

The Use of FM Technology for Pre-School Children with Hearing Loss

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Abstract

The aim of this research was to evaluate and explore the benefits of FM technology with preschool hearing aided children. The research was of a longitudinal prospective design, including seven families of pre-school children. Daily diaries, data logging and questionnaires were used to collect quantitative data. Five of the seven families were able to establish regular FM use in a range of environments and settings with the most frequent being at home, in the car, at nursery, during shopping and when outdoors. Situational analysis of FM use was collected and improvements in listening in noise, auditory only and distance were identified over time. Six main themes were identified: access to speech, listening, communication, wellbeing, engagement/ownership and practicalities of FM use. Overall the analysis highlighted the potential benefits, barriers and challenges to pre-school use of FM technology. The language environment analysis (LENA) system was used to compare differences in language environment with and without FM use. The acoustic environment results suggested that largest portion of children's day was spent in environments where speech was at a significant distance or within background noise, thereby identifying areas that would benefit from the use of FM technology. The LENA Language Developmental Snapshot (LDS) results indicated that those children who started the study 'at risk' and had used FM technology, were within normal levels or close to normal limits, by the conclusion of the study.

In establishing the importance of early identification of hearing loss in children, very little attention has been given to how advanced FM technology may improve outcomes. Distance, noise and reverberation remain considerable challenges for individuals using hearing aids, more so in really young children. Given that infants tend

to have a systematic progression in language acquisition they are more susceptible to environmental acoustic challenges. In general, young children with normal levels of hearing experience greater difficulty than adults in discriminating speech in noise (Bradley and Sato, 2008; Eisenberg et al., 2000; Neuman et al., 2010; Nishi et al., 2010; Valente et al., 2012; Yang and Bradley, 2009) and speech in reverberation (Neuman et al., 2010; Valente et al., 2012; Yang and Bradley, 2009).

The effects of reverberation and signal-to-noise ratio (SNR) on adult hearing aid users compared to normal hearing individuals have been well-substantiated (Finitzo-Hieber and Tillman, 1978; Hawkins and Yacullo 1984). A significant difference between the two groups was documented, with a disproportionately greater effect on the hearing aid users as acoustic conditions deteriorated. Acoustical conditions that are mild or moderately disruptive to normal listeners can result in severely reduced auditory perception in hearing impaired individuals. These challenges would expectedly be greater for younger children with hearing loss. Even mild to moderate sensorineural hearing losses alter a young child's speech perception in quiet and noise and can impact linguistic development (Moeller et al., 1996)

The negative acoustic effects of distance, noise and reverberation can be overcome for children with hearing loss by the use of FM systems. FM systems transmit speech sounds directly from the speaker to the listener at a greater intensity than the surrounding noise. This enables an audible speech signal to be conveyed to the hearing aid user. FM systems have been widely used in academic settings to overcome problems associated with speaker to listener distance, reverberation and poor signal to noise ratio (Bess et al., 1996; Brackett et al. 1992). However, very little consideration has been given in the research to the use of FM technology in non aca-

demic settings especially with children who have not yet reached school age. A few studies (Moeller et al., 1996; Brackett, 1992; Gabbard et al., 2003; Statham and Cooper, 2009) have reported benefits on the use of FM technology with pre-school children, however little or no data on the actual use of FM were presented. Furthermore, the equipment used, especially in the study by Brackett (1992) and Moeller et al. (1996) was cumbersome and bulky making it unsuitable for younger children. Similarly, Statham and Cooper (2009) found even ear level receivers attached to hearing aids via audio shoes raised concerns for parents.

The lack of evidence available on the use of FM technology with pre-school hearing aided children is evident. With newborn hearing screening resulting in much earlier identification of hearing loss and the continuous advancements in FM amplification technology there is a critical need to evaluate this technology for pre-school children. The present research (Mulla, 2011) was aimed to address the gap in knowledge on FM use with pre-school hearing aided children with three studies:

1. Quantitative evaluation of FM use with pre-school children;
2. Qualitative evaluation of FM use with pre-school children;
3. Language ENvironment Analysis (LENA) with and without FM.

