FM for Children

Chapter 3

Personal FM systems for children with auditory processing disorder – successfully fitting this heterogeneous population

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Auditory processing has been defined as the "efficiency and effectiveness by which the central nervous system (CNS) utilizes auditory information" (ASHA, 2005, p. 2). Considerations for identifying auditory processing disorder (APD) include accurate identification of the disorder using reliable tests that distinguish APD from other disorders (e.g. ADD/ADHD) (ASHA, 2005). Children with APD are a heterogeneous population (Domitz & Schow, 2000) and therefore rehabilitation needs to address each child individually. Options for rehabilitation include environmental modifications, auditory discrimination training, language training and/or FM systems (Bamiou, Musiek, & Luxon, 2001).

While there are several studies supporting the use of FM technology there are relatively few related to the use of personal FM systems and children with APD. Friederichs and Friederichs (2005) noted significant improvements on a frequency discrimination and sound lateralization task in 10 children with ADD/ADHD with suspected APD, compared to a control group, after a one-year trial with a personal FM system. Cortical auditory evoked potentials (CAEPs) showed increased P2 amplitude in the children who utilized the FM compared to the control group of children with ADD/ADHD and co-morbid APD who did not receive