87	81.06	79.32	83.21	65.75	1.74	17.45	66.61	76.61	73.95	65.31	-10.00	8.64
		3	71.95	74.14	-2.18	72.63	62.77	9.86	83.86	75.14	84.40	59.05	8.72	25.35	68.60	72.35	73.58	62.01	-3.75	11.58
		4	83.09	65.92	17.17	64.94	54.81	10.14	82.14	68.33	82.30	57.11	13.81	25.20	65.05	65.64	67.88	58.60	-.58	9.28
		5	82.00	70.75	11.26	80.75	69.58	11.17	85.60	76.91	85.96	72.50	8.69	13.46	80.44	77.94	82.01	71.49	2.50	10.52

.

Table 5

Classroom Recording Analysis

Class ID		Teacher Mic DF Speech dB A	Teacher Mic DF noise dB A	Teacher Mic DF SNR dB	Class Mic DF Speech dB A	Class Mic DF noise dB A	Class Mic DF SNR dB	Teacher Mic MS Speech dB A	Teacher Mic MS noise dB A	Teacher Mic MS Speech 2 dB A	Teacher Mic MS noise2 dB A	Teacher Mic MS SNR dB	Teacher Mic MS SNR 2 dB	Class Mic MS Speech dB A	Class Mic MS noise dB A	Class Mic MS Speech 2 dB A	Class Mic MS noise 2 dB A	Class Mic MS SNR dB	Class Mic MS SNR 2 dB
1.00	Mean	76.6750	54.2750	22.3967	68.5067	53.8183	14.6917	81.3150	68.4817	81.6333	51.3100	12.8333	30.3200	67.8117	70.8650	71.8867	51.8433	-3.0533	20.0433
	Std. Deviation	6.86526	8.61957	3.40196	3.11641	5.82002	5.34967	4.57797	3.82964	4.45630	2.00867	4.40513	4.15828	2.91174	5.25027	1.97777	3.31740	6.34106	4.72439
	Minimum	67.37	44.58	18.81	64.36	47.29	5.93	76.98	62.87	77.14	48.70	6.13	25.01	63.15	62.13	68.51	48.04	-10.00	14.12
	Maximum	87.09	68.28	28.51	72.30	60.64	20.74	87.19	73.27	87.25	54.51	18.87	37.25	72.17	78.19	74.32	56.82	5.46	26.28
	N	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
2.00	Mean	70.4167	49.2333	21.1833	59.1100	44.6283	14.4833	77.2950	68.2700	78.1660	54.9180	9.0233	23.2440	52.7867	61.2467	60.7800	51.3240	-8.4600	9.4540
	Std. Deviation	6.47139	6.22347	5.17982	1.78482	5.12472	4.13858	2.19411	4.11994	1.87965	7.33038	5.60846	8.61769	5.75960	2.38811	2.01149	5.27875	5.87134	6.53732
	Minimum	58.97	41.90	13.24	56.96	40.78	7.01	74.54	62.21	76.07	46.40	2.87	13.07	41.33	58.11	58.29	44.05	-18.69	2.92
	Maximum	78.33	60.46	27.42	61.44	54.43	19.53	79.74	73.29	79.91	63.00	15.23	33.51	57.22	64.14	63.13	57.30	-2.69	19.08
	N	6	6	6	6	6	6	6	6	5	5	6	5	6	6	5	5	6	5
3.00	Mean	72.6686	65.1943	7.4757	65.7814	59.6629	6.1186	78.5700	66.7729	78.8043	65.2071	11.7986	13.5986	61.0286	64.5786	59.4500	61.4429	-3.5500	-1.9914
	Std. Deviation	9.67242	8.81273	12.42768	6.53103	8.91262	8.49274	4.57984	9.58279	4.43708	10.29133	10.86665	10.58007	4.48015	10.07386	5.81539	10.28498	10.14930	10.28027
	Minimum	53.48	52.46	-5.48	57.57	47.93	-4.21	71.60	52.03	72.02	52.03	-3.31	-3.31	54.05	50.19	50.94	48.60	-15.92	-15.92
	Maximum	81.66	74.31	22.77	73.83	70.80	21.28	84.33	78.14	84.33	78.14	25.45	25.45	67.74	73.60	67.74	72.25	8.69	12.02
	N	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
4.00	Mean	78.1571	62.9329	15.2286	71.2643	60.5986	10.6686	81.5286	66.8886	80.7867	65.3300	14.6400	15.4583	65.9300	65.9957	69.0700	63.4983	-.0657	5.5717
	Std. Deviation	6.07395	6.78193	6.02245	3.60736	7.19670	4.56939	5.49826	5.86897	5.25209	5.40100	6.42428	5.17113	4.68669	6.57291	1.59751	6.32180	9.68140	6.66095
	Minimum	70.28	47.62	6.57	65.37	45.40	5.10	74.60	54.96	74.60	54.96	3.37	8.03	58.12	51.66	66.63	51.66	-10.00	-.95
	Maximum	85.82	66.56	22.66	76.47	65.71	19.98	87.31	74.46	87.31	70.81	19.64	19.75	70.93	71.67	70.50	68.58	18.26	18.26
	N	7	7	7	7	7	7	7	7	6	6	7	6	7	7	6	6	7	6
5.00	Mean	80.1150	64.1800	15.9350	70.9100	59.4325	11.4800	83.6275	68.8700	83.6400	68.7900	14.7600	14.8500	64.5150	69.4375	64.9625	68.3875	-4.9225	-3.4275
	Std. Deviation	8.57380	12.01548	13.75844	10.55096	9.16140	2.95245	4.64992	7.56388	4.67583	6.68207	6.08600	5.65148	9.07488	8.64041	10.79749	6.51848	5.46183	4.81685
	Minimum	72.19	53.11	-4.45	57.64	46.99	8.95	76.80	62.44	76.78	63.00	7.11	7.32	53.06	61.09	51.85	61.85	-10.00	-10.00
	Maximum	92.12	76.64	25.00	80.44	67.69	15.75	87.23	78.33	87.28	78.15	21.95	19.82	75.20	79.23	78.24	77.00	2.37	1.24
	N	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
6.00	Mean	83.2783	63.0483	20.2317	68.5917	57.4700	11.1183	90.1083	67.4967	88.9300	58.6733	22.6133	30.2567	75.1417	64.6500	73.2267	56.8567	10.4900	16.3700
	Std. Deviation	8.27586	8.76625	14.07833	4.91852	9.31887	7.91766	2.74654	6.70233	3.55325	8.67532	4.99764	6.90287	3.82440	8.65063	3.15154	6.93945	6.69336	7.12715
	Minimum	67.11	49.12	-6.29	62.04	47.76	-1.29	84.88	60.64	84.89	53.56	15.23	22.88	69.01	53.96	69.59	50.50	3.34	10.90
	Maximum	90.80	73.41	35.06	76.03	66.77	19.79	92.76	77.53	91.57	68.69	29.68	36.56	80.20	76.86	75.16	64.26	20.96	24.43
	N	6	6	6	6	6	6	6	6	3	3	6	3	6	6	3	3	6	3
7.00	Mean	77.0300	59.3533	17.6750	71.2750	60.9567	10.3183	86.2683	65.8983	83.2875	62.8375	20.3717	20.4525	65.0183	70.5767	58.4400	68.7450	-5.5583	-10.3050
	Std. Deviation	10.26673	5.34141	7.24332	5.74784	6.75324	2.83188	8.48842	4.31329	8.36861	2.28060	6.48271	7.27126	9.39776	5.26242	9.33697	6.14203	9.73024	13.69338
	Minimum	63.49	54.51	7.89	64.33	54.70	6.53	70.69	61.21	70.89	60.71	8.28	10.18	50.89	60.30	45.88	59.81	-18.99	-27.44
	Maximum	90.65	68.90	28.20	80.85	71.12	14.65	96.51	72.89	88.48	65.25	27.01	27.14	80.41	73.80	65.91	73.32	6.61	5.36
	N	6	6	6	6	6	6	6	6	4	4	6	4	6	6	4	4	6	4
8.00	Mean	86.8560	60.5600	26.2940	69.4640	56.5500	12.9140	93.7180	65.6160	96.3700	67.5200	28.0980	28.8467	74.5260	65.2740	76.3267	67.1900	9.2520	9.1400
	Std. Deviation	6.00912	8.02249	5.50588	9.09462	7.26286	10.14803	5.43913	8.36842	4.14720	11.40391	6.59049	7.27875	4.72843	9.12945	4.53680	12.62506	6.37520	8.15022
	Minimum	81.82	53.50	20.08	57.53	48.09	-5.07	85.80	57.91	92.58	57.86	21.14	20.70	69.15	57.05	71.94	56.20	1.49	.03
	Maximum	96.66	73.73	32.26	79.08	63.12	18.98	100.81	79.46	100.80	80.10	35.76	34.71	81.67	80.18	81.00	80.98	16.94	15.74
	N	5	5	5	5	5	5	5	5	3	3	5	3	5	5	3	3	5	3
9.00	Mean	78.9000	70.4080	8.4960	72.5860	63.3640	9.2240	83.9740	73.8020	84.6300	62.2860	10.1720	22.3440	70.4180	72.4900	74.2040	63.0680	-2.0700	11.1400
	Std. Deviation	6.11268	3.81270	9.73368	5.91410	6.19703	2.01870	2.49918	4.79633	2.01802	6.73273	6.09016	6.75893	6.08290	5.00688	5.04344	5.55513	5.03525	2.77935
	Minimum	71.95	65.92	-2.18	64.94	54.81	5.87	81.06	68.33	82.30	57.02	1.74	13.46	65.05	65.64	67.88	57.93	-10.00	8.64
	Maximum	84.81	74.14	17.65	80.75	69.58	11.17	87.21	79.32	87.28	72.50	17.90	30.26	80.44	77.94	82.01	71.49	2.50	15.68
	N	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Total	Mean	77.8735	60.8444	17.0296	68.4252	57.3148	11.1113	83.7227	67.8669	82.8777	61.5674	15.8560	21.3098	66.0777	67.0119	66.9553	60.8088	-.9342	6.1470
	Std. Deviation	8.57771	9.24420	10.34487	6.68762	8.63570	6.18992	6.75613	6.30147	6.28328	8.64249	8.57627	9.18139	8.49077	7.46272	8.06714	9.04314	9.41932	11.57721
	Minimum	53.48	41.90	-6.29	56.96	40.78	-5.07	70.69	52.03	70.89	46.40	-3.31	-3.31	41.33	50.19	45.88	44.05	-18.99	-27.44
	Maximum	96.66	76.64	35.06	80.85	71.12	21.28	100.81	79.46	100.80	80.10	35.76	37.25	81.67	80.18	82.01	80.98	20.96	26.28
	N	52	52	52	52	52	52	52	52	43	43	52	43	52	52	43	43	52	43

The calculated speech and noise levels for the full length class recordings are shown in Table 6.

Table 6 Distribution fitting method speech, noise and SNR analysis for full class recording with minimum and maximum distribution fitting method SNR for one minute segments (separated by 10 minutes) in the recording.

Class ID		Class Mic DF Speech dB A	Class Mic DF noise dB A	Class Mic DF SNR dB	Segments Minimum Class Mic DF SNR dB	Segments Maximum Class Mic DF SNR dB	Teacher Mic DF Speech dB A	Teacher Mic DF noise dB A	Teacher Mic DF SNR dB	Segments Minimum Teacher Mic DF SNR dB	Segments Maximum Teacher Mic DF SNR dB
1		69.52	54.42	15.10	5.93	20.74	82.85	66.54	16.31	18.81	28.51
2		58.41	41.63	16.78	7.01	19.53	69.36	45.21	24.16	13.24	27.42
3		68.15	54.14	14.01	-4.21	21.28	75.25	55.88	19.37	-5.48	22.77
4		65.22	45.89	19.34	5.10	19.98	69.87	64.30	5.57	6.57	22.66
5		78.80	61.70	17.10	8.95	15.75	78.34	69.33	9.02	-4.45	25.00
6		69.85	52.63	17.22	-1.29	19.79	90.41	68.56	21.85	-6.29	35.06
7		68.93	65.82	3.11	6.53	14.65	76.93	59.75	17.18	7.89	28.20
8		76.94	65.98	10.96	-5.07	18.98	88.85	63.41	25.44	20.08	32.26
9		77.60	72.60	5.00	5.87	11.17	79.22	74.99	4.23	-2.18	17.65
Total	Mean	70.3800	57.2011	13.1800			79.0089	63.1078	15.9033		
	Std. Deviation	6.55802	10.10644	5.70323			7.39214	8.70897	7.89558		
	Minimum	58.41	41.63	3.11			69.36	45.21	4.23		
	Maximum	78.80	72.60	19.34			90.41	74.99	25.44		
	N	9	9	9			9	9	9		

The mean speech and noise levels and the mean SNR for the class and teacher microphone recordings are shown in the figures. Figures 13 to 16 show examples of segment positions for MS method and fitted distributions of DF methods.

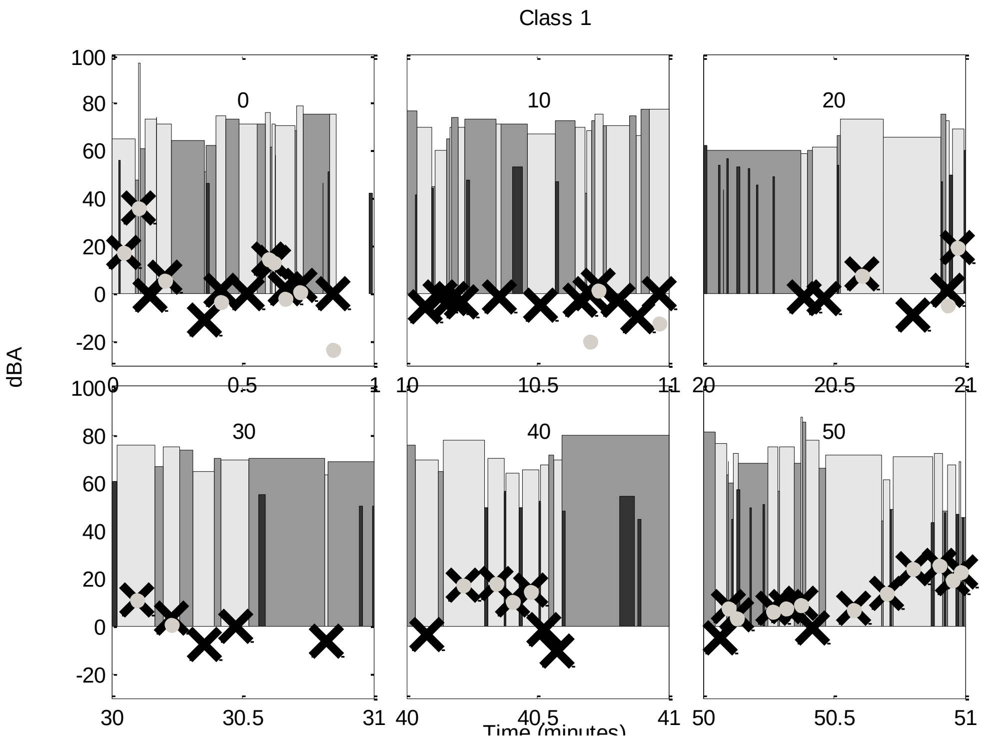


Figure 13 Class 1. Classroom recording. Modified Shaw method marked segments for one minute periods at ten minute intervals. Bar widths represent time period of sement and bar height the SPL of the segment. Light Grey Bars Speech Periods, Dark Grey Bars Noise periods surrounding speech, Darkest Grey Bars Noise 2 periods. Black ‘X’ SNR for identified speech periods, grey circle markers corrected SNR.

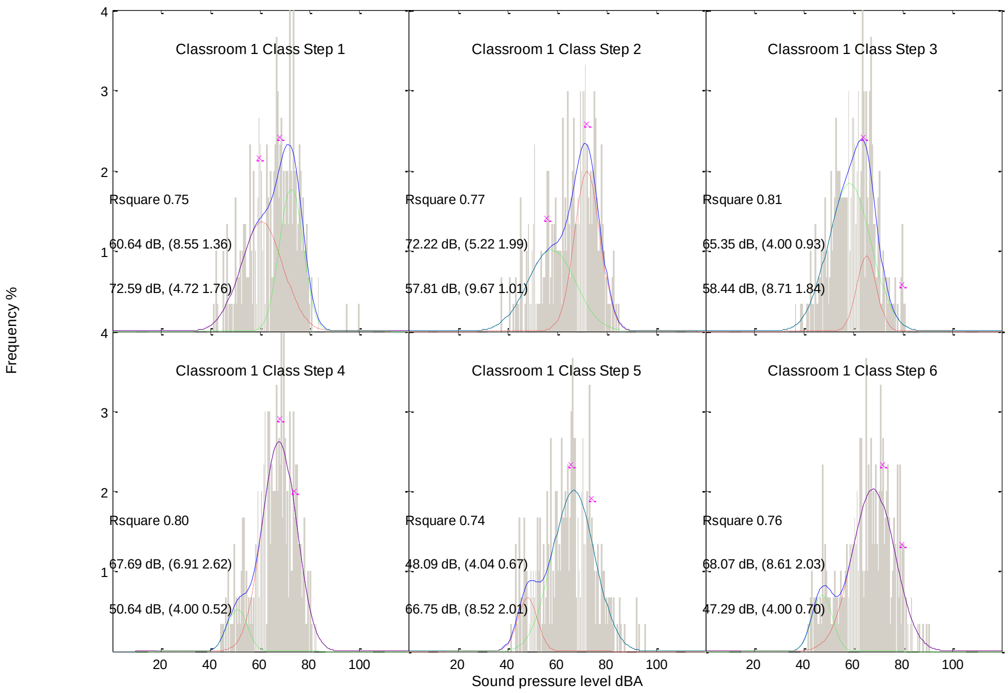


Figure 14 Class 1. Classroom recording. Distribution fitting method analysis in one minute segments at 10 minute intervals.

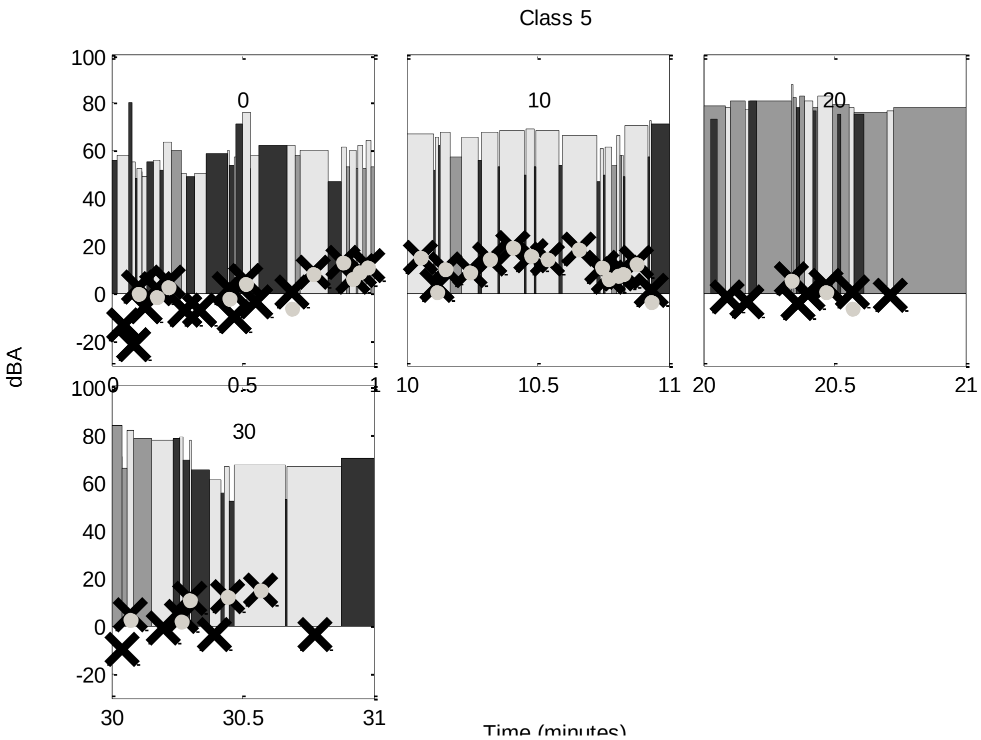


Figure 15 As for 13 but for Class 5

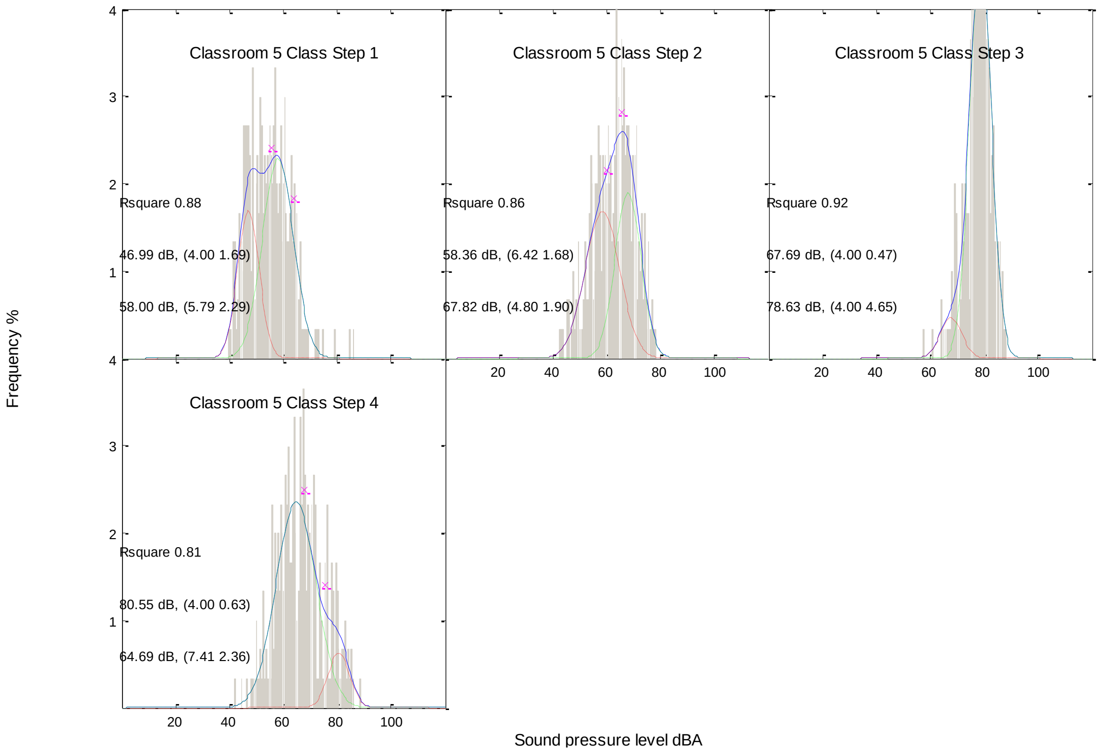


Figure 16 as for 14 but for Class 5

The mean speech levels at the child classroom microphone position (of each time position in each recording) were 68 dB A (SD 7) for the DF method and

66 dB A (SD 9) for the MS method. The mean noise levels at the child classroom microphone position were 57 dB A (SD 9) and 67 dB A (SD 8) for the DF and MS methods respectively.