Study 1: Quantitative Evaluation of FM use with Pre-School Children

The primary aim of this study was to establish quantitative results on the daily usage of FM technology with pre-school hearing aided children including the average duration of FM use, the total hours of FM use, the number of days FM was used as well as the environments and situations where the FM was utilized. Data logging was used to verify daily diaries and overall there was good consistency between the two reports. On occasions where there were discrepancies the more conservative measure was accepted.

The key findings from this study are described below:

- Five of the seven participants were able to establish regular use of FM technology in a variety of settings. For the two participants who did not establish regular use of the FM technology, age of the child (11 months at the outset) was identified as possible reasons that may have affected FM technology use. This was fur-

ther explored through the qualitative analysis (next section).

- Overall the participants were involved in the study for a total of 1198 days from which 837 days (71%) of FM technology use was recorded. The total number of hours of recorded FM use was 2874 hours and 15 minutes. From the total hours of recorded FM use, parents reported 2801 hours of FM use were with benefit, 2 hours and 30 minutes of FM use without benefit and 73 hours and 45 minutes of FM use were where they were not sure of benefit. The average duration of FM use on days the device was utilised was 3 hours and 2 minutes.
- The home, nursery, car, shopping and outdoors categories were the most consistent settings for FM use. Although the largest percentage of hours used was recorded for the nursery setting, the highest number of days during which the FM was used in any setting was the home situation followed by the car environment and then the nursery setting.
- The FM Listening Evaluation for Children (FMLEC) questionnaire was conducted after one month of use and at the end of the study. The questionnaire evaluated children's listening with FM in four situations: noise, quiet, distance and auditory only. The overall total scores for listening in all four environments improved over time for six of the seven participants. As expected the highest improvements from the four listening situations were reported for background noise and significant distance situations.
- The children's language development over the duration of the study was assessed using the LENA Developmental Snapshot (LDS) questionnaire (Gilkerson and Richards, 2008). Results from the beginning, midway and end of the study were compared to identify any trends in language development associated with FM device use. Four children whose LDS scores were 'within normal level' or border line 'within normal level' at the beginning of the study did not show any significant improvements overtime. Of these four participants two had made regular use of FM technology and two had not. Three children whose LDS results were significantly 'at risk' at the start of the study made significant improvements in LDS scores by the end of the study. Two of the participants were 'within normal limits' and one close to 'within normal limits' at the end of the study. All three of the participants had made regular use of their FM technology. The results suggest pre-school hearing aided children who are significantly 'at risk'

in their receptive and expressive language scores (as assessed by the LDS), may achieve better language development with the use of FM technology.

Study 2: Qualitative Evaluation of FM Use with Pre-School Children

The primary aim of this study was to qualitatively explore the views and experiences of parents and carers on the use of FM technology with pre-school hearing aided children. Although the quantitative methods described above do provide an insight into the use of FM technology with pre-school hearing aided children they cannot provide an insight into the meanings, views and perspectives of the users of the technology. The qualitative approach identifies what is meaningful based on what emerges as meaningful from experience and not by what may be decided as meaningful by researchers (Willig, 2001; Silverman, 2005). Caregivers completed an open ended diary on a weekly basis; semi-structured interviews were conducted at the end of the study to further explore views and experiences. Each individual was regarded as a 'case' rather than each of the seven interviews and eight diaries. Overall there were eight 'cases', seven of which included data from both diaries and interviews for each participant and the final eighth 'case' referred to the diary kept by the nursery. The key findings for this study were:

- The improved access to speech FM technology provided was highly valued, especially in situations where the child was not facing parents, i.e., in the car or pram, in noisy situations, at a distance and when hearing aid microphones were covered.
- Improved listening behaviours in the child were noted when using the FM including improved attending, locating of FM user, comprehension, improved concentration and reduced listening effort.
- The use of FM technology allowed access to intelligible speech over distances, in noise and more challenging listening situations. This provided more opportunities for overhearing which is important for children to acquire language and learn novel concepts (Akhtar et al., 2001; Akhtar, 2005; Floor and Akhtar, 2006).
- A theme of child-control FM use as well as parent's abilities to identify when their child did not want to wear the FM device emerged. A clear sense of ownership and ability to establish preferred use of FM emerged - even in children as young as 16 months of age.
- Improvements in language as a result of FM use were reported with more copying, more accurate intonation and increased clarity of speech being described.
- Improved well-being was a strong theme reflective of the use of FM technology resulting in positive emotions for the children. Children were also reported to have been calmer and more comforted with FM technology in use. Increased engagement and participation in activities at the child's nursery and outdoors was noted with children described to have an increased sense of social belonging. Parents reported children being more confident when parents used the FM device and of their children using the technology as a "safety blanket" when engaging in new activities.
- Parents of two of the children who had not established consistent use of their hearing aids found it difficult to introduce FM technology into their regular routines. These parents highlighted age of the child, ear infections, earmold issues and the child not keeping hearing aids in place as reasons for not establishing consistent hearing aid use. However, in contrast, two other participants reported that the introduction of FM technology helped overcome the difficulties associated with the child not keeping hearing aids in place. This resulted in an increase in hearing aid use by these children to the extent that the children started requesting their hearing aids. This finding suggests the use of FM technology may increase the use of hearing aids by children with hearing loss.
- The addition of FM technology was reported to have been "easy to use" and parents were able to establish daily FM management routines with ease. The FM transmitter was likened to a simplified "mobile phone" and the advanced features were easily accessed and used by parents.
- Remembering to mute the FM device was identified by parents as a challenge when using FM technology. Parents were able to identify situations where they forgot to mute the FM system and they acknowledged the need to be more careful when using the FM technology. On many occasions the child overhearing adult discussions made parents aware that the FM device was, in fact, turned on and working.

Study 3: Language ENvironment Analysis (LENA)

The LENA device is a small recorder that is attached to a garment worn by the child over a minimum of 12 hours in their natural environment. The results of the

recording are transferred to a computer with LENA software to analyse the child's language environment. The analysis includes detailed report counts on the number of adult words (AWC) spoken in the vicinity of the child; the number of conversational turns (CT) taken by the child with another child or adult; and the number of the child's personal vocalisations (CV) during the 12 hour recording. Furthermore, the software provides detailed analysis on the acoustic environments the child was in during the entire recording period. The software defines five acoustic categories: 'meaningful', 'distant', 'silence and background', 'TV' and 'noise'. The primary aim of this study was to compare the language environment of pre-school hearing aided children in the home setting and in the outdoors setting, with and without FM technology use. The key findings from this study are highlighted below:

- When comparing the AWC's, CT's and CV's, with and without the use of FM technology, the unfortunate caveat was that the LENA system was not sensitive enough to fully detect potential FM benefits at a significant distance. All report counts (AWC, CV and CT) were generated using only the 'meaningful' category which referred to speech occurring within six feet of the child without any 'overlapping' noise or competing speech present. Speech that may have occurred at a distance of over six feet or with 'overlapping' noise was categorised in the 'distant' category and any potential FM benefit was not analysed by the LENA system.
- Approximately 20% of speech in children's language environment on a typical day was interpreted to be in the 'meaningful' category; whereas over 40% of speech was identified to be in the 'distant' category. These findings highlight the importance and increased need for FM use with pre-school hearing aided children. These findings also suggests participants in this study could have benefited from further use of the FM technology on a daily basis.
- Even with the limitations, the comparison of report counts for the different settings resulted in a significant difference in CT counts for the outdoor setting. This finding suggests that although no differences were detected in the 'meaningful' category for other report counts and in other situations, the benefits of FM use for this particular setting and report count were picked up within the 'meaningful' category. This may be a result of increased conversations in the car and pram settings where the child is within six feet

of the parent. Although 'overlapping' noise may be expected in these settings, the noise may have been at a minimum.

- Children with hearing loss in this study had language exposure that was near the 50th percentile or better when compared to their hearing peers. This finding was contrary to the suggestions of previous literature where it was expected that children with hearing loss may have less exposure to language. However it needs to be noted that because distant speech was not included in the LENA counts, this may have a bearing on comparing results from the previous literature.
- The language exposure percentiles are the only report count where all four participants' percentiles were below the median 50th percentile for CTs in the outdoors recording condition without FM use. In comparison, with FM use, three participants' CT counts ranged from the 59th to 68th percentile. Although one participant's CTs were below median at the 36th percentile, this child showed an increase in CTs in the 'with FM' condition compared to the 'without FM' condition (22nd percentile). This further highlights the potential benefits of FM use in the outdoors setting to facilitate conversations with hearing aided children. As a result of FM use, their CT environment in outdoor conditions could increase to the percentile levels of their hearing peers.