The mean speech levels at the teacher microphone position (of each time position in each recording) were 78 dB A (SD 9) for the DF method and 84 dB A (SD 7) for the MS method. The mean noise levels at the teacher microphone position were 61 dB A (SD 9) and 68 dB A (SD 6) for the DF and MS methods respectively.

The mean SNR at the teacher microphone was 17 dB (SD 10) and 16 dB (SD 9) for the DF and MS methods respectively. The mean SNR at the child class microphone position were 11 dB (SD 6) and -1 dB (SD 9.5) for the DF and MS methods respectively.

The mean improvements in SNR from the teacher microphone, that was positioned by the FM transmitter microphone, to the child microphone using the MS method (first noise type) are summarised in Table 7.

Table 7 SNR improvements between teacher and class microphone. Mean, SD, minimum and maximum difference between teacher and class SNR of one minute segments analysed at 10 minute intervals using the modified sound assurance method (first noise type).

SNR improvement from teacher to class microphone

MS teacher microphone SNR improvement

Class ID	Mean	Std. Deviation	Minimum	Maximum	N
1.00	15.8867	8.40038	.67	23.63	6
2.00	17.4833	9.31190	6.77	32.59	6
3.00	15.3486	6.05030	6.69	24.98	7
4.00	14.7057	7.76845	1.38	22.52	7
5.00	19.6825	6.21274	11.13	25.62	4
6.00	12.1233	2.94387	8.72	16.83	6
7.00	25.9300	8.51468	17.01	39.74	6
8.00	18.8460	1.09646	17.01	19.85	5
9.00	12.2420	3.84058	6.19	16.42	5
Total	16.7902	7.40458	.67	39.74	52

The mean difference in SNR from the two microphone positions was 17 dB (SD 7).

Discussion

In the first time period of class 1, shown in the figures, the teacher was addressing the class but there was also some child interaction. It was noted that during that period the child speech was removed from the noise to give the second noise type (shown as noise 2 in the figures and tables). The noise 2 had a lower sound pressure level than the noise period (70 dB A vs. 48 dB A). Thus, the two SNRs calculated for noise one and noise two different by 24 dB (26 dB vs. 2 dB). It was noted that for the DF method the SNR was 12 dB. The true SNR in this period is unclear. In some cases the interjections by the child overlapped the teacher speech and in some cases it did not. It is clear that the DF method cannot clearly detect true SNR in such cases as the speech from the class teacher and the interjecting child merge into a single upper distribution. It is also worthy of note that the data revealed that the SNR within each one minute segment is highly variable. This factor is visually demonstrated in the examples shown in Figures 17 and 18.

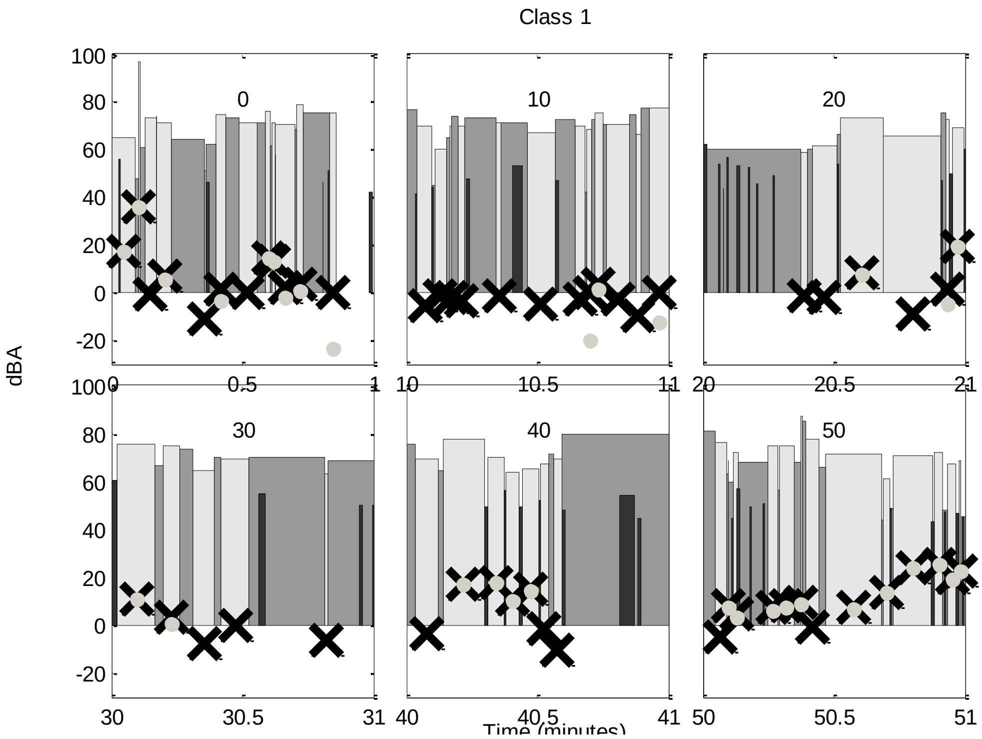


Figure 17 Class 1. Classroom recording. Modified Shaw method marked segments for one minute periods at ten minute intervals. Bar widths represent time period of sement and bar height the SPL of the segment. Light Grey Bars Speech Periods, Dark Grey Bars Noise periods surrounding speech, Darkest Grey Bars Noise 2 periods. Black ‘X’ SNR for identified speech periods, grey circle markers corrected SNR.

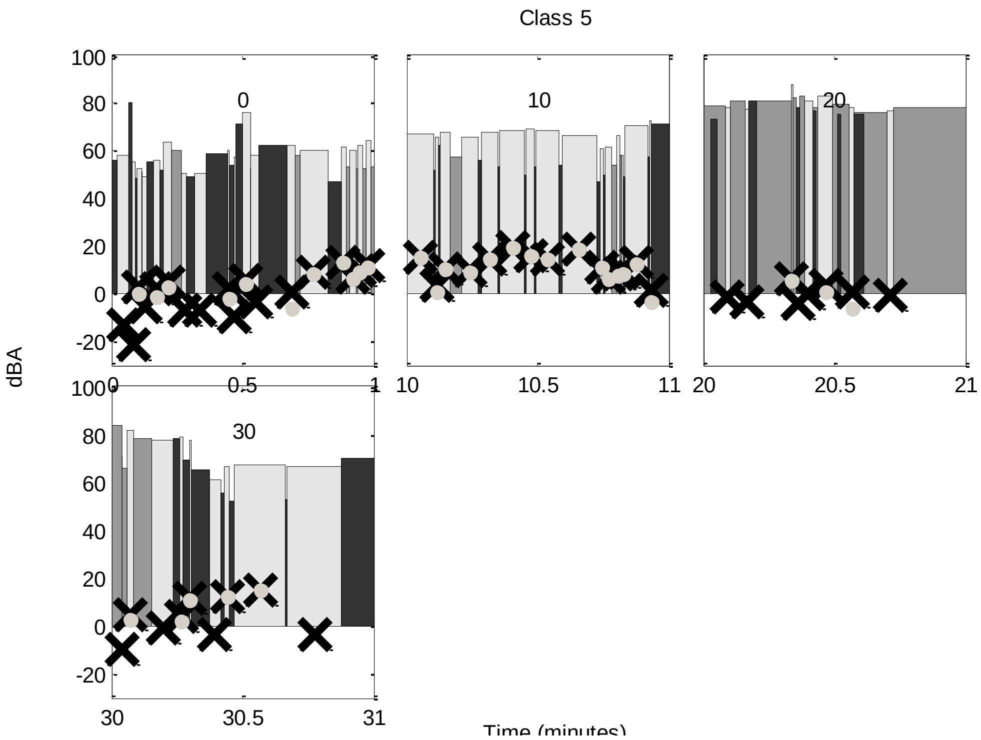


Figure 18 As for 17 but for Class 5

It could prove important to examine SNR for individual short segments, perhaps individual words, rather than longer periods as in a classroom environment the child is presented with many novel facts, new vocabulary, and task instructions. It is possible that not clearly hearing single words or short segments of words due to temporary short periods of poor SNR could prove highly deleterious to a child's learning outcomes.

In this paper we provide evidence that the methods used by previous experimenters are unsuitable for use in active primary (aged 5-11 years) and secondary (aged 11-16 years) school classrooms. The alternative manual method proposed by Shaw (the sound assurance method) appears to be more suitable, but is suboptimal as it does not clearly define the method. The modified Shaw (MS) method that we present in this work could, with further refinement, prove to be optimal. It is acknowledged that all methods, including the MS method, are imperfect. The SNR ratio calculations were based upon the assumption that the recorded noise levels would also be present during the recorded speech signal periods. In the DF method the source of the two fitted distributions is unclear and it is possible that periods of noise (perhaps in interjecting child) could mix with the upper distributions that are attributed to signal and thus the SNR calculations are incorrect. The Sound Assurance methods, and our MS method, is subject to similar errors if the periods marked as speech were not comprised of speech and noise at the same level found in the adjacent periods marked as noise. It is possible that in the MS method this factor is less problematic due to the proximity of the noise periods to speech periods compared to the work of others who recorded noise from entirely separate periods from the speech.

Crandell and Smaldino (2000) reviewed classroom acoustical research and commented that one oversight of previous work is that noise was measured in dB A without any account for its spectral shape. They describe how it is important to ascertain the spectral shape of the noise as it is possible that two classrooms may have similar noise levels as shown in dB A but the effect of that noise could greatly differ between the classrooms due to difference in its spectral shape. A preliminary analysis of spectral shape is shown in Figures 19 to 22. for two example classrooms at child class and teacher microphone positions.

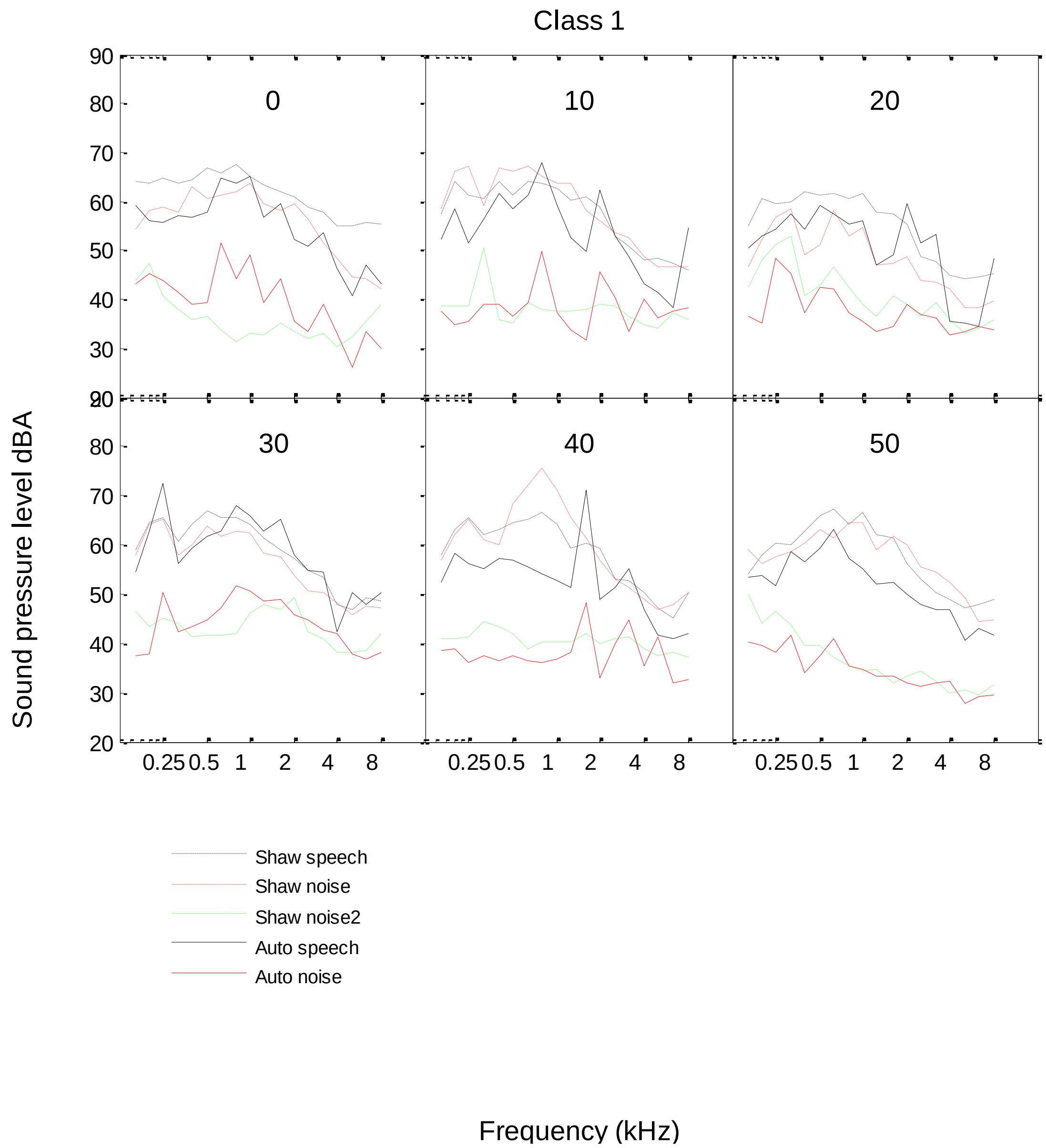


Figure 19 Class 1. Third octave Analysis Class Microphone. Shaw speech (dashed lines) is the modified shaw method, auto speech (solid lines) is the distribution fitting method.

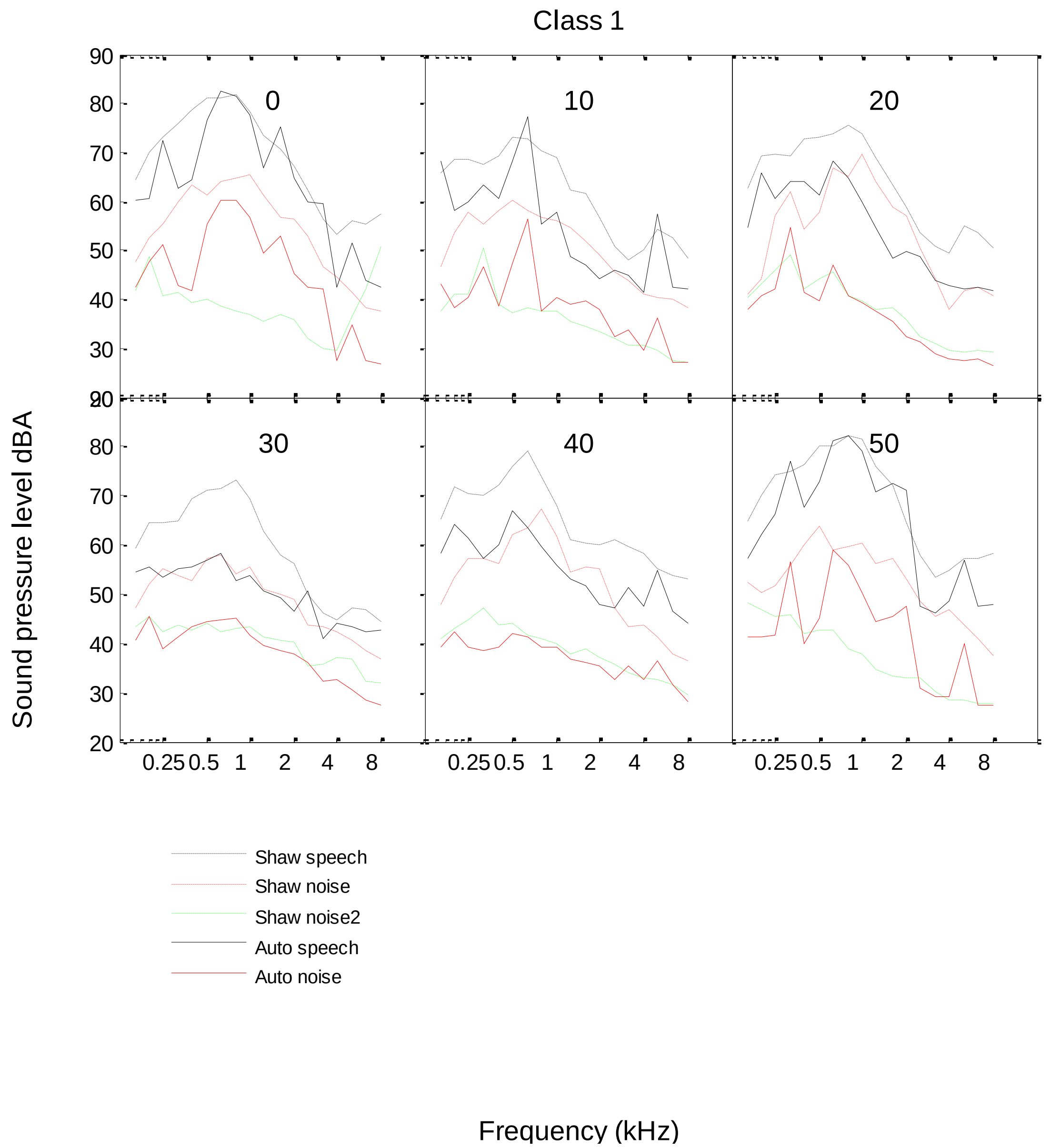


Figure 20 as for Figure 19 but for Class 1 Teacher Microphone.

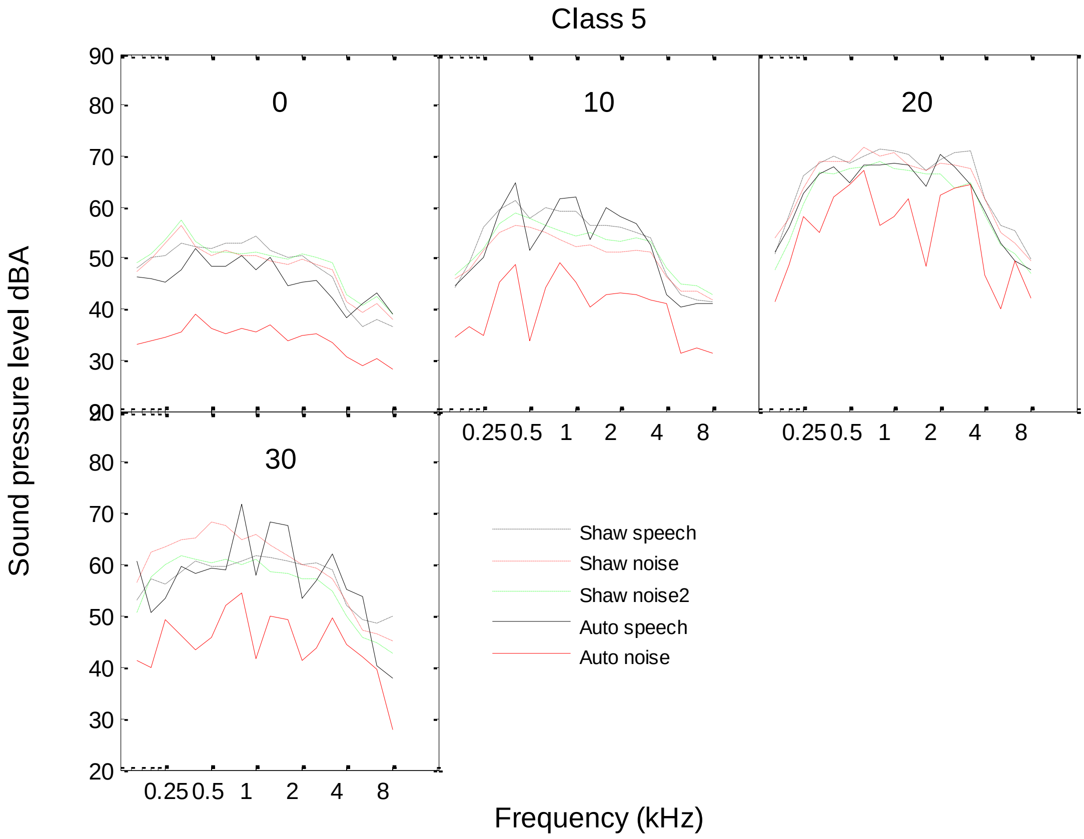


Figure 21 as for Figure 20 but for Class 5 Class Microphone.

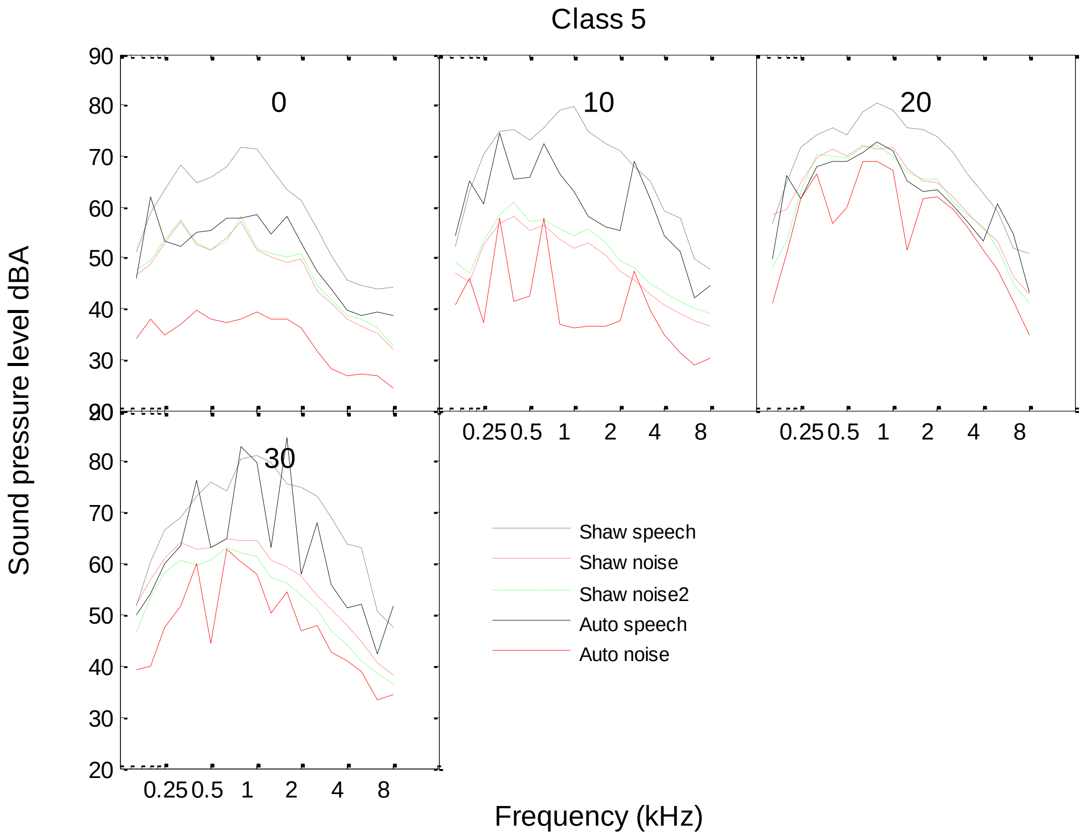


Figure 22 as for Figure 21 but for Class 5 Teacher Microphone.

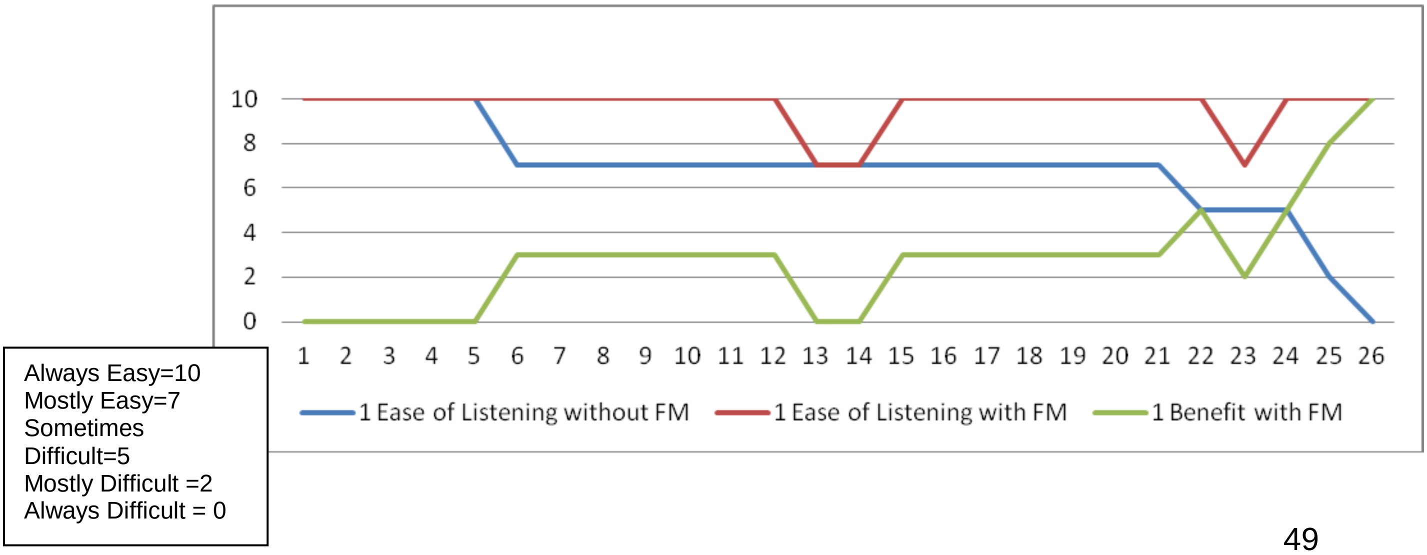
Cornelisse et al. (1991) examined the LTASS at chest-level microphone positions in a laboratory condition and concluded that the LTASS found at a chest-level microphone position is different in both level and spectral shape compared to LTASS found at a hearing aid microphone. It can be seen from the examples given in the figures that the spectral shape of signal differs between microphone in the classroom and on the teacher's chest. The speech spectrum at the teacher microphone is at a higher level than that of at the child position as expected due to the reduced distance from the sound source. This occurs as the direct field propagation of sound dominates the reverberant sound at distances close to the sound source. However, the spectral shape reveals greater emphasis of frequencies in the 500 Hz to 1000 Hz regions compared to the speech received at the hearing aid and normal LTASS. The emphasis of those frequencies appears to be greater than that which is expected from the derived predicted LTASS at chest-level calculated by Cornelisse et al. (1991), which considers both microphone location and vocal effort effects. It is not known why such a difference occurs. Further work and analysis of this factor is warranted. A further analysis of the recordings made could provide a real-world FM microphone LTASS that could be used to assist with balancing of FM and hearing aid microphone inputs in the hearing aid. The fact that the FM input signal may not match the assumptions of LTASS that are used to determine hearing aid targets may have implications for audibility as the hearing aid may not be processing the input signal appropriately. It is also possible that a greater than normal bias to low frequencies could have a deleterious effect at the FM transmitter depending on the transmitter compression scheme.

LIFE-R

No significant statistical correlation was found between Implied Perceived Benefits (IPB) and any of the variables considered.
When considering individual scenarios some patterns emerged, but these could not be used as predictors in any way due to the significant variation in IPBs.

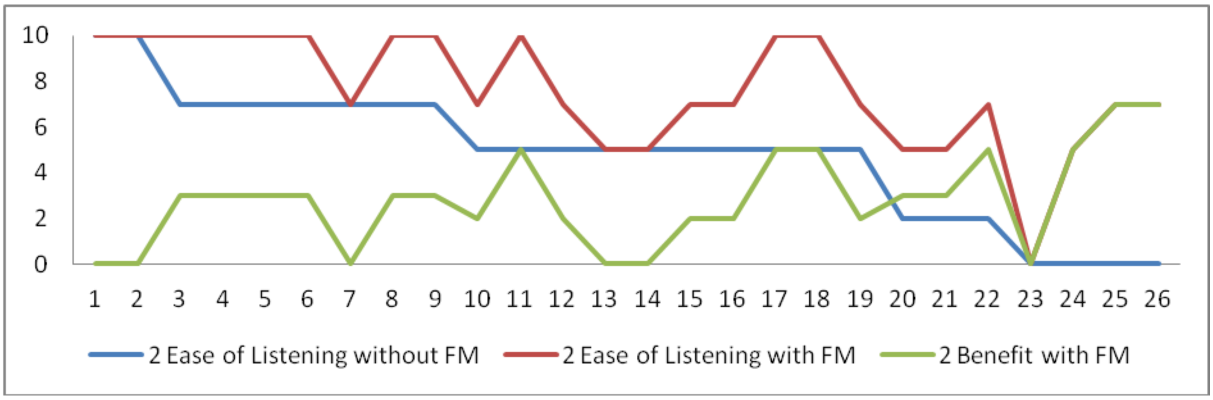
A simple analysis revealed that in the first two scenarios:

'The teacher is talking in front of the class. The kids are quiet. Everyone is watching and listening to the teacher. How well can you hear and understand the words the teacher is saying?' (mean IPB=0.97)



and:

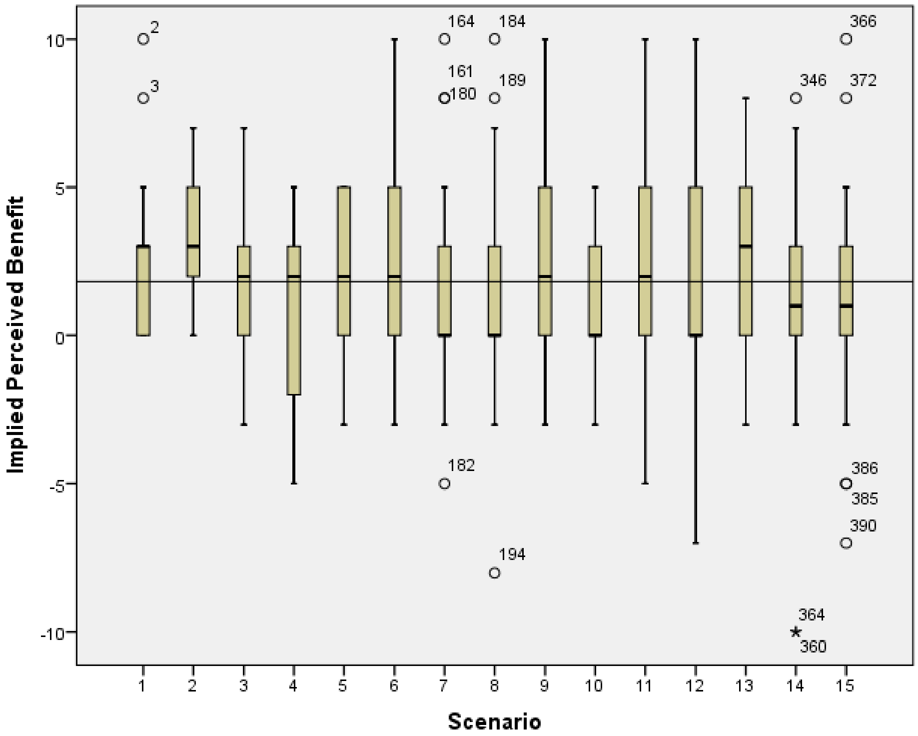
'The teacher is talking, but his back is to you as he writes on the board or faces another student. You cannot see the teacher's face. How well can you hear and understand the words the teacher is saying when you can't see his face?' (mean IPB= 2.81)



Twenty four out of twenty-six children implied benefit where it was reported as being perceived to be required, and no children implied negative benefit.

However, in all other scenarios the range of IPBs was significant (Figure 23) and included negative IPBs for some children in some scenarios.

Figure 23



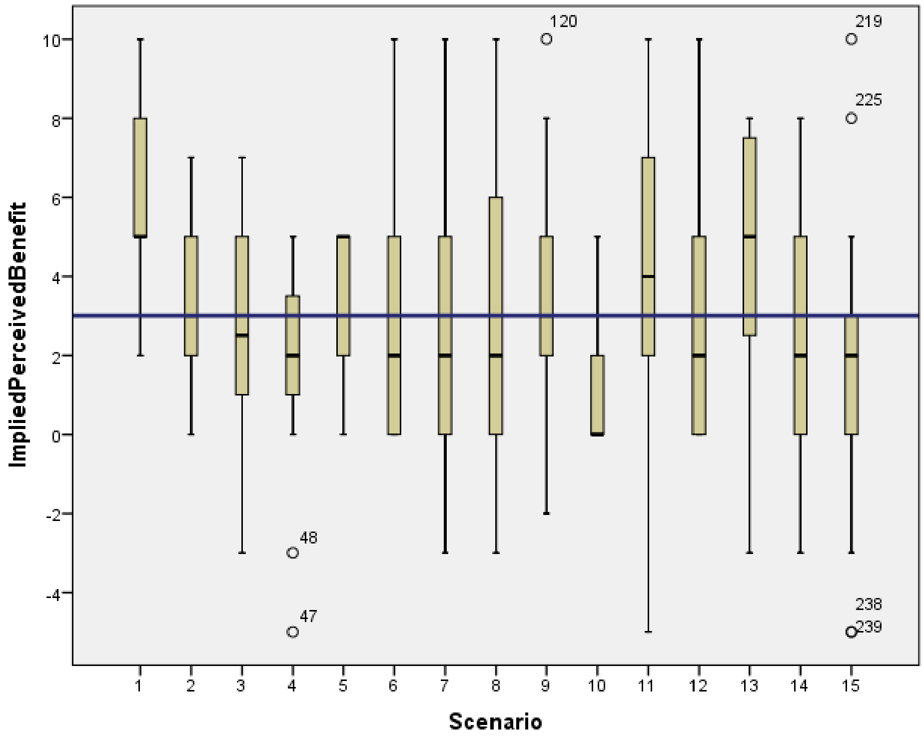
Always Easy=10
Mostly Easy=7
Sometimes Difficult=5
Mostly Difficult =2
Always Difficult = 0

Mean IPB across all scenarios =1.82

Again, the variety of IPBs was so wide and diverse it was not possible to correlate to any specific known variable.

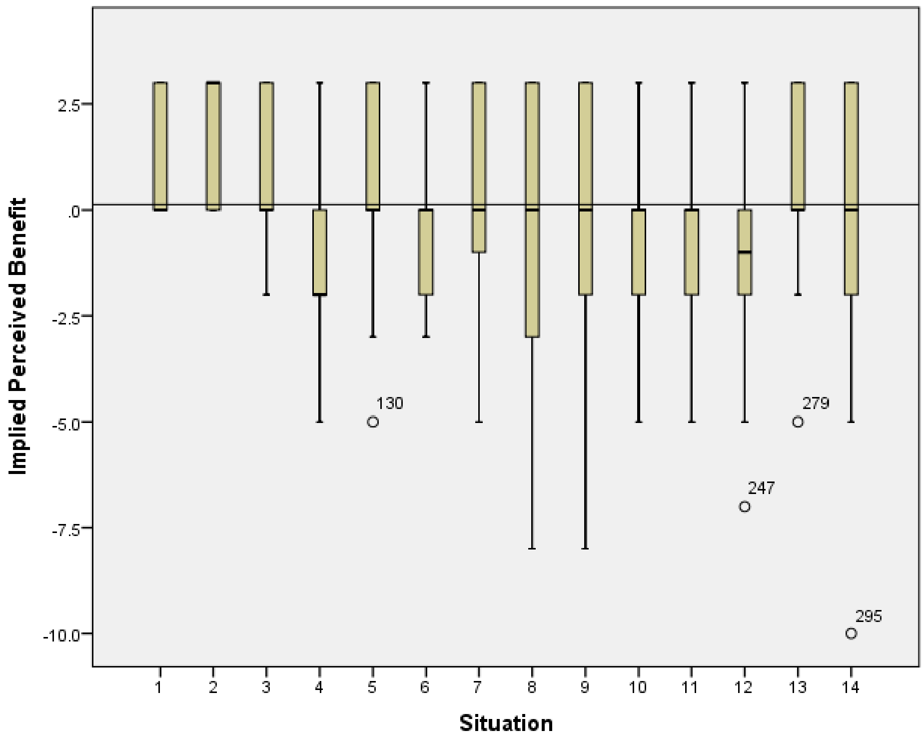
A pattern emerged that pupils reporting that they perceived they heard always, mostly or sometimes with difficulty without FM in any scenario implied most consistent benefit, (mean 2.82). Figure 24 However variety was again too great to use this as a predictor of benefit.

Figure 24



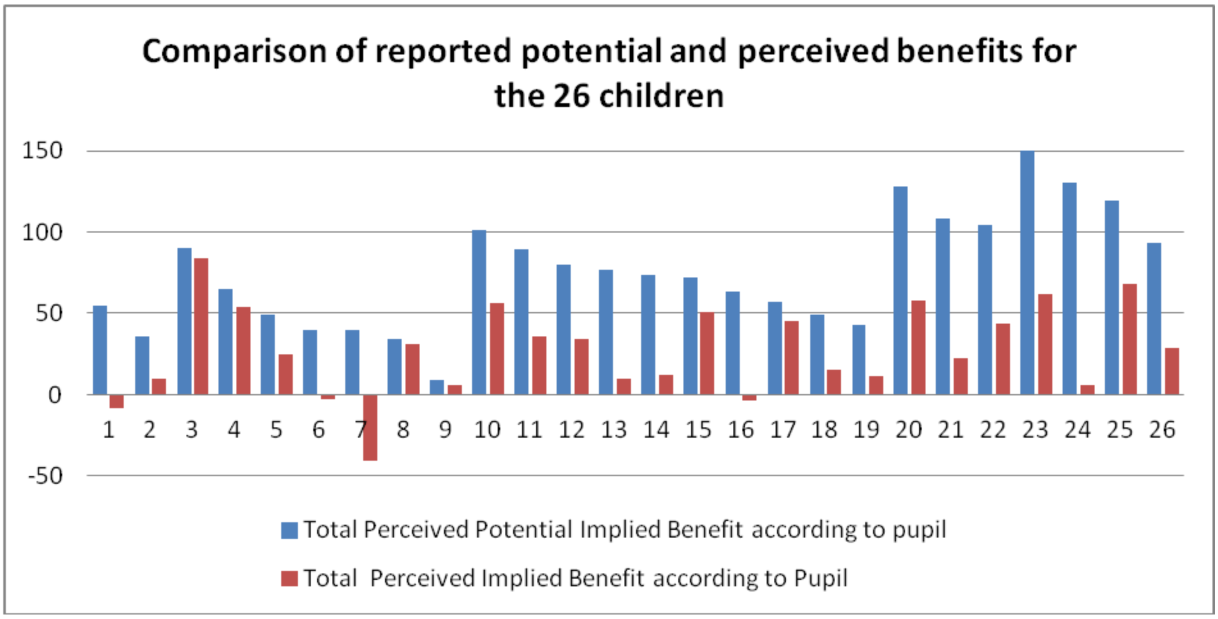
Pupils reporting that they perceived they heard mostly or always well without FM in any scenario were more likely than other pupils in the study to imply negative perceived benefit with FM. (mean 0.13) Figure 25.

Figure 25



Teachers' and teaching assistants' comments and LIFE scores for pupils did not always correlate well with pupil perceptions, either positively or negatively. The responses were too patchy to analyse in detail. Teachers' and teaching assistants' perception of listening difficulty with FM implied additional improvements were desirable. It was also clear from pupil responses that the full perceived potential benefits of FM are not being widely achieved. Figure 26

Figure 26



The difficulties with distribution of the questionnaires via specialist staff to mainstream teachers and pupils, and the low level of adherence to test protocols appears to have highlighted the difficulties faced by specialists seeking to communicate effectively with geographically diverse and busy mainstream staff. These difficulties make effective training in the use of FM and accurate assessment of FM benefit for pupils both difficult and time consuming.

However, our results demonstrate that whilst FM can be of significant benefit, it can also be perceived to be significantly unhelpful. Pupil perceptions were corroborated by audio recordings of their listening environments which

revealed the potential negative impacts of the technology when it is not used optimally. The same recordings, along with classroom observations, however, revealed the complex nature of modern classrooms, and thus the significant challenges of training already busy mainstream staff and children in the appropriate use of FM.
The LIFE-R with LIFE UK pictures provided a useful starting point for considering the possible benefits of FM. However our results reveal that further discussion with individual children about individual scenarios is essential to secure optimum benefit of FM. The range of factors which might be restricting benefit in any particular situation would appear (from our classroom observations and pupils comments at focus groups) to be very wide ranging and diverse.

Twenty -five of the twenty-six children whose responses were studied implied benefit in at least two scenarios. The twenty-sixth child implied no benefit in any scenario and is considered in vignette 14. This child is required to wear FM for all lessons because an assumption has been made that it will benefit him/her. On closer analysis details relating to use of FM by teachers and pupils, along with issues related to social and emotional wellbeing as a deaf child were relevant.

LIFE-R is a useful start, but details of when, how and why pupils find FM beneficial or otherwise are so diverse that detailed analysis of all practices, attitudes and approaches is essential to promote optimum benefit. Pupil comments at focus groups implied that their views may be overlooked, or undervalued and that this detailed analysis is not the norm. Effective analysis is likely to involve significant time for evaluators (usually teachers of the deaf) and training for all staff and pupils involved. The significant numbers of deaf children in mainstream settings suggests that a strategic change in both allocation of ToD time for evaluations and trouble shooting, and training of mainstream staff is essential to ensure optimum benefit of FM to deaf children

Qualitative study.

Three groups were involved in the qualitative study; deaf children who make use of FM amplification, the parents of these deaf children, and professionals both Teachers of the Deaf and Educational Audiologists who work within the educational sector. Three different perspectives on the use of FM amplification demonstrate this is a complex dynamic area influenced not only by the user and the technology but also by the social setting in which it is used and the way in which it is used.

The views of deaf children.

The views of deaf children have received little attention in the literature, yet as the end user this group have a unique perspective that should be directly informing practice. The fourteen children involved were all keen to share their experiences and interested that their views were being sought. They were equally surprised that they could be open and their response would be anonymised. A number of key themes were identified in the children's narrative:

- Benefits real and perceived
- Classroom management
- Responsibility
- Technical issues and ideas

Benefits, real and perceived:

All the children felt that parents and teachers assumed that FM systems would be beneficial and should always be worn in lessons.