Discussion

There has been little exploration of FM technology use with early identified children with hearing impairment. Three previous studies that explored FM use with pre-school children did not report data on daily usage of FM technology (Moeller et al., 1996; Brackett, 1992; Gabbard et al., 2003; Statham and Cooper, 2009). Moeller et al., (1996) required parents to complete daily use logs, which documented device function and hours of amplification use (FM use, HA use and no amplification periods). This study was unique in that it examined daily usage of FM technology, capturing not only data related to the duration and frequency of FM use, but also the varied and complex listening situations of young children. The detail with which usage data has been captured, including the number of days FM is used, how long FM is used, where FM is used and whether parents felt FM was useful in that situation has previously not been reported.

While the value of early access to well-fitted and evidence-based amplification parameters has been established, both in relation to hearing aids (Yoshinago-Itano

et al., 1998; Moeller, 2000) and cochlear implants (Sharma et al., 2002), there is little understanding of 'early' in the use of FM technology. Logically, it can be argued that once a child reaches the developmental phase of crawling, close microphone distance is potentially lost. Given the importance of access to speech in the first years of life (Moeller et al. 2009; Cole and Flexer, 2011), any distance between the speaker and the microphone will degrade the quality of the signal. Integrated FM technology, which overcomes the ergonomic restraints of traditional FM systems, both in respect of body-worn and shoe-based FM technology, potentially offers significant benefits. It is unclear at what developmental point it is most appropriate to introduce FM technology from the perspective of children and their families. Findings from the present studies identify the fact that families of children as young as 15 months are able to include FM technology in their child's daily routines. Future studies might benefit from including a more representative sample of the pediatric hearing impaired population to help understand and define 'early' in the use of FM amplification.

All seven study families reported very few hours of use where they felt the FM device was not helpful. Although a high percentage of benefit with FM use was reported by parents (97%), this finding is more indicative of parents being able to recognise where they would prefer to use the FM system and where they were finding most FM benefit. Once this was established for these parents in their daily routines, they were able to make regular use of the FM, resulting in highly positive feedback to the authors. It would be counter intuitive for parents to carry on using the FM in settings where they felt minimal or no benefit was being achieved. As a result, the feedback in the daily diaries for "no benefit" and "not sure of benefit" was indeed minimal compared to the overall device use.

The two participants who did not establish consistent use of the FM technology with their children did not identify any situation where they felt the FM was not beneficial. Although they noted in their diaries when they felt they were not sure of benefit, the majority of their recorded FM use was logged as "beneficial." These results appear counter intuitive because these two participants reported the use of the FM device beneficial, yet their recorded use of the FM technology was low. Both sets of parents indicated that they felt their child's age was a barrier to the use of FM. One mother explained that because her child was pre-verbal, the benefits of the FM were limited; apparently she was unable to establish a conversation with her child. This is an important point

and suggests the value and importance of contingent language was not fully understood by the mother. Although it is natural for a mother instigating a conversation with an 11-month old child to expect some reaction, it is unclear whether this specific mother was sensitive to her young child's non-verbal responses. This is an important area that could be a focus of parental guidance by the professionals working with the family. The second set of parents also mentioned age as a barrier to hearing aid and FM use. Both sets of parents explained that ear molds not fitting properly, ear infections and the child not keeping the hearing aids in place, resulted in inconsistent use of the hearing aids, thereby limiting the opportunities for FM use.

To conclude, research on the use of FM technology with pre-school hearing aided children is both timely and topical. The current research has provided a unique contribution to the existing literature and research base and provides a basis upon which further research in this area can be taken forward. It is anticipated that this work, together with future research, can lead to the provision of FM technology to pre-school children with hearing loss as a standard part of early intervention programs.

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