"My teacher thinks its super because I can hear her. My Mum and Dad think it is good for my education and my friends think it is a lot better because I can hear what they say" [P1]

" You have to wear them because all of the teachers check every lesson."[P2]

“My teachers understand they know I have to wear it because it gives me lots of benefit. My Mum and Dad think it’s very good and they tell me all about the benefits.” [P12]

“My Mum thinks it’s really, really helps with my education and everything, and I think it does too because I can hear what they put on the radio and some of the videos. We watch Quick-Click and we have got to answer the most out of 35 questions. We have got about 10 minutes so it helps loads of things like that.” [P10]

Deaf children were very clear about lessons or activities where the FM was essential and provided significant benefit and sessions where the FM system was not felt to offer significant benefits.

“I always find the radio aids work well in some situations and not in others, like in assemblies or where there are big groups and when you are at the back you need your radio aid. In the classroom I think I don’t know why I am wearing the radio aid.”[P6]

Peers can clearly perceive the potential benefit of an FM system and try to ensure their deaf friends are using the technology to support understanding both at school and socially.
“ She knows and says X where’s your FM? She has good understanding and I forget it when I am at my friends and she’s not even deaf” [P8]

Similarly other children had supportive friends who were happy to help in the daily management of the FM system.

We have to go into school and when I am taking my coat off and getting ready, they say ‘do you want us to go and give it [transmitter] to the teacher for you’? And I say ‘yes please’ and they go and do it” [P5]

Classroom Management

Whilst Teachers of the Deaf are trained in the use of FM amplification systems mainstream teachers are reliant on training in service. Most FM systems are actively used to in classrooms by non specialists. Where there is good practice children are clear that this provides them with a positive experience. However many examples of poor practice were reported by the deaf children. One of the major issues was the failure of class teachers to use the mute button. This would mean that discussions with other students and staff would be directly transmitted to the deaf child. This was not only irritating and embarrassing and made it harder to concentrate.

You 've got the radio aids in and you can hear the teacher speaking….and I can't concentrate [P2]

"…*but we are trying to concentrate on our work but they are talking in our ear….it is annoying" [P3]*

The teachers leave the mike on when we go for lunch and talk about you so we can hear them. [P6]

" I am hearing more things then they (peers) hear and then sometimes they are doing a surprise I hear what the surprise is, so its not a surprise for me…it's bad. I want a surprise." [P7]

Even when teachers do remember to use the mute facility this does not always mean a positive experience, as one child explained:

"My teacher has got it muted but often forgets to turn it back on and I have to tell the teacher that I need it" [P9]

Classroom practice was a major concern for all the deaf children interviewed. As one child poignantly noted it seemed quite simple to her:

“*The teacher should know they have the radio aid on their chest and remember to turn it on and off, [P4]*

Responsibility, locus of control and stress

The day to day use of FM amplification in mainstream settings relies on the deaf child and mainstream staff working together. Initially this may be facilitated by a Teaching Assistant but as a child matures they take responsibility for giving the transmitter to the teacher. Whilst obvious challenges may arise in a busy secondary school, challenges may start much earlier. In a primary setting the size of school usually allows training to be provided to all staff. Despite this children had concerns about the use and management of the FM system.

“ Worried, worried that I couldn’t hear, worried that I couldn’t hear the lesson and couldn’t learn” [P9]

“Because its very frustrating. Very, very frustrating to hand it to the teacher , giving it in assembly. I hate doing that.” *[P10]*

“I have got one teacher at the moment who is used to it but I am a bit worried about secondary school having to give it to a new teacher every lesson.[P4]

“I just give it them and sometimes they just put it on their desk so I have to get up and give it to them.” [P8]

Technical issues and ideas.

Any equipment is only as good as its management. All the children interviewed were very clear that faulty equipment and interference was problematic, especially where there was no one immediately available to troubleshoot difficulties. In addition to crackly microphones and difficulty getting replacement batteries the main feature children wanted was to be able to mute the transmitter so they did not have to listen to a signal that was irrelevant to their work.

The children did have some interesting ideas that they wanted to share with manufacturers, these are included in the appendices: Appendix x

<u>Parents views of the use of FM amplification.</u>

The parents split into two groups one where parents were familiar with the FM system and where it went home as a matter of course. The second group of parents, primarily those who had children at special schools for the deaf, felt they knew little about the FM system and thought it use was restricted to educational settings. As parents met at the focus groups the discussions were lively and questioning with parents rapidly taking on information other parents shared and questioning their own child’s access to and use of FM amplification. All parental contributions were valued, however it was initially unclear to some parents how they could contribute to the research.

“ *I just feel stupid…I was never told anything about it. I was just told she used one and that I didn’t need to know anything because it was all in school.”* [P1]

Where the FM system did not go home parents reported a range of settings that were difficult and presented problems for them and their child. These \were typically poor acoustic environments where noise and or distance made reliance on personal aids unrealistic.

“ Dancing-because you have the music and you cannot hear the instructions” [P3]

“We don’t really communicate in the car or I have to turn round if I’m not driving.” [P2]

"He's nine years old but I won't let him walk behind me. The other children walk behind me………..[if he had a radio aid]……it would make him independent" [P10]

" Shopping. She goes off in one direction and I go another. I have a whistle pitch that she hears quite well, and she knows my whistle from one side of the shop to another. People look at me as if to say you are calling a dog." [P5]

In discussion with other parents at the focus groups it became clear to these parents that FM amplification could potentially make a significant contribution to the quality of their child's and their own life.

<u>Seeking an ordinary life.</u>

Parents were well aware that their child faced specific challenges and sought to ensure that their child had access to a normal life, actively participating in family, social and educational activities. Where the FM system went home it was used in a variety of settings. Parents also respected their child's choice not to use the FM system, even though they were concerned about hearing instructions they recognised socially a child may prefer to blend in and not draw attention to their FM system or themselves.

"She loves using her MP3 player with it because its wireless and she can dance round the house." [P14]

"He plugs it into the television if he wants to watch a long film and he is doing that a lot more often now I have noticed" [P13]

"We have a cellar conversion and her bedroom is down there. I was up and down and up and down. When we got this on and I just say "A…. time for tea" and she comes up, so she does not miss out, there's no shouting" [P10]

"Yes he just plugs it into the computer."[P8]

“Yes he used it a lot in the past when learning to cycle. I cycle with him using the transmitter so I can “ keep left , keep to the left.” [P7]

“Even the park because its windy. We live by the sea and you can get an awful lot of wind and crashing of waves and things, so it really helps.” [M14]
Although parents recognised the potential benefit of an FM system in these situations they also recognised their child’s right not to make use of it. In some cases other adjustments were made but in others parents had to trust their child would manage adequately.

“M asked us not to take it (to Kids Own club) again I think he just wants to be one of the boys.”[P13]

“I have tried to get him to wear it for Scouts but he won’t” [P2]

“…he likes to go to Scouts as a boy, not a deaf boy, he just likes to go there. They know about his impairment but they don’t ask too many things and I don’t get involved” [P12]

“Its interesting they do create other strategies….so when he plays football out of school his team all know he can’t hear the coach so they have a system for passing messages” [P5]

<u>Potential benefit of FM systems in educational settings</u>

All parents felt that FM amplification offered considerable benefits at school. Parents understood that if used appropriately FM systems help to overcome the challenges of distance and noise. After watching her child undertake a speech test in noise one mother commented:-

“ I was really shocked with the result because B has got a mild loss with glue ear which makes it worse at certain times of the year. And the hearing aids make a spectacular difference……and I thought it was sorted…but then I realised …radio aids make a huge difference as well.” [P6]

“He feels nervous facing a school day without it”[P6]

“ He would not go to school if he couldn’t have it so he wears it all the time at school and he does find it very beneficial” [P4]

“She had fallen way, way behind but since she has had the radio aid she is up now, she has managed to catch up because she is not missing anything”[P10]

“He said he could hear everything the teacher said. I think it is way less tiring for him, when the use the FM system all day …it improves their level of concentration.”[P9]

“He enjoys the fact he can hear the teacher and he doesn’t have to put his hand up because that is what he dislikes through the day, and he is less tired.” [P5]

Parents were aware that such systems requited active management and did raise some concerns regarding such management by mainstream teachers.

“One particular classroom teacher didn’t appreciate the radio aids and didn’t get them switched on and he ended up having to do it himself ……it depends on the person you are encountering at school as to how co-operative they are going to be” [P7]

“Some teachers are very good and very compassionate in the primary years, but some teachers aren’t and tell M ‘no’ for whatever reason and we have had to intervene.” [P12]

“ When the Teacher of the Deaf went in it (FM system) wasn’t working and so she spoke to X and said ‘are they checking these?’ ..she said ‘once a week’..they were supposed to be doing it every morning.” [P14]

A child who joined the school running club was taken out with other children to run on the road. When asked about using the radio aid the teacher had said *" no, you don't need that do you?"* He thought it was annoying as he had worn it (transmitter) once when he was running it was rubbing on him so he decided not to wear it. I was very worried about her safety on the road.

" G tells me her radio aids are working and she gets interference. She has told them lots of times. He just said oh come back in a week or two and we'll see" [P2]

Where schools were informed and sensitive to the individual deaf child's needs systems were put in pace to ensure the FM system was appropriately managed and used, as one parent noted:

"They charge it up every night at school. She takes it to reception and plugs it in, it's the last thing she does. Then when she gets to school she picks it up again…….Her school is really good. I can't fault them. I am confident most of them will ask her if she has any problems." [P11]

<u>Information and training.</u>

Parents were keen to point out that mainstream teachers had to be trained to use the FM system in a way that would most benefit there child. Parents were aware that Teachers of the Deaf and Educational Audiologists undertake training in mainstream schools. One parent who worked in a school where such training was provided noted:-

" They came in and did this brilliant programme where the type of hearing loss of two people were..[simulated?] yes-…you could watch the faces of the people because the example had more hearing than A. You could audibly hear the gasps round the room." [P10]

Some parents were actively involved in the decision to introduce FM amplification.

“The Teacher of the Deaf had told us about the FM system and she came to see us at home. How it played how it sounded , without the FM system to her …so we were very happy for her to use the system and it made a huge difference to her.” [P 12]

The problem of Supply teachers, large secondary schools were turn over means training has to be undertaken annually. For children being taught in the mainstream contact with Teachers of the Deaf (ToD) was frequently on a weekly or even termly basis. This means that daily management and troubleshooting problems with FM systems falls to non-specialists who have a range of other duties to undertake. However, detailed training is by ToDs, the demands on a teacher are such that additional information may not be fully understood or may not be integrated into daily routines. This places the onus on the individual deaf child to ask for appropriate use of the FM system or to request the system is checked. At the most basic level parents found it difficult to understand why Audiologists with the Health service are unfamiliar with FM systems. Parents were concerned that some teachers despite training failed to internalise the needs of deaf children and how this should positively impact on classroom management and strategies.

“there needs to be a module right at the beginning where they [mainstream teachers] can understand what the requirements are, what the children’s experiences are. They need to have case studies of the children’s experiences going through school and what they have to deal with.” [P12]

“It’s difficult for them to understand, I think, because they have got 30 odd other children to look after haven’t they?” [P8]

All the parents that were interviewed were equally keen to have more information and training on the use of FM amplification. They wanted to understand the full potential of such equipment and to be able to exploit this to ensure their deaf child was provided with maximum benefit, not simply at school but as part of their child’s life experience. Where the FM system was kept at school, parents felt both disempowered and unable to advocate for their child’s use of FM equipment at home.

“ It would be nice to know what is available.” [P8]

“Sometimes I feel stupid if I don’t know how things work…I feel I should know what questions to ask but I don’t.” [P3]

“*Can you plug it in to the computer as well as the TV?” [P10]* addressing question to other parent

“ Yes you can plug it in to the computer or an Ipad, the TV” [P12]

“Just a switch you can press and it picks up the sound – you can put it on the table ,it picks up everyone’s voice. The kids at school love it because they can take charge as well.” [P13]

One father summed up the comments of the parents by noting
I have learnt more about FM and the possible uses from talking to you (other parents). I am going to try all these out but I wish I had known about this before. [P10]

Parents were surprised to hear that manufacturers provided information on line and that they had not thought about exploiting this avenue to learn more about the FM systems.

<u>Ergonomics</u>
Parents were clear that wireless FM offered very considerable social and psychological benefits to their child. They felt that bodyworn systems were both heavy and cumbersome and clearly singled out their child as different. Wireless FM was seen as current, similar to using mobile phones with Bluetooth and thus more cosmetically acceptable. The parents felt that being a deaf child in a hearing society meant children had to work harder and were at a disadvantage. They saw wireless FM as one of the tools that enabled

their child to be less obviously different and that enabled them to be more included.

"It was robust and wouldn't break easily. Either it stopped her doing a lot of activities that her friends were doing so it was counterproductive (bodyworn FM). With technology the way it is and it (wireless FM) just makes sense to have something that encourages her and enables her to be more independent and less obvious." [P9]

"He has wireless…… but he still has these things hanging down, these silver things and why are they silver….they stand out" [P14]

When she first started using it , it was wired and that was one of the reasons why she probably didn't want it. Now it [wireless] looks no different to normal." P2

"I think they should be given wireless, because in X you don't get wireless unless you go to Secondary school" [P4]

<u>Teachers of the Deaf and Educational Audiologists.</u>

When this research was undertaken Teachers of the Deaf and or Educational Audiologists were responsible for fitting and managing FM systems. With the development of wireless FM and the need to FM enable, together with the development of fully integrated FM treating the hearing aid and FM system as separate technologies is no longer viable. Training has, in the past, entrenched the view in some cases that FM is an educational tool. This implies education occurs only within formal educational settings. It is clear that all children learn constantly, at home and when interacting with friends, at social clubs and in wider society. Whilst personal hearing aids offer very significant advantages to deaf children they do not overcome the challenge of distance or noise.

ToDs are trained to actively manage FM amplification and have the responsibility for identifying appropriate funding for both the FM system, spares and repairs and for cascading training to mainstream staff, parents deaf children and their peers. A number of key themes emerged in the focus groups:

- Criteria for fitting an FM system
- Funding and insurance
- Training
- Responsibility and self esteem
- Technical issues

<u>Criteria for fitting an FM system</u>

The FM working party QS states that …… this is recommended good practice but carries no mandatory requirement or funding to ensure this can be achieved. With pressure on budgets ToDs feel they have to consider which children are most likely to benefit. Decisions were focussed round acoustic environments, management, a sense of being ready linguistically and in respect if listening skills.

“I think we begin to consider it when they go into those noisy environments, like Nurseries and pre-school settings.” [T1]

“When we feel a child is ready, when they are settled with their hearing aids.”T7)

“This child is conductive-long term conductive it has to be said but Mum wanted to try, so that is what we have been doing.”[T5]

We base it really on once they have acquired a level of language, so they get used to listening with just their cochlear implant or hearing aids- we don’t really start them until nursery or reception (school entry).” [T7]

" I think we observe children in their setting and in their home …..but we would say that all children with hearing loss would benefit from a radio aid…..if their functional listening skills come up as poor. So its every much observation and the other criteria if the school is open plan and the acoustic are far worse …it's even more urgent a that child has good access to spoken language" [T9]

Funding and insurance

At the time of writing this report the provision of FM amplification in the UK is split between Health and Educational providers. The hearing aid is fitted by Health with the transmitter and receivers being provided from Educational budgets. This raises a number of issues including whether a child can take their FM system home. Technically the system belongs to the Educational service and any damage or loss at home would not be covered. Additionally reduced budgets mean that some areas have to rethink how they provide access to FM amplification.

"I am just having the first experience of presenting the school with the correct website and the correct information so they can look and discuss, liaise with me but ultimately the school will pay for the equipment."[T2]

" Unfortunately there are issues about insurance and (FM components) getting lost at home and we do try to ask parents to put it on their insurance but some companies say 'it's lent item and therefore its not your possession."[T6]

"They tend not to have wireless systems in primary as much as high school because we have to be more discerning about where these things are a premium…………………but you do get parents who have access to the internet and find out about wireless and they see other children, and it just makes it very difficult" [T4]

"We always let it go home, if it's appropriate……. It's on a child by child basis."[T6]

“In an ideal world we would like it more for use in every aspect of life , but it’s the money side of it, it’s the funding, it’s the insurance at the minute we are trying to work it out...” [T12]

“ Where equipment in used in schools , they sign an equipment letter agreeing to care for it , any loss or damage occurring in school is the schools responsibility, they pay for it…..Parents do not have to pay for anything. We have spares so if a system is needed we are always able to provide one. Children who continually lose or break equipment tend to be given older equipment so it’s less of an issue” [T15].

Training

This was a major area of concern for Teachers of the Deaf that were interviewed. Teachers of the Deaf are trained to use and actively manage FM amplification. For mainstream teachers, Teaching assistants and parents, training is essential if FM systems are to be used effectively. However a range of challenges are associated with providing such training. Where it works well significant benefits are gained.

“I am working with a girl in year 7 (12 years old) and in certain situations, Sciences and English particularly. \very good use is made of the transmitter with the peers and TA who works with the pupil….They all enjoy using it and the pupil involved really participates fully and gets an awful lot out of it, so that’s fantastic” [T7]

“They were sitting in a circle the first person who speaks has a teddy bear and I suggested the transmitter was attached to the teddy bear so as each child as they spoke passed it on. On child on the other side of the circle form the hearing impaired child was saying at the bottom of her Christmas stocking was a pair of new flowery knickers. Of course anything lavatorial at this age are very hilarious. Everybody started laughing, including the hearing impaired child at the same time as everybody else. I pointed this out to the class

teacher that if the transmitter was not used in that way the Hearing impaired child would have missed that." [T1]

However, many mainstream teachers do not find the use of FM systems easy to integrate into their teaching sessions.

"It's managing the teachers which is quiet difficult as well .Keep emphasising that it's not just a matter of turning it on and leaving it, that you actually have to mute it and decide when it's going to be beneficial for the child to have it on."[T3]

" Some schools connect it to the Whiteboard, it's just normal practice and then other's it's a nightmare, it's all down to the school isn't it? I have seen it work brilliantly, seamless and at any point in the lesson it can be plugged in."[T9]

" And turnover of staff is really high so you think you have trained everyone and then you go a couple of weeks later and you find people have gone and you have got a new lot to train."[T10]

" If the staff aren't trained properly on how to use it, so everything elsecoudlbe perfect, charging up, the organisational skills of that child, giving over to the teacher, but if the teacher isn't skilled in how to use it then that could all fall apart." [T 4]

"I have also had a teacher say to me 'Oh it's been broken for a few weeks' And when I ask why they didn't contact me she said she knew I would be coming in a couple of weeks. Every time you think you have it sussed and every time you think you have trained staff, because children move on year on year, you are constantly having to give in the time to the school to make sure everybody is clear if there is a fault who they contact immediately." [T6]

"The kids must find it terribly embarrassing …every time the child gave him the transmitter he would do the whole thing of '1,2,3,1,2,3 testing' and I had to say you just can't do things like that. They just don't think." [T 13]

Responsibility, self esteem and confidence

It was clear that deaf children bore a considerable responsibility with the mainstream for ensuring teachers used the transmitter. Additionally whilst children recognised significant benefits from the use of such equipment the pressure of peer groups and increasing self awareness means that such use can be compromised.

" When we are talking about older children we very much have to consider all the factors that affect them and their decision….we need to respect their autonomy and their independence , their thinking, their free will and negotiate with them." [T4]

"Well it gives her confidence and obviously she can't be that close to the instructor (at riding school) during her lesson so the radio aid is really helping." [T3]

In one service independence in audiological management is actively encouraged through a scheme.

"We have had a big push on connectivity and their independence. We have audiological independences which they work through so they should be very au fait at handling, fault finding and connections. …..they have a long way to travel and just plug in their iPods and think nothing of it and their phones…..it's important for them to see that it's a tool for everything" [T12]

The over riding challenges of ensuring teachers wore and used the transmitter was a concern to all the ToDs.

" it very much depends on the member of staff and how discreetly they deal with all of that……and don't take the transmitter and say 'can you hear me?' ….at secondary it only needs to happen once and that would definitely put the pupil off." [T6]

" I have got quite a few students who do not like the teacher to use it with Smartboard. They don't like the fact that the teacher has to take it off and fiddle."[T10]

"It's hard because with some staff it does not matter how much time you spend with them they do not remember (to use the transmitter)."[T13]

"I had an agreement with the school that she would put the transmitter on the edge of the desk…. So the teacher would just come in pick it up and wear it. Her big issue was actually walking in the room and having to go up to the front to hand it over. It made her feel very embarrassed."[T9]

<u>Technical issues</u>

As the professional responsible for the management of this technology ToDs had specific concerns about technical issues. They were concerned that all controls should be very obviously marked for use by non specialists. They wanted the mute facility to be readily available and easy to use quickly rather than having to switch on and off. The position of the microphone was a concern so that the ideal distance should be clearly marked or that some alerting system activated if it was too far away. Some reported regular problems with wireless components being faulty or not being securely linked to the shoe. Some concerns were raised regarding the sophisticated nature of FM technology and the training needs of the ToDs if they were to advocate and manage such systems. Where there was an Educational Audiologist in post ToDs were confident that they could quickly and easily access additional support.

There were very specific issues relating to the use of FM technology with cochlear implants(CI). When discussing interfacing the FM system with the CI and exapling how the FM adaptor looked one teacher explained:

"You have this lovely slim, sleek colour matched(CI) then you go a put a bit on almost a carbuncle on the side" [T9]

“The Nucleus ones the leads keep falling out of those .We also have two children getting chronic, chronic interference…….we tried everything, the school turned their wireless off, they turned a transmitting dish off, it made no difference. We worked out there are two problems , there is general FM interference and there is another one specific to the CI.” [T 12]

Summary and conclusions

This is the first study that has looked in detail at the use of FM amplification in real world settings and provided a voice for deaf children, parents and Teachers of the Deaf on the matter. It demonstrates the challenges of measuring the exact signal to noise ratio in a busy classroom environment where much of the teaching and learning is through group activities.

- The SPIN and SART data are interesting in that SPIN is recommended by the FM Quality standards 2008. The SPIN results all demonstrate that all the children received benefit from use of FM technology in test conditions. The SART data clearly shows that when a secondary task is added word scores are significantly reduced. Thus projecting classroom performance from SPIN is likely to overestimate the benefits that children can accrue from using FM amplification. This may result in teachers of the deaf making assumptions about positive benefit which are not necessarily borne out by experience. Interestingly word scores in noise during SART testing were significantly improved by using FM. When the signal to noise ratio was +10 those with a mild degree of hearing loss received no significant benefit from FM. For all other degrees of hearing loss word scores were significantly better using FM. Whilst SART may be too challenging for very young children it would appear to have the potential to be useful in considering sustained attention in deaf children.

A number of key areas have emerged from this study:

- Educational environments in the early 21st century in England are typically dynamic, active sessions which involve active student participation. Didactic teaching has been largely replaced by an interactive questioning approach. This challenges the traditional use of FM amplification. Identification of the lead speaker during teaching sessions is complex; it may be the Class teacher, Teaching assistant, or a pupil. Sessions include the use of interactive Whiteboards, DVDs and computers all of which can be used with direct input to an FM transmitter.

- Establishing the signal to noise ratio during a dynamic teaching session is challenging.
- Classrooms in the study from 10 local authorities were diverse, including mainstream and special school settings in both urban and rural areas. Of the twenty-seven classrooms tested none met all of the BATOD recommended standards for reverberation times, and only seven met these standards for mean reverberation times. The majority of deaf children in this study are working in challenging acoustic environments. It is important to note that other pupils in these settings, as immature listeners, are also being disadvantaged by these poor listening environments.
- Where the use of the FM transmitter was proactive, sensitive and child-centred children gained significant benefits. In both special school settings policy dictated that FM systems would be worn and used for all taught sessions. Additionally FM systems were seen as school based. Services were more open to discussion with pupils regarding when and where the FM system should be used. Some services allowed and facilitated use of FM systems at home whilst others felt the FM system should be school based. Concerns about insuring FM systems against damage and loss whilst in the care of families were significant for many services. These concerns prevented home use in some services.
- Use at home revolved mainly round use in the car, when learning to ride a bike, for sporting activities including horse riding and cricket but also when going for a family walk and when shopping. Additionally children used FM at home with other technology.
- The mute facility was rarely used, even where mainstream staff asserted that ‘excellent training had been provided’. The majority of

children using FM in this study spent a significant portion of their lesson time seeking to focus on an activity whilst receiving FM signals which were unrelated to their activity.

- Children found that managing the FM posed a number of challenges. Ensuring teachers had the transmitter was a significant challenge. Forgetting to turn the transmitter on, poor positioning of the microphone, making inappropriate comments to the FM user all raised concerns.
- Children were frustrated that mainstream class teachers failed to use the mute facility of the FM systems. Where children's hearing aids had only two programmes: one for FM only and the other for Mic. only this presented the added problem that children could not hear their peers either.
- Deaf children have informed insider views regarding the use of FM technology. These are not represented in the literature. All the children who attended focus groups expressed surprise and pleasure at the fact that we genuinely wanted their views. Some children said that nobody listens to their views, other implied it with their comments about problem resolution. Some services do actively engage the children to seek out their views on FM. Three of the services we spoke to said that they consider these details very carefully and change their practice accordingly for children who are clearly concerned.
- Where children had experienced the use of FM in social settings and with other technology they were positive about the possibilities FM offered.
- Despite being aware of the potential benefits of using FM deaf children are very clear that there are situations in which they do not want to make use of such equipment.
- Where parents have been actively involved in the decision to introduce an FM system and such systems are seen as part of the child's amplification package, they were keen to exploit the possibilities such equipment offers. For those parents who were not involved and knew little about the system or its potential uses the feeling was one of lost

opportunity. When asked about the timing of the introduction of FM amplification 98% wanted this to be done at first hearing aid fit after the identification of deafness.

- Parents felt that hardwired systems stigmatised their child and that wireless systems offered benefits both in terms of listening ease and the individual child's social experience.
- Teachers of the Deaf and Educational Audiologists were all concerned that neither they, nor mainstream teachers, have sufficient time to allocate to appropriate training in the use of FM systems. Daily management and monitoring of systems is thus compromised.
- There was concern regarding funding of FM systems. This is exacerbated in the UK by splitting responsibility for the hearing aid and FM system between Health and Education rather than viewing this as part of the child's amplification package.

<u>Recommendations</u>

1. A robust system is required to ensure that the views of all deaf children regarding their use of FM are actively sought and responded to in a timely manner.
2. Changes in the funding stream for FM equipment to enable audiologists, working collaboratively with education services, parents and children to provide a complete package of auditory support.
3. Mandatory national training for serving mainstream teachers in deaf awareness and the creation of effective listening environments using FM, soundfield and other technologies as appropriate.
4. Such training should be included in all initial teacher training courses.

This study has provided the first opportunity to gain an understanding of the listening experiences of deaf children in current classroom settings. More than this it has highlighted that despite the potential of current FM technology the fact that it is predominantly used by non-specialist teachers would appear to result in less than optimal use. This study is also important in that it provides clear evidence of the psychological and emotional aspects of FM use in children, an area that has received scant interest in the literature. In the 21st century with the widespread use of technology in the home and wider society it is time to see FM as a part of the child’s whole amplification package that allows them to access both school and wider society.

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Appendices

Appendix 1 Vignettes

Appendix 2 What children told us they wanted others to know

Appendix 3 Dissemination plan

<u>Individual vignettes.</u>

As any group of deaf children is by definition heterogeneous eight vignettes have been produced to give a detailed snapshot of the data as it relates to individual children. This group includes a mix of primary and secondary aged children with the majority form mainstream but also several from special school settings. All these children attended focus groups.

9 yrs 10 mths: hearing loss identified at 1 year 10mths, aids fitted 1year 10mths

PTA	250	500	1k	2k	4k	6k	8k	Hz
R	130	100	100	100	85	85	80	
L	70	65	55	20	5	5	5	

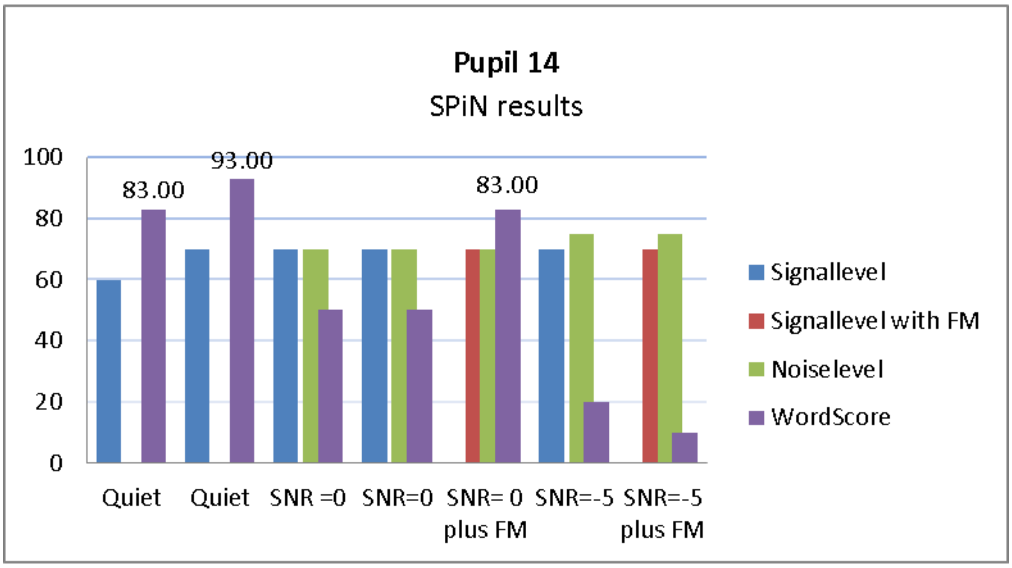
Fitted using DSLi/o bilateral Externa 311 dAZ and MLxi*

Upgraded to bilateral Nathos UP [R] and Nathos SP [L] during project: Inspiro transmitter

Setting : a special school for deaf children

This subject has an FM system which is used in school but does not go home. He is in a small class of six children. The reverberation times for this classroom meet the BATOD standards for class RT. A class session was observed for 56 minutes. Within this time didactic teaching took up only 3 minutes of the session. There was no clear lead speaker for 53 minutes, during which the teacher did not mute the FM transmitter and the Teaching Assistant was talking to individual pupils. Didactic teaching without the FM system occurred twice. Use of the FM system is mandatory at school although use of the FM system by the staff during this observation was less than optimal.

Speech in noise testing in the school, using the AB word list, demonstrate this subject can score 93% in quiet but that once noise is introduced he experiences difficulty. At a signal to noise ratio of 0db with FM he scored 83% but at a S/N ratio of -5 even with FM his score is 10% as illustrated in figure 1



He was unable to complete the dual task which suggests that in class he will find it hard to perform. Given this profile it is clear this subject may have other more central problems. He was dismissive of FM amplification saying that he *"it gives me a headache, chat ,chat, chat, chat, chat…".* His scores on the LIFE R questionnaire demonstrated that when specific scenarios were presented this subject could identify situations where he felt there was benefit in using an FM system:

- The teacher talking but unable to see his/her face
- Teacher walking round the classroom
- When there was intrusive outside noise
- When working in small groups
- Listening to class announcements
-

The subject did not feel his FM system was helpful when

- Teacher was talking in quiet
- Another student comments in a lesson
- When two adults are in the class and both are talking
- In assembly in the hall *
- When a teacher is giving directions about an assignment

As this subject is in a small class of six children his responses may simply reflect the close proximity in which this group works. The only response which is different in this respect in listening in the hall where distance and reverberation should mean there is a significant advantage in using an FM system. This subject only uses the FM system at school, where there is a policy of wearing that children must wear FM for all formal school activities. He has no experience of using the FM system with for example an MP3 player. He experiences considerable challenges when asked to listen in test situations. This requires further detailed investigation.

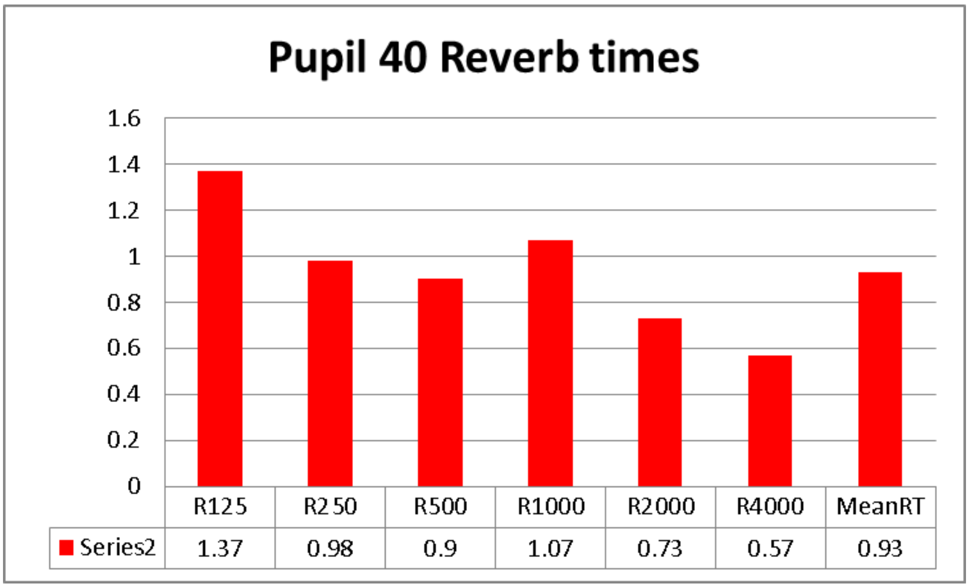
Vignette 2: Subject 40

This female subject age 14years 6 months. At risk hearing loss identified at birth.

PTA Hz	250	500	1k	2k	4k	6k
R	45	55	100	110	115	110
L	40	65	90	100	115	100

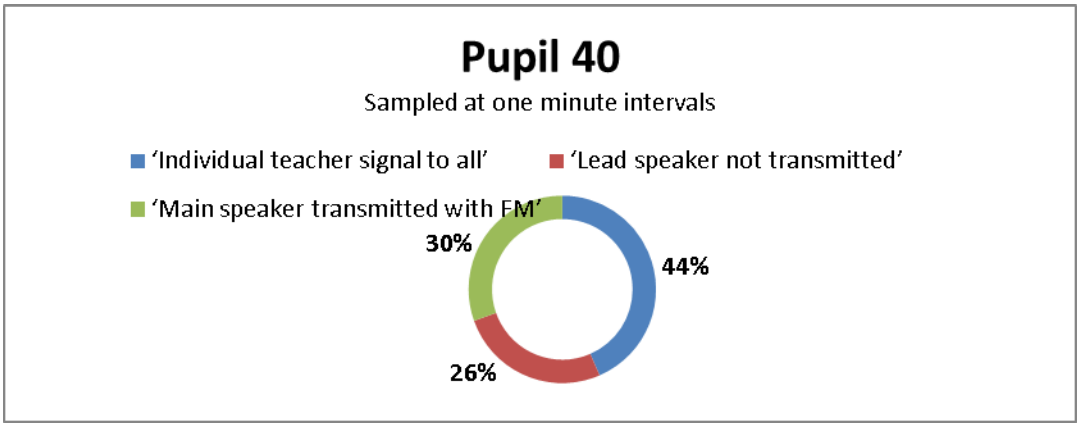
Fitted DSLi/o bilateral Naida SP with MLxi and a Zoomlink transmitter

This subject is working in a hostile acoustic environment, the reverberation times were all outside the recommended guidelines.

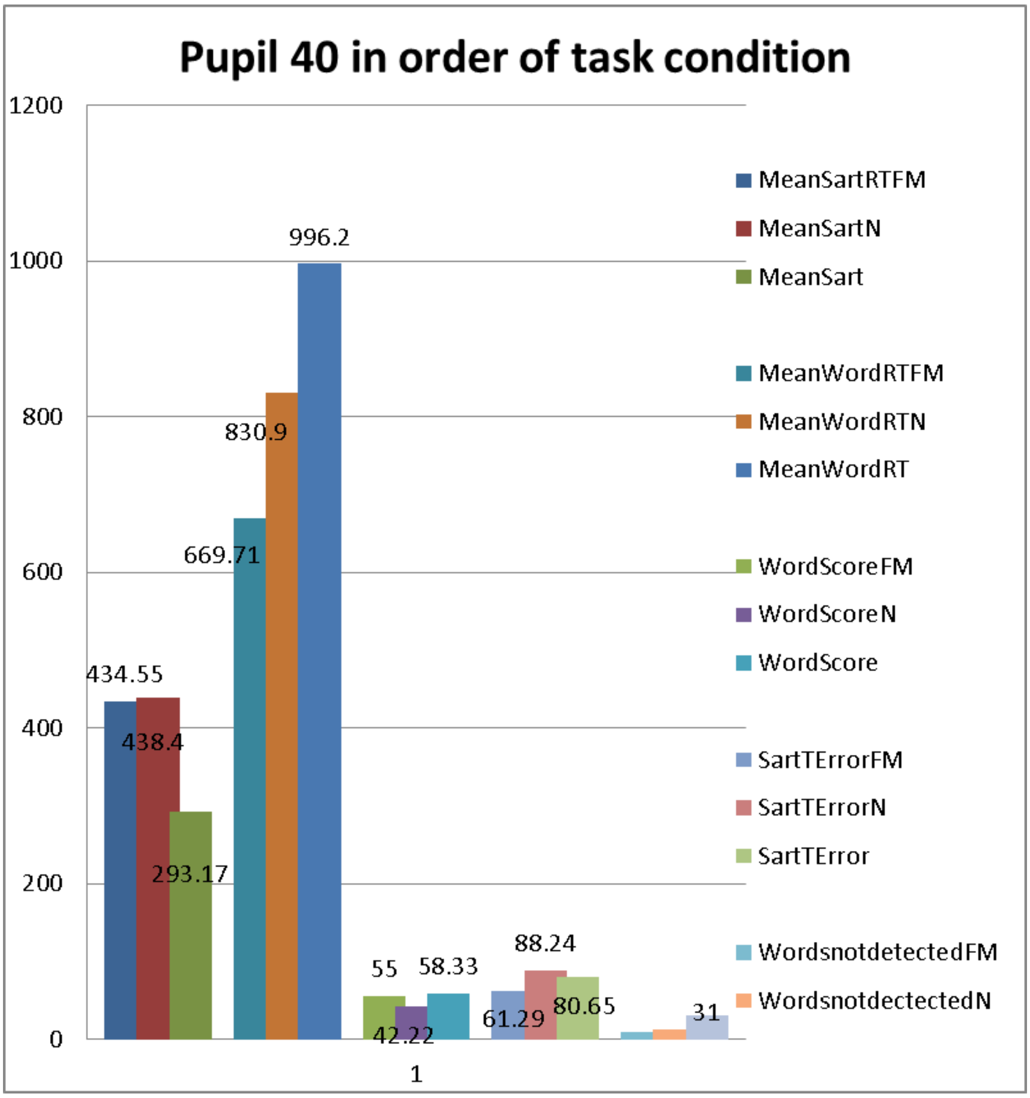


In a total of 56 minutes observed in the classroom there were 19 minutes where the teaching was didactic in nature and the FM was used appropriately. However 20 minutes of the lesson where there was no clear lead speaker the teacher was talking to students without muting the FM transmitter. On 13 occasions a lead comment was made that was not transmitted through the

FM transmitter and therefore would not have been accessible to this subject. In summary 30 5 of the lesson the main speaker used the FM transmitter. For 56% of the lesson it was used inappropriately for this subject.



There were no speech in noise test results available. Despite being one of the older subjects there would appear to be evidence of an order effect in the dual task situation. Word reaction times were considerably faster when using the FM system and the SART error scores were lowest. Word scores uing FM in noise were significantly higher than without FM as would be predicted.

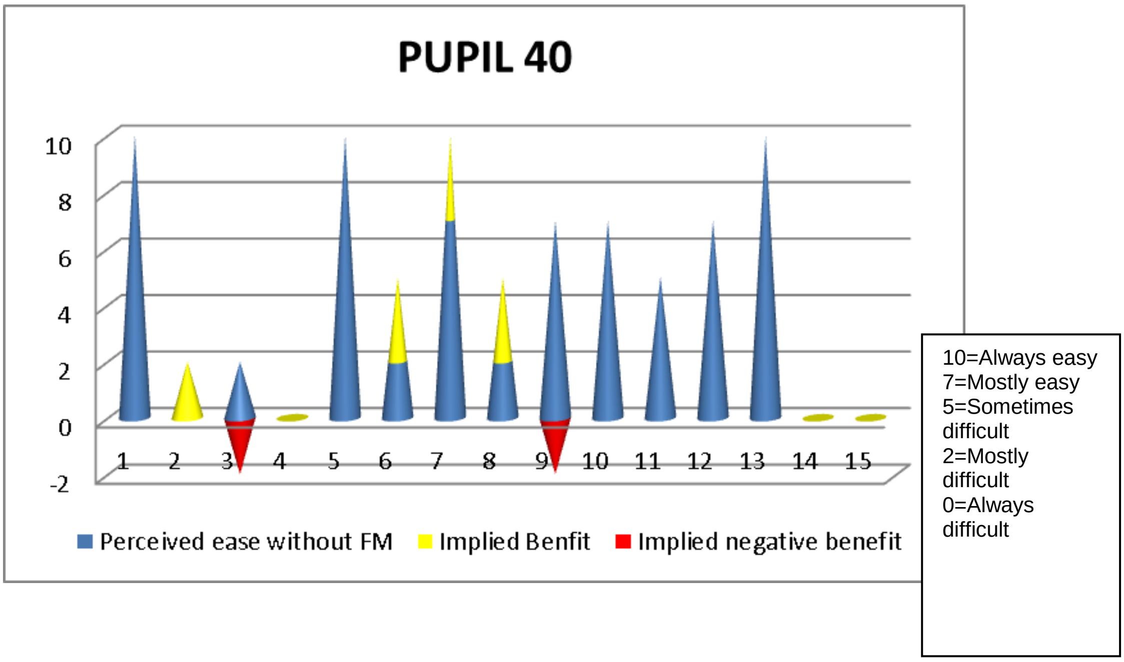


The FM system was used during all lessons but was not taken home. When completing the LIFE questionnaire this subject felt she could clearly identify scenarios when the FM system was helpful and when it was felt to be of negative value. The following situations were all judged to be negative in respect of using the FM system

- The teacher is using a projector that is making a noise, or air is blowing from the heater/cooler in your classroom. How well can you hear and understand the words the teacher is saying when there is a fan-type noise at the same time.

- One teacher is talking in front of the class. Another teacher is talking to a small group of students at the same time. How well can you hear and understand the words the teacher in front is saying.
- The class stops to listen to class announcements. Sometimes kids are making noise during the announcements. How well can you hear and all the announcements when there is some noise.
- The teacher is talking. She is also walking and moving around the room. How well can you hear and understand the words the teacher is saying if you can't see her face and she is across the room

All these situations should demonstrate a benefit from using the FM system suggesting that use of the transmitter may well be problematic.



Setting 14 and 14 were not reported as the student had no experience of listening in these situations.

This pupil is considered by the professionals involved to be responsible for all management and a 'fantastic FM user'. The Teaching Assistant noted that

the pupil is very independent with equipment. The class are used to using the equipment. The Class teacher also reported that :
'I had fantastic training from the teacher of the deaf'. Whilst the class teacher reported feeling confident, the subject teacher observed failed to mute throughout the session. It is also interesting to note that the FM transmitter does not appear to be shared in class as the response to hearing a peer's comments (q.4) does not show any benefit.

Vignette 3: Subject 70

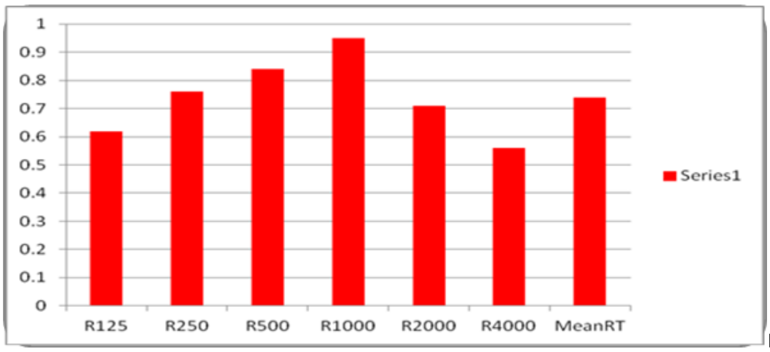
Identified hearing loss at 1 yr 11 mth
Hearing aids fitted 1 yr 11mth

PTA	250	500	1K	2K	4k	6k	8kHz
R	75	80	80	85	70	60	65
L	105	105	95	90	85	80	70

Fitted using DLSi/o Bilateral aids Naida SP with Connevans Genie FM system

This subject is a mainstream primary school. He is in a busy classroom where reverberation times exceeded the recommended times cross all frequencies. A lesson was observed over of 45 minute period. During this time the teacher was involved in didactic teaching for a period of 16 minutes when the FM transmitter was used. There were ten occurrences where the lead speaker –a pupil of Teaching assistant spoke and the message was not relayed via the transmitter. For a period of 15 minutes the FM transmitter was left on but the teacher was addressing other individual children or groups. During this time the deaf subject received an irrelevant signal that did not relate to their work

Figure 1: Class reverberation times for subject 70



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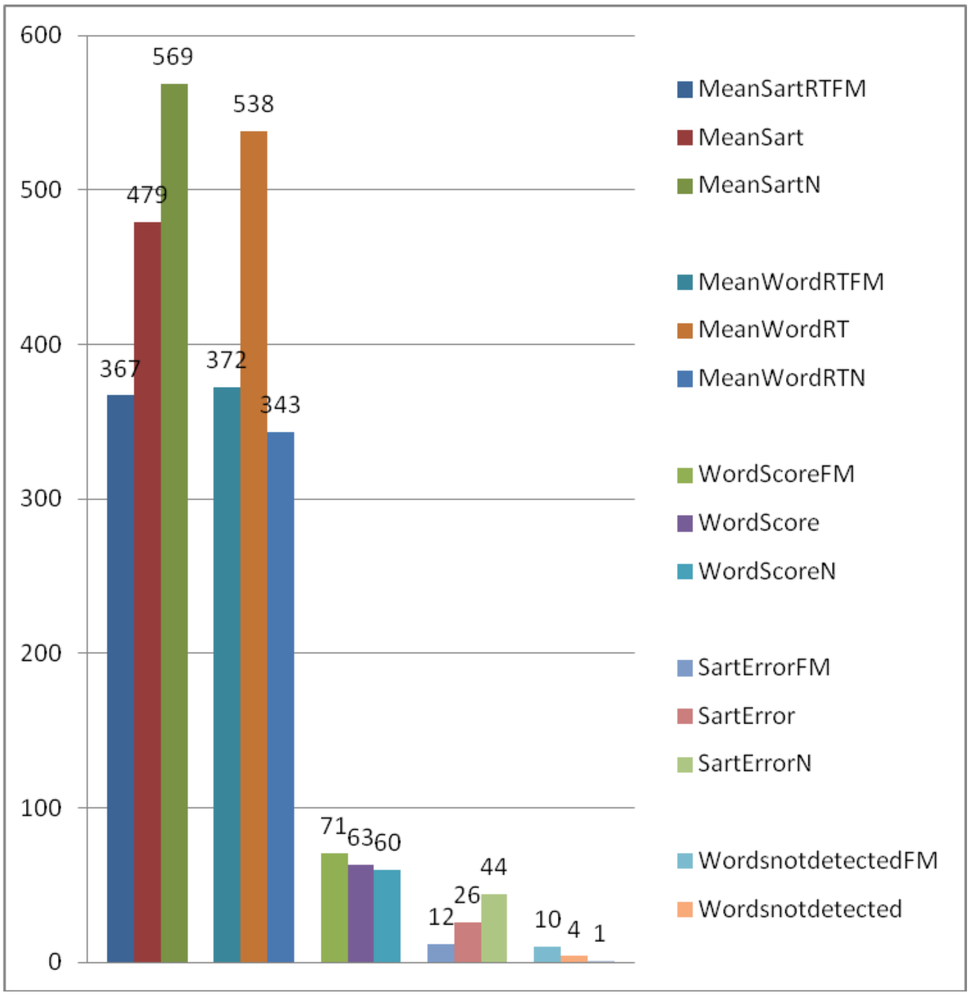
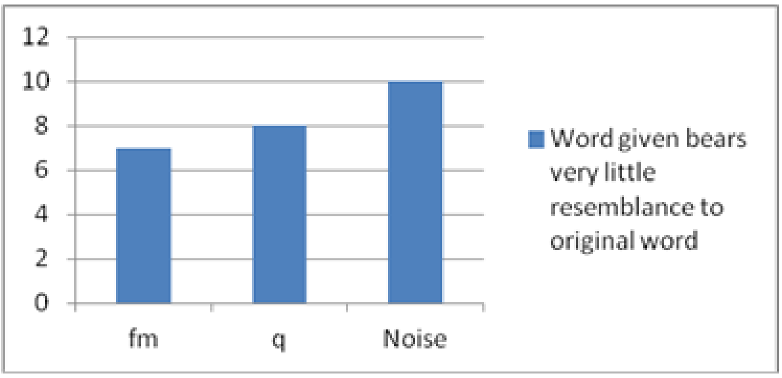
Speech in noise testing was undertaken by the Educational Audiologist and clearly demonstrated an FM advantage when listening to speech in noise. When an additional task was added that aimed to simulate classroom experiences of listening whist completing a task. The mean reaction time on the Sustained Attention task [SART] was fastest when the FM system was being used, however this appears to have resulted in the reaction time for the word score on the AB word list being sacrificed for the number task where the mean score is considered. The overall word score was highest when the FM system was used. Fewer errors were made on the SART when the FM system was used.





When asked to complete the LIFE questionnaire subject 70 identified four situations where he felt the FM system was helpful but also where he felt it was unhelpful or made listening more challenging. He felt there was no benefit when there are two conversations happening simultaneously, or when there was an announcement in class but children were still talking. Similarly when working in a small group with children talking and others groups talking and moving papers around were difficult and the FM was not felt to be helpful. Negative benefit was implied when the teacher was walking round the room making it hard to see her face. This is particularly interesting as this is exactly the situation where the system should be providing a significant benefit. When the child's perceptions of benefit are compared to those of the Class teacher and Teaching assistant [TA] it becomes clear that some significant differences exist. Figure 4 demonstrates the LIFE scores suggesting that there needs to be careful consideration of use of the FM, including when the hearing aid microphones are used at the same time.

Vignette 4: Subject 83

Female aged 13 years; deafness identified when she was 5 years old

PTA	250	500	1k	2k	4k Hz
R	100	100	105	100	105
L	95	100	95	85	75

Fitted using DSLi/o bilaterally with Naida V UP and MLxi receivers

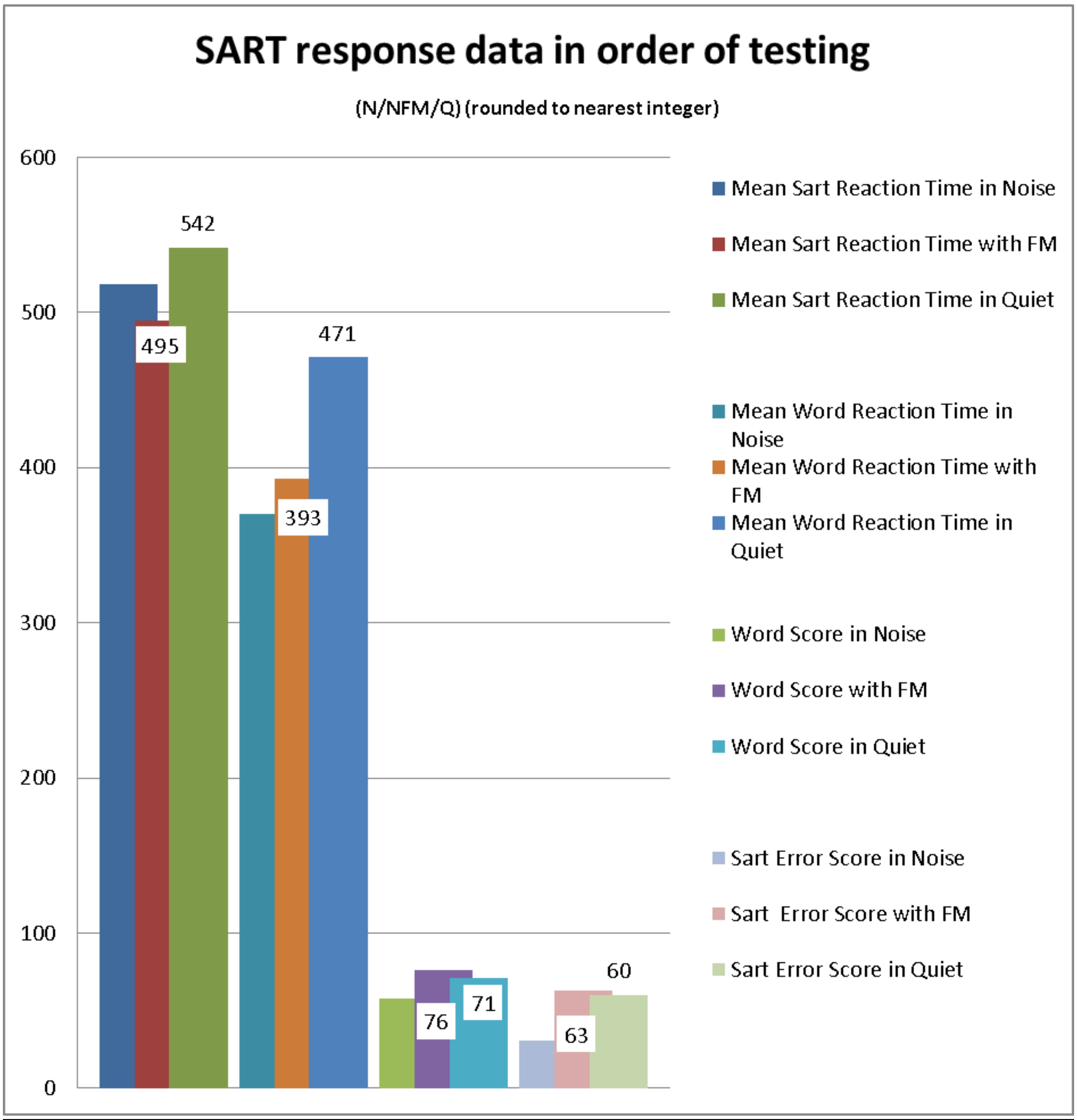
Phonak Inspiro transmitter

Attends Special school for the deaf

This subject was late identified.

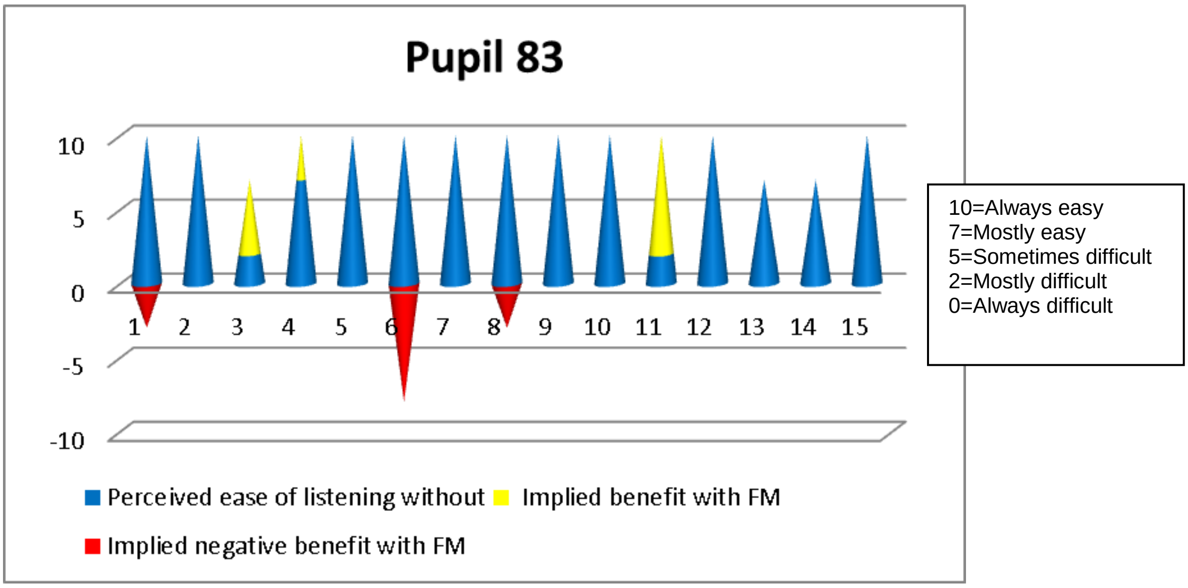
Her teaching is split between a Special school and mainstream school. She uses her FM system at school only. Classroom observations and reverberation times RT were undertaken within the special school setting. Teaching was observed for a total of 52 minutes. Within this time didactic teaching with appropriate use of the FM system occurred for 19 minutes, for a total of 20 minutes there was no clear lead speaker, the FM was not muted and the Teaching Assistant was talking to individual pupils. There were 13 occasions on which didactic teaching was occurring without use of the FM transmitter. Whilst this session may not typify use of FM amplification in this setting, it is an example of poor practice. Within this as many other settings use of the FM system was mandatory during all lessons.

Speech in noise testing using the AB word list suggests that this subject can score well in quiet [90%] but that when noise is introduced even when using her FM system she finds listening in noise very challenging scoring a maximum of 57% at a signal to noise ratio of -30. At this level it is likely the FM system would be in compression. When working on the dual task this subject's reaction times went down when using the FM system. The word score in noise with FM was marginally better than in quiet.



In the dual task scenario this subject demonstrated a better word score when using the FM system but also had a high SART error score. The mean word reaction time was noticeably better in noise using the FM and reaction time to SART was also quickest when using the FM system

Despite such use of the FM system, when asked about perceived ease and benefit of using the FM system this subject when assessed using the LIFE-UK questionnaire this pupil was able to clearly identify when FM was useful and how much benefit she perceived resulted from this.



The three situations where this subject felt that there was a clear advantage in using the FM system were:

- In assembly
- Outside listening to a friend
- When the teacher was walking round the room

These contrast to the three settings where this subject perceived she received little or no benefit from her FM system:

- When the teacher was at the front talking to the class
- When other children were making a noise in the classroom
- When a video was being shown and the teacher was talking

These results contrast with both the teachers who completed the LIFE UK questionnaire who recognised that use of FM was sometimes difficult but who always felt there was a positive benefit

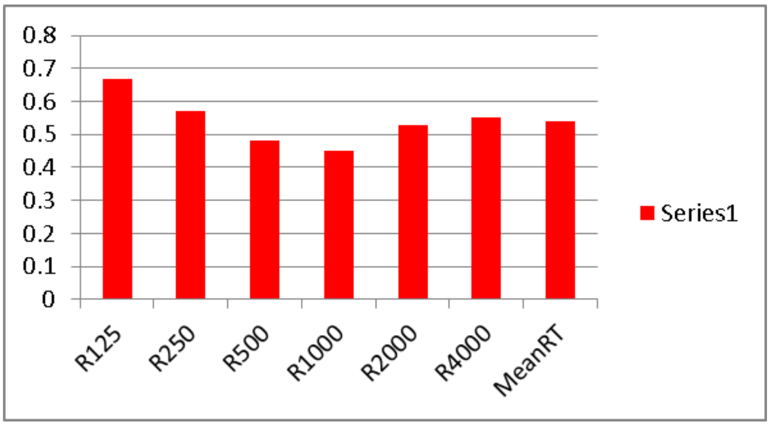
Vignette 5: Subject 121

This 11 year old male subject was identified as deaf at 3years 8 months and fitted with aids at 3ys 8 months

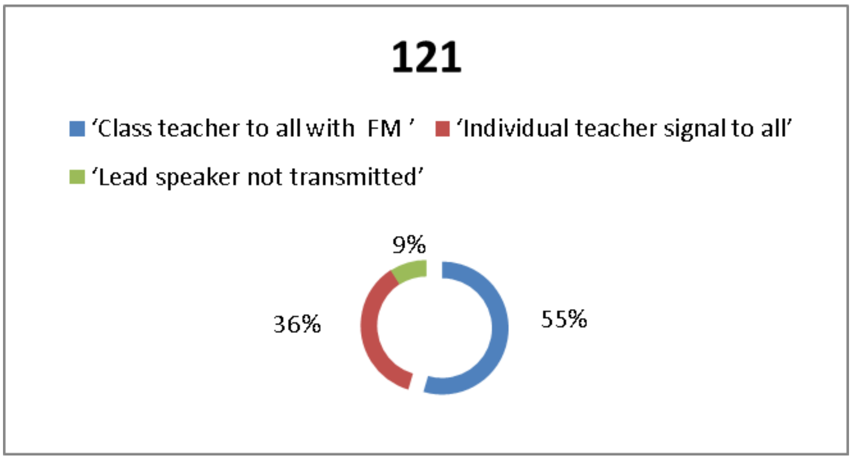
PTA	250	500	1K	2k	4k	6k	8k Hz
R	85	100	105	95	85	80	70
L	90	105	105	95	90	80	70

Fitting protocol unknown.
Bilateral aids Eterna 411dAZ with MLXi
Genie transmitter Connevans

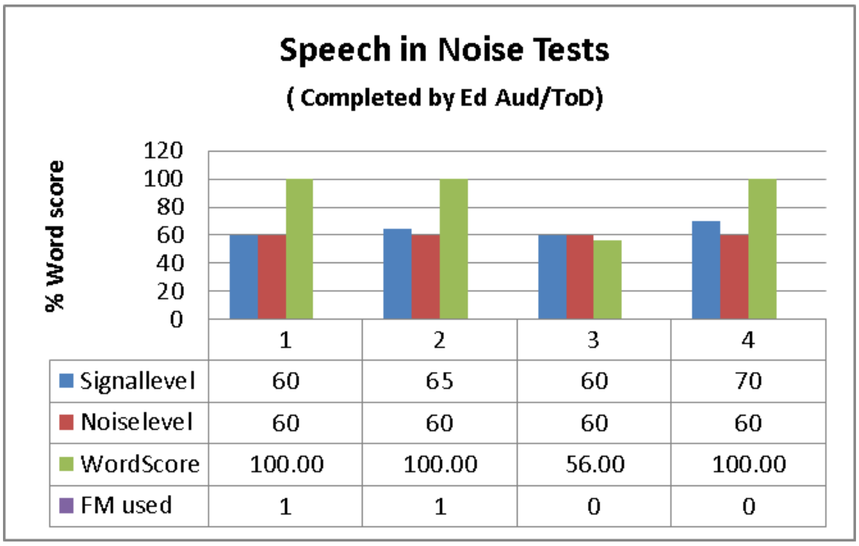
This male subject attends a local mainstream secondary school. He was observed during a science lesson. There were 26 children in the class. Reverberation times [RT] for the classroom demonstrated that at every frequency the RT were above those recommended by BATOD



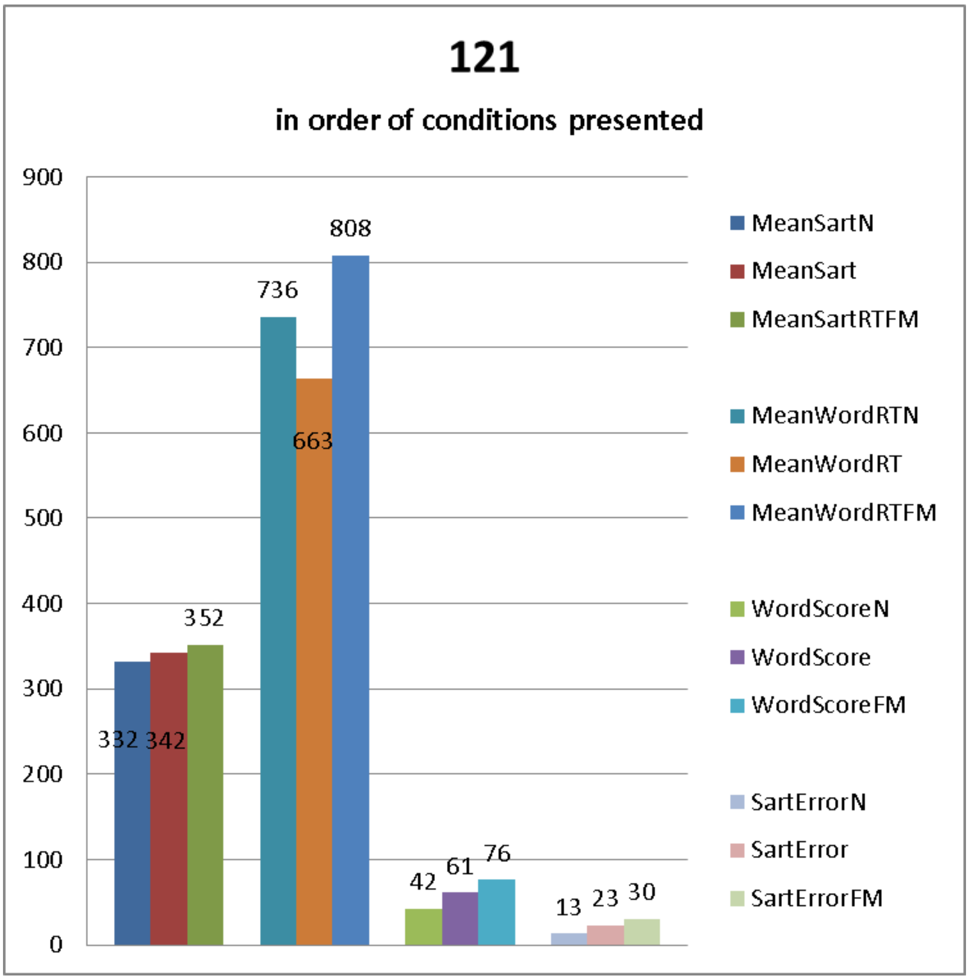
The class was observed over a period of 38 minutes. This was unusual in that for over half the lesson the FM transmitter was used appropriately. However for the rest of the lesson the speaker did not have access to the transmitter or it was not muted and used whilst discussing points with other children.



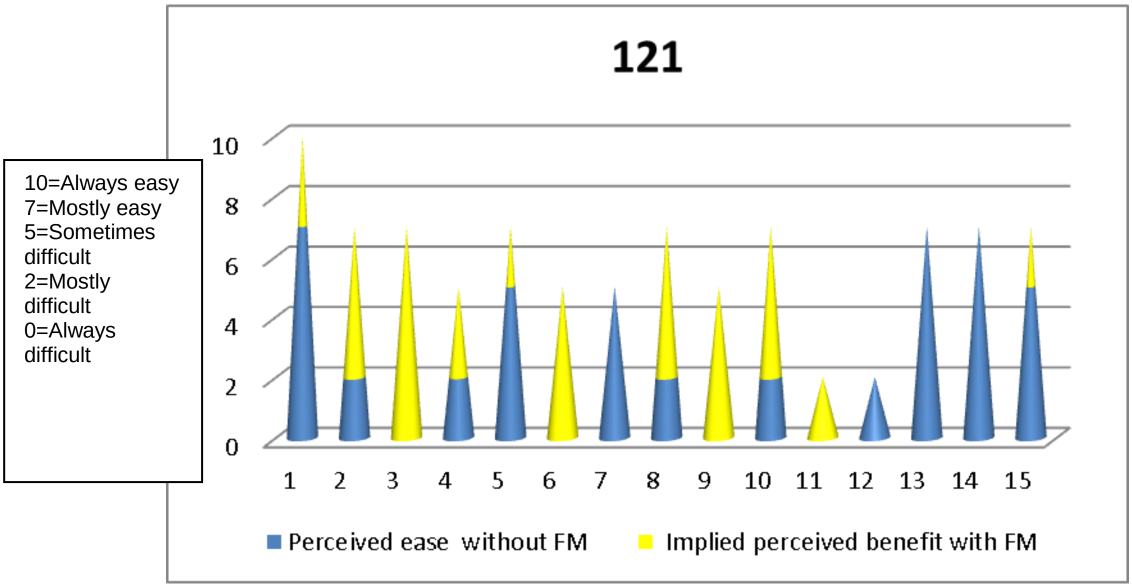
When undertaking speech in noise tests with the local Educational Audiologist this subject was able to demonstrate a clear advantage using the FM transmitter.



When the task was made harder by adding an additional activity it would appear that the mean reaction time on the SART and on the AB word list when using the FM system were slower. Interestingly the overall word score was highest when using the FM system with a corresponding increase in SART errors.



Responding to the LIFE questionnaire this subject uses the FM system for all lessons with the exception of PE. He does not use the FM system at home. He found the FM system particularly helpful when the teacher is walking round the classroom and talking; when the teacher is talking and other children are making a noise and when working in small groups with other children. These all imply good use of the FM transmitter



The Teacher of the Deaf and Educational Audiologist reported that the FM system was used all the time by Classteacher/TA and by other students in 1:1 or group work. This subject is learning to be an independent learner manages himself well, knows when to ask for suppport. He has devloped independent management of the equipment. Once infomred of the relevance and importance of the FM system peers are reported to have been very accomodating and helpful in ensuring the system is well used. The feedack from the Class teacher and TA suggests the FM system is used with other technoogy in the classroom. Attention to muting would ensure that this subject was able to gain maximum benefit from using his FM system.

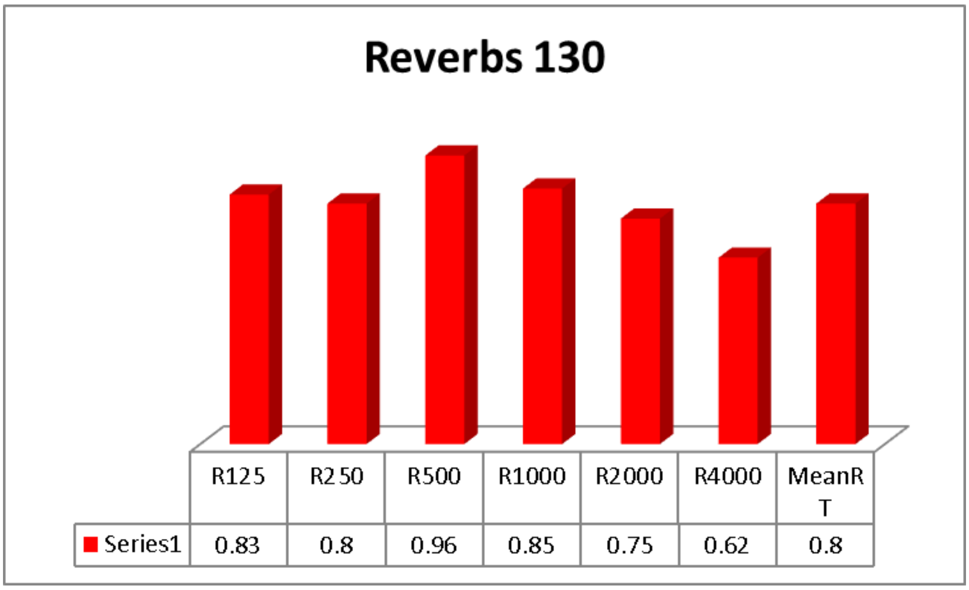
Vignette 6: Subject 130

This 11year old male subject was identified as deaf at 3 years 5 months and fitted with aids at 3 years 6 months.

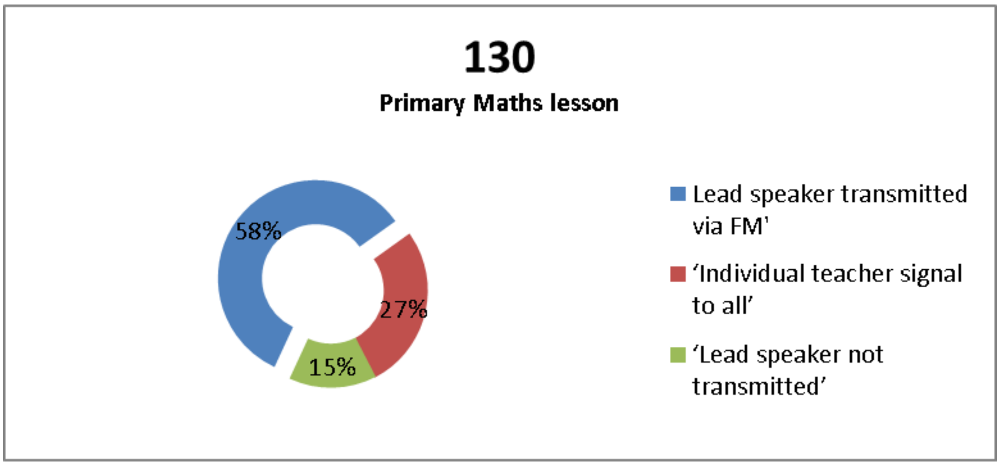
PTA	250	500	!k	2K	4K	6k	8K	Hz
R	70	80	95	100	105	120	130	
L	70	75	85	90	90	95	100	

Fitted using DSLi/o Biateral aids Nathos SP W with MLXi and Inspiro Transmitter
MAINSTREAM

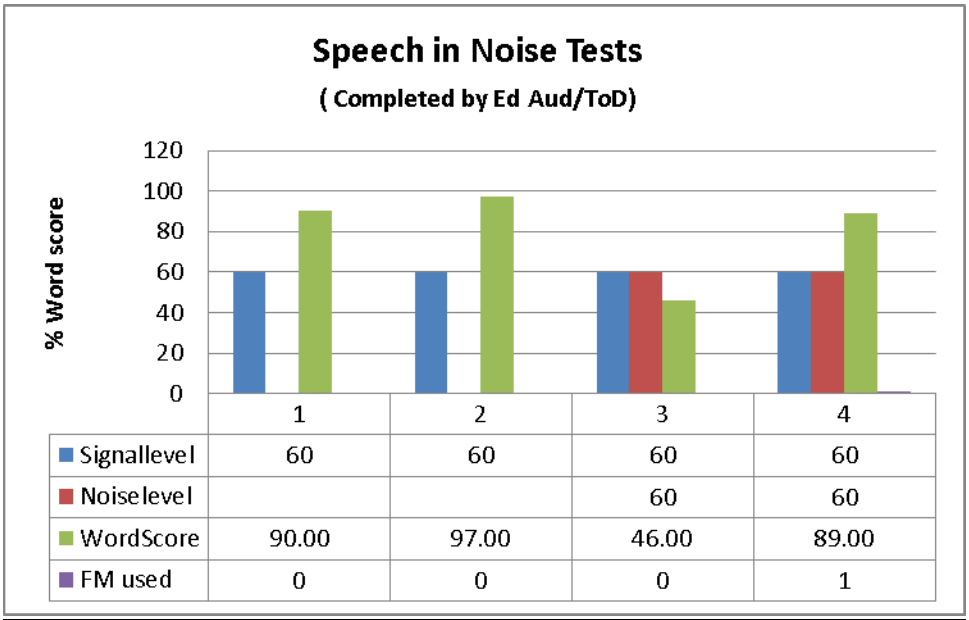
This subject is in his final year at primary school. He was in a new build school however classroom reverberation times failed to meet any of the BATOD recommended RT times.



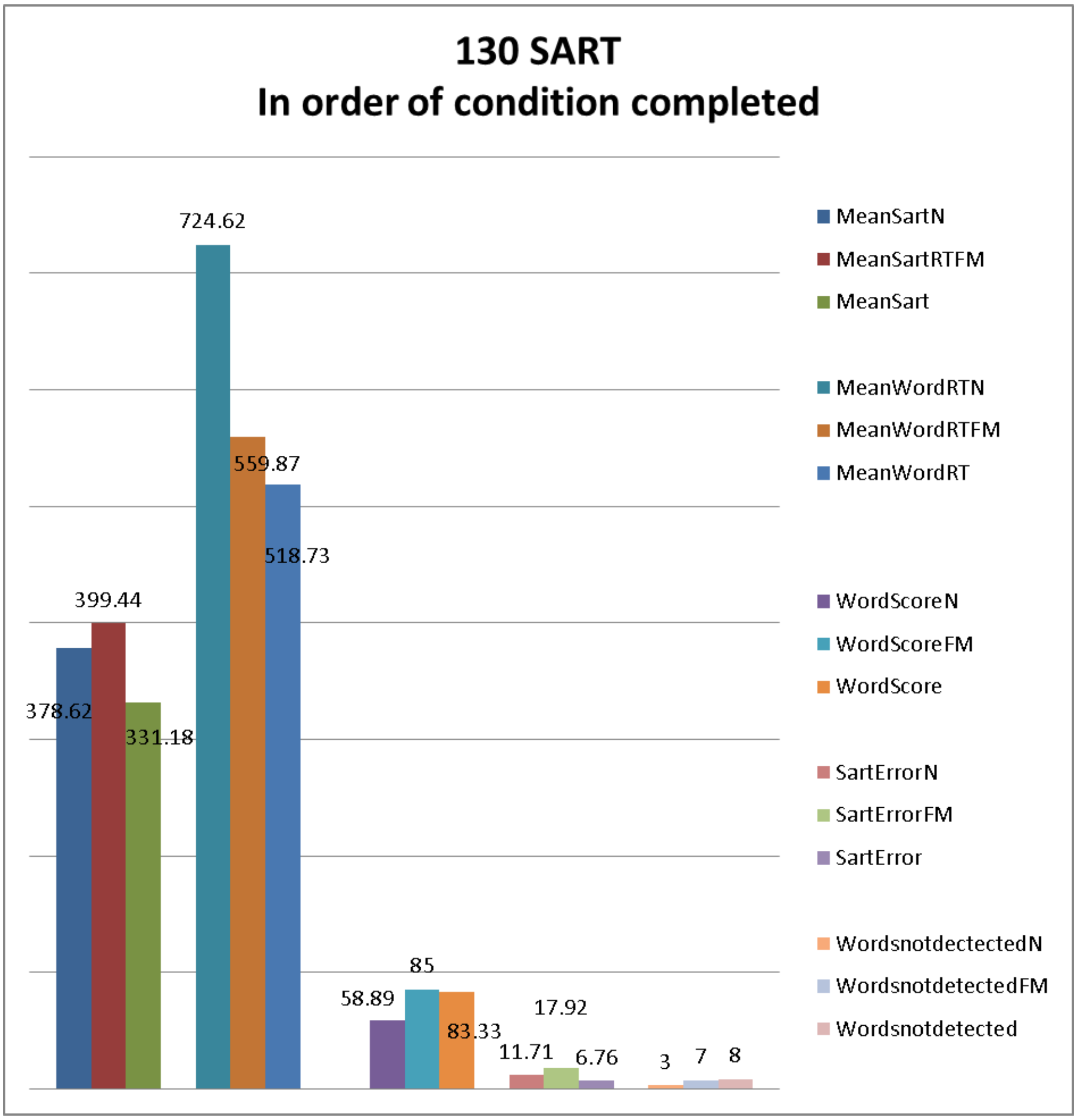
The class were observed during a maths session for a period of 56 minutes. There were 28 children in the class and two adults. The session consisted of didactic teaching with the class teacher using the FM for 58% of the time. Thus for 42% of the session the transmitter was not muted or used by other speakers. For a profoundly deaf mainstreamed child learning in a poor acoustic environment appropriate use of the FM system is central to promoting access to the spoken word. Figure 2 illustrates the use of the FM transmitter during the observed session.



The speech in noise tests were undertaken by the Educational Audiologist and clearly demonstrate an advantage of using the FM in noise when listening for speech.



When asked to complete the dual task of listening in quiet, noise and noise with FM at the same time as interacting with the SART he demonstrated no apparent differences in reaction time to the SART but reaction times to word stimuli were reduced when using the FM system. The word scores using the FM were similar to those achieved in quiet. Interestingly the SART error scores were highest when using the FM system. By increasing reaction times when using the FM system this subject did not allow time to complete the SART more slowly to reduce errors.



In completing the LIFE questionnaire this subject was clear that he felt there were a number of scenarios where the FM system did not in his view provide any benefit. He uses the FM system in school for all activities' with the exception of PE. He does not use the FM system at home. A number of situations where the FM system was felt to be of little benefit were:**-.**

- Everyone is looking at the computer, TV or video screen. The teacher is showing a video or you are listening to something shown on the computer screen. How well can you hear and understand the words said whilst you are watching the screen?

- The teacher is talking. You hear noise outside the class. It could be kids in the hallway, the playground outside, voices next door cars or aeroplanes. How well can you hear and understand the words the teacher is saying?

- The teacher is talking. Some kids are making noise at their seats. They may be trying to find papers, dropping pencils, whispering or moving their feet. How well can you hear and understand the words the teacher is saying as the kids make noise?

Vignette 7

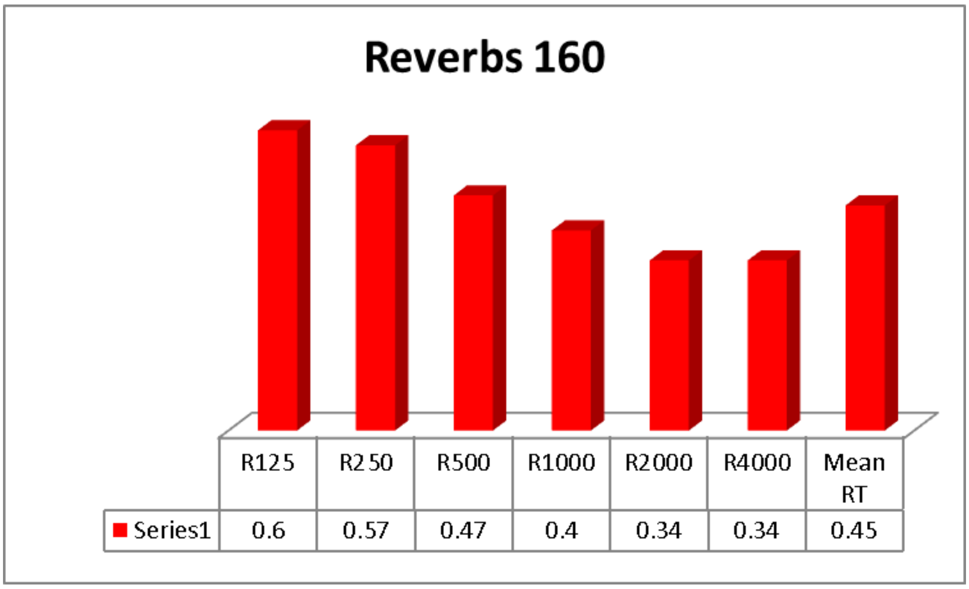
Age of identification of deafness 2yrs 10 mths
Age of first hearing aid fitting 3 years

PTA	250	500	1K	2k	4k	6k	8k Hz
R	0	5	10	65	85	90	85
L	5	10	5	60	85	85	80

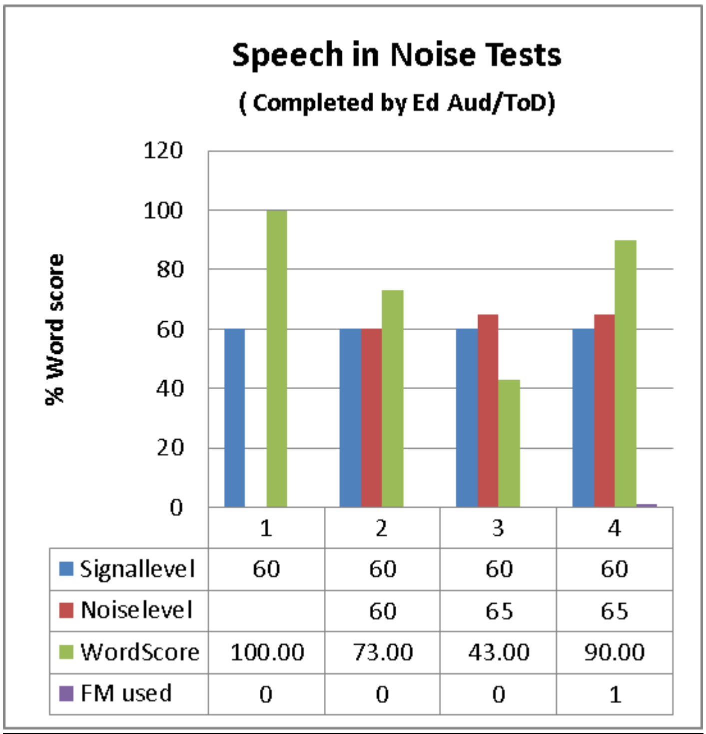
Fitting protocol DSLi/o
Bilateral Spirit Zest aids with MLXi Phonak Zoomlink
Mainstream setting

In class observation of a 48 minute lesson during that time didactic class teacher with appropriate use of FM accounted for 17 minutes. There were nine occasions where there was a lead speaker-either a teaching assistant of other pupil where the FM system was not used. There was no clear lead speaker 22 minutes but where the teacher had the FM active rather than muted. Thus for just under half the session the deaf pupil was listening to an FM signal that was irrelevant to their work.

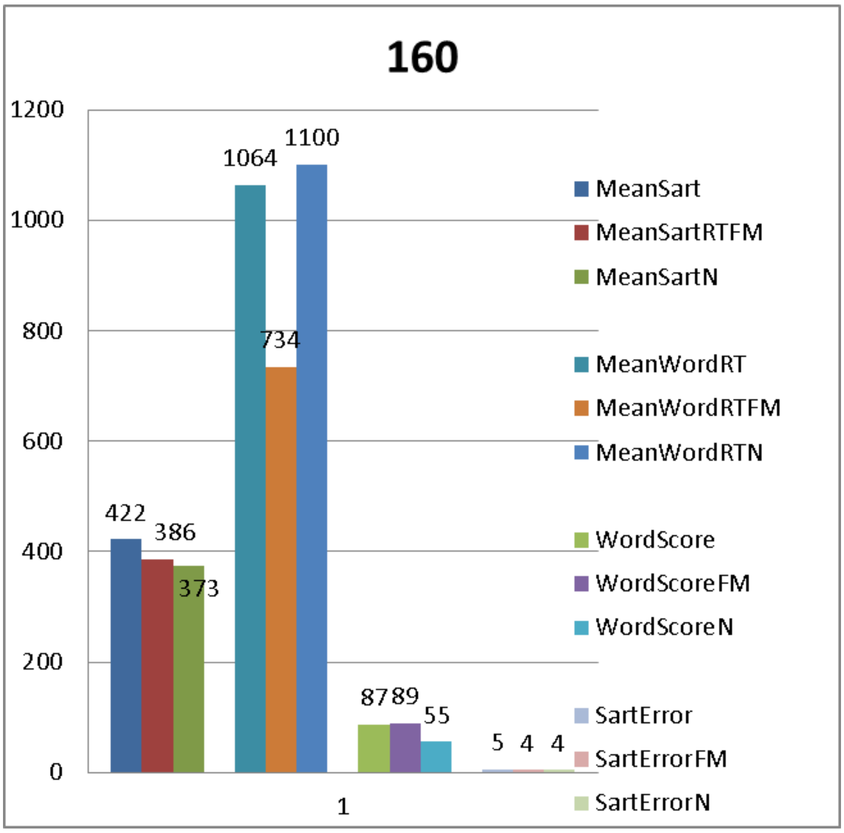
Classroom measures of reverberation times identified that this classroom did not meet the BATOD standard RT for any frequency: figure 1 RT times for classroom subject160



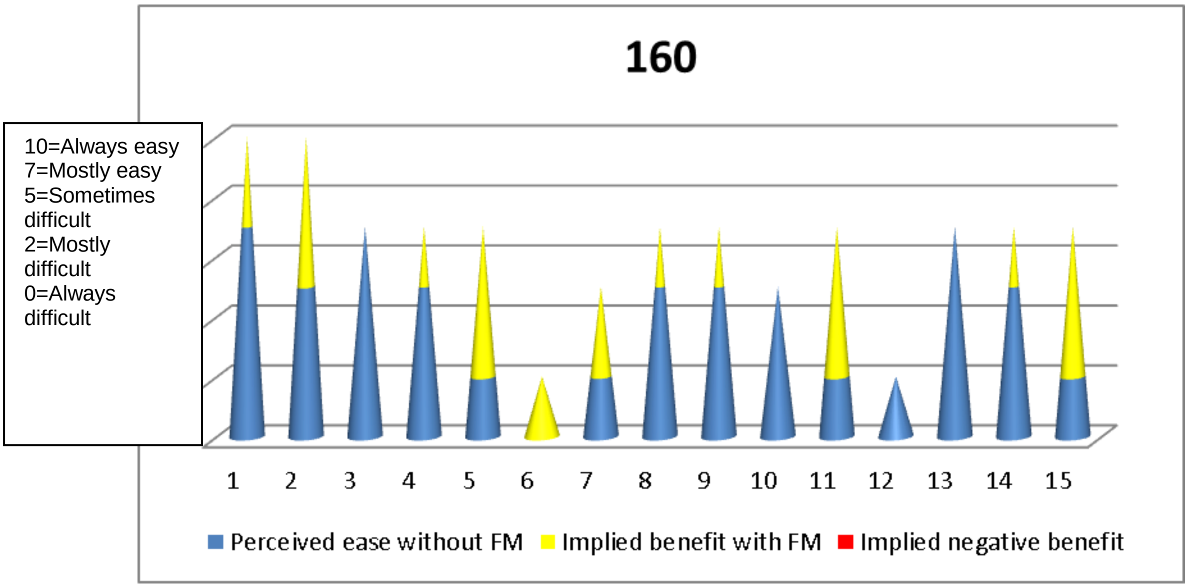
Speech in noise tests undertaken by the Educational Audiologist demonstrate a clear benefit of using the FM in noise as demonstrated in figure 2



When undertaking the dual task in quiet, noise and with noise plus FM this subject demonstrated a significant difference in word reaction time and word score when using the FM in noise. The basic response to the sustained attention task did not demonstrate a benefit, may be an order effect. Figure 3 demonstrates this subject's responses to the dual task.



This subject completed the Life questionnaire and was clear in demonstrating that she always felt the FM system provided her with benefit. Her scores are summarised in Figure 4



The only situation in which this subject felt there was no benefit was the scenario described as “The class stops to listen to class announcements. Sometimes kids are making noise during the announcements. How well can you hear and all the announcements when there is some noise?”

There was no feedback from the class teacher but the Teaching assistant reported that this subject *‘makes very good in using equipment , readily reporting any problems She sometimes needs reminding to give FM to all teachers in all lessons. Equipment practicality is good, works well for student and has improved hearing quality in classroom’*

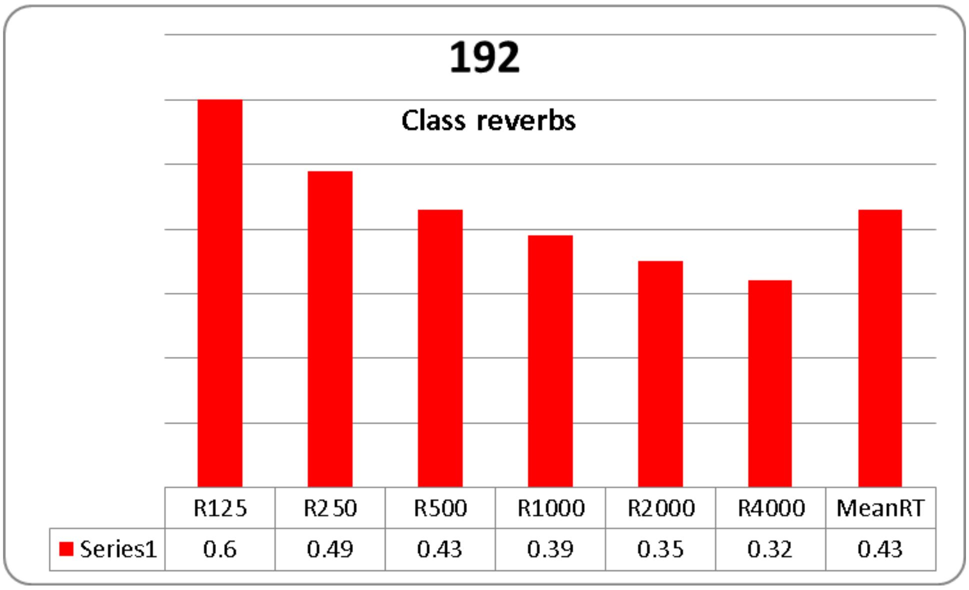
Despite the fact that this subject is working in adverse listening conditions and that use of the FM transmitter is less than optimal this pupil gains clear and measurable benefits from the use of FM amplification.

Age of identification of deafness 4 years 6 months
Hearing aids fitted 4 years 6 months

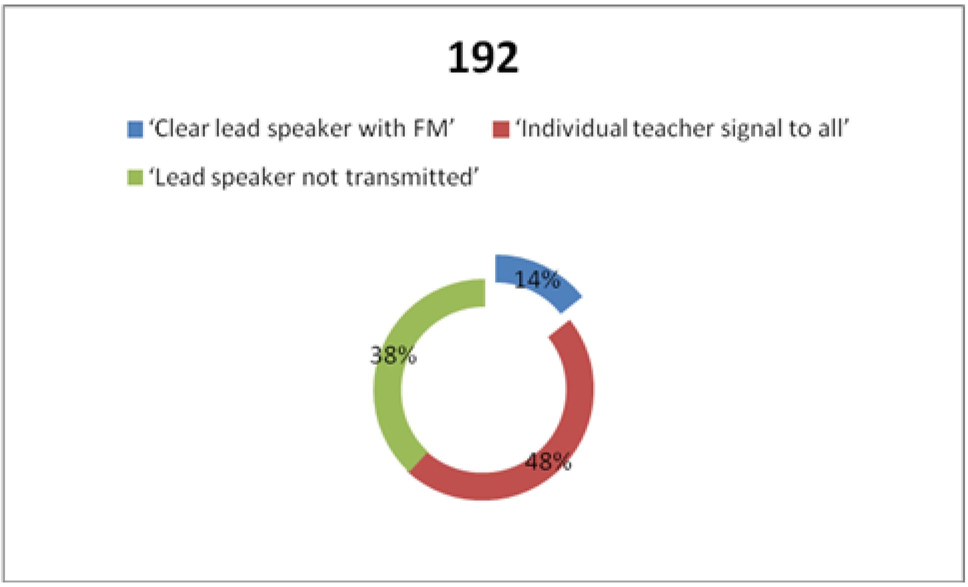
PTA	250	500	1K	2K	4k	6k	8kHz
R	35	40	40	45	35	25	35
L	35	35	50	45	35	25	20

Fitted using DSL v 5a bilateral Spirit Zest MLXi Zoomlink

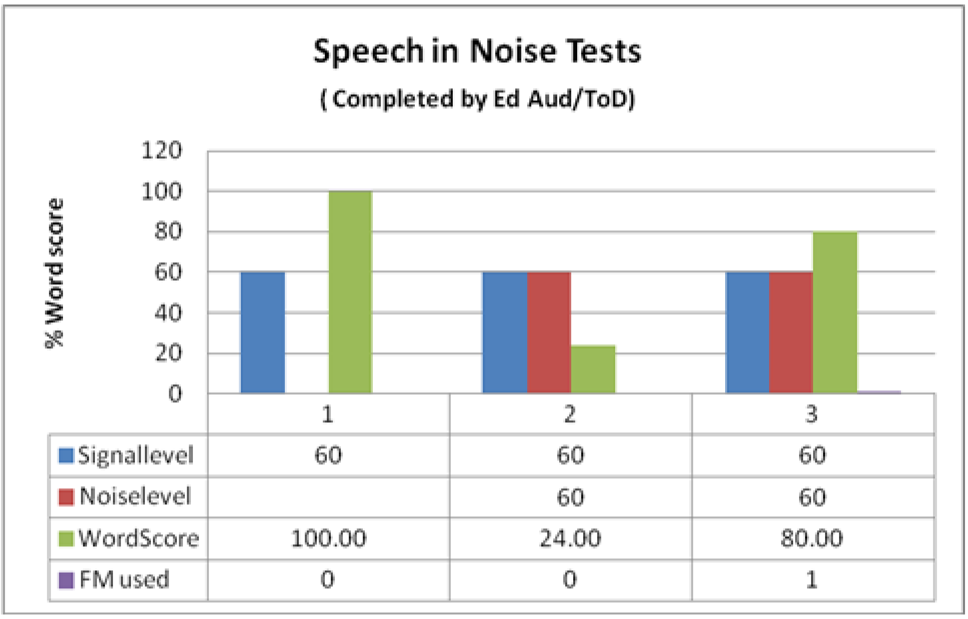
This subject was observed during a maths session at his primary school. Reverberation times for the classroom were all outside the BATOD recommended levels, figure 1.



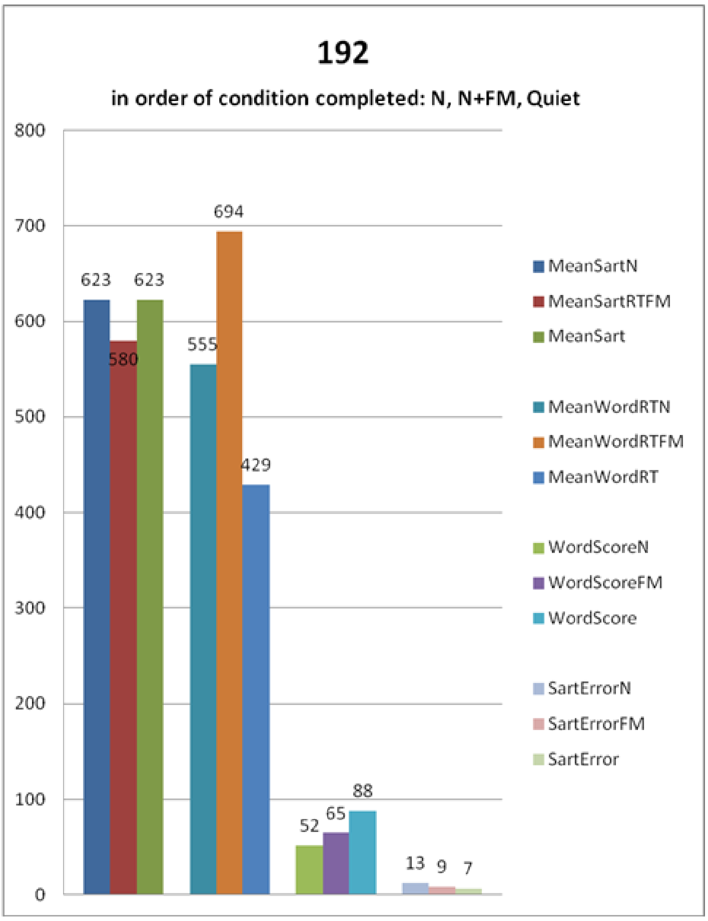
During the 31 minutes of observation didactic teaching to the whole class only occurred 6 times equating to 14% of the session. There was no clear lead speaker for 38% of the session. Of most concern is the 48% of this session where the transmitter was not muted and this subject had an inappropriate signal via his FM system whilst trying to complete the set task: figure 2



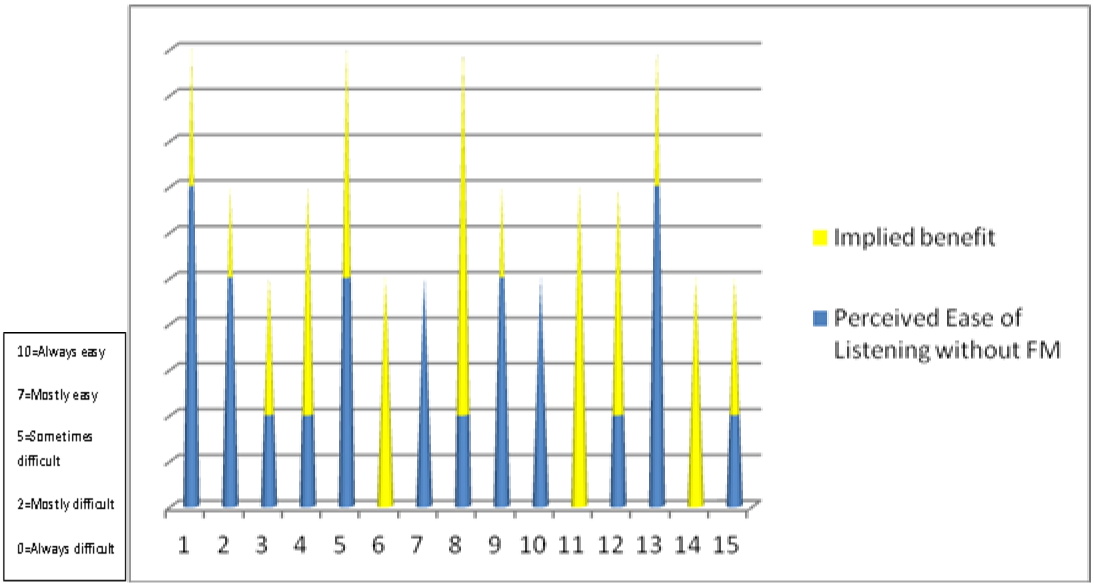
Whilst this child has a moderate degree of hearing loss the effect of noise on speech perception are clearly demonstrated in the Speech in Noise results provided by the Educational Audiologist in figure 2.



When required to undertake a word list whist completing a secondary task this subject demonstrated considerable difficulties. The use of the FM system showed no benefit. It may be that the order of testing with noise and no FM first was so challenging that this subject felt unable to attempt the task he was given.



Given the dual task results it is interesting to note that this subject's results for the LIFE questionnaire demonstrate that he feels he gains significant benefit across the range of listening situations, see figure 5



The two situations where this subject reported no benefit were when two teachers were talking in the same class and he had to focus on one speaker and where the teacher if talking and there is significant noise outside the classroom. Both of these situations could be improved by appropriate use of the FM transmitter. This subject was reported to use the FM system for assembly and whole class work. For group work the subject preferred to sit by the teacher and lip-read, unless high level of background noise. He was reported to occasionally need reminding to use equipment, keep it safe. No problems with other pupils, they were reported to be very accepting familiar with it.

Appendix 2 Children's ideas and requests regarding FM equipment:

Things the children would like other people to know:

Audiologists

.......that if the radio aid is rubbing against necklace it makes crackling noise and how it effects the background noise when the radio aid is on

....that when you put the mould in it tickles can you try not to put it in so hard

......I think they need to know about at least the basic about FM because they often don't know anything

Mainstream teachers

That the class should stop shouting and everything so that hear better.

....not shout through the radio aid when shouting at others pupils

....not to put the wire round their neck

....that even though the FM benefits much it is still difficult if they turn their backs, walk across the room etc.

...that when you wear the FM system not near your tummy you need it up near your neck

...how the radio aid works and what it's for

Parents need to know

...information about FM

..Iant to bring my transmitter home, so I can plug it into the TV

Children need to know

...not to speak too fast and not move around when talking

....that the FM is not a play thing and it is extremely distracting when they interfere with it

....not to lose your FM

...that the FM is there for a reason and it's not something to laugh about or say stuff mean/harsh

.....

....that even though we have a disability doesn't mean they can pick on us

....you can't tease someone about their disability because everyone is equal
....that to speak slowly and speak properly
...what your needs are
...to stop shouting and start to talk with your friends in lesson

Manufacturers need to know

....please make the microphone less crackly
...that I would personally love it if diamantes were added onto the simple design
..that the colour is boring, I think it needs brightening up
...it doesn't work well outside
....I think that the channels should have passwords

Teachers of the Deaf need to know

...mute the radio when talking to one person or group
...that the radio aid isn't needed as much in small groups
....to turn the radio off at lunchtime and break because we can hear them talking about us
.....to unmute the microphone and turn it on
.....to remember to put the radio aid off and on. Also mute and unmute.
....not let the children use the transmitter because children will shout it hurts my ears

If I could change one thing about FM systems

..choose when you want to wear it
...I would rather not wear it
...use the radio aid when you really need, and not use it all the time
....not to have radios anymore because some people don't need it but most people do.
...doesn't feedback and being able to hear people next to me, because the radio aid blocks all background noise
..channels having passwords
...making the mic not crackle
...make it look amazing and put diamantes on it
.......change it to red
....take it home to plug into electrical devices
....change it, make it red, green or yellow

...make it bright pink

.....make it pink, or yellow, blue and red

...to bring FM to sports

In response to thoughts and discussions about the frustrations regarding teachers forgetting to mute four pupils explored alternative designs to resolve this problem:

A: I can't hear my friends. They keep saying 'what' because I can just hear the teacher and it blocks out what everyone wants to say to me, so if I am doing classwork and the teacher is going round the class I can't hear my friends because it blocks everything out.

Al: You have to keep telling them to switch it off.......

A: with mine I can switch the signal between the radio aid and my hearing aid so I can just hear my friends but when I put it back on I can hear the teacher, so if they made a switch available instead of asking the teacher loads of times 'can you turn it on, can you turn it off' it would be easier to just switch it on the hearing aid.

Al: so you could give it to them and they wouldn't have to figure it out and they could go to lights on and then they could switch it off.

W: Sometimes they forget... they have it round their neck and I think 'why can't I hear anything' and they have forgotten to turn it on and I have to walk all the way up, or do some sort of actions, like this, but she doesn't know what I'm talking about and it's really hard to put it on or sometimes they forget it.

M:Because when I give it to my teacher, I just give it to them, and sometimes they just put it on their desk so I have to get up and give it to them.

W: I have drawn a picture of what would be a good idea for a transmitter.

Remote Control designed for pupil use designed:

We can change these (ref buttons on Tx) into proper buttons we can press, One can be quiet, quieter, loud.......

..if they are too loud in PE you canturn it quieter so it is still loud enough, like medium and really quiet, or if you are wearing it and you are working instead of having to turn it off when you want to talk in it in a minute, you can turn it to quiet, (*.......and turn it up when you need it.*)

Researcher:
'If those buttons were round the teacher's transmitter ....how would you switch the buttons?'.........
...various discussion between children....
W: we could use a (*remote)* control to contact the transmitter......
W:...I've got a good idea. Maybe this thing could be like a secret kit and when you pull it out it's a lock in the back that has another spare remote controller. .....I don't want the children to touch my equipment..
M: (Explains his drawing) It is the transmitter and that button is for quiet, that button is for the channel on, this button is for the volume up, and that button is for the channel down and this button is for louder, very loud instead of....and this one is for volume down. That's for silent. This is like a book and this pops inside.
(The remote control is hidden within what looks like a book, designed to be discrete and protective, with the remote control not visible to peers.)
Researcher: ' what happens if you switch it off and you are so busy working, and the teacher wants to talk to you....
M: when the teacher talks it automatically turns on....
W: But how is it going to know you are going to talk to the whole class. What if she says....
M: Because it has a special thing on it.

A possible solution to one of the children's concerns:
Child held remote control which was automatically over-ridden when the pitch- (or other feature of speech-) sensitive microphone recognised teacher voice changes when speaking to the whole class.

Appendix 4 Dissemination plan:

1. 4,000 copies of a summary document have been printed and 1,600 will go out with the January edition of the British Association of Teachers of the Deaf professional magazine. Copies of this will be sent to all the children, schools, teachers, Teachers of the Deaf and Educational Audiologist who participated in this study. Several have asked for multiple copies to distribute to their local schools.

2. Copies will be sent to the Ministers of Education, Health, the Children's Minister, to relevant voluntary agencies and to all FM manufacturers. In additional electronic copies will be sent to Heads of Services for Deaf Children, Service managers and the Special Educational Need Forum

3. A talks with preliminary data have been delivered at a national study day run by the BATOD foundation and the Ewing Foundation. It is anticipated that additional national and international conferences will also be targeted.

4. A range of academic articles are planned to include:

- Signal-to-noise ratios in school classrooms. A comparison of analysis methods Ear and Hearing
- Classroom acoustic conditions: An analysis of typical SNR conditions encountered by hearing impaired children and the possible advantages of radio aid use. Ear and Hearing
- Classroom acoustic conditions: Aided speech and speech-in-noise test scores in school-aged children. JASA
- Listening effort in school classrooms. Dual-task paradigm testing in classroom like conditions with and without radio aid use. JASA
- Children's real world experience of using FM. Journal of Deaf Studies and Deaf Education
- LIFE-R: Children's perceived benefit of FM amplification. Deafness and Education International
- Listening to user's: children's, parents and teachers views of FM. Ear and Hearing

- The listening experience in today’s classrooms. Times Educational Supplement
- What the gap: the challenge of cascading training to non-specialists. Nature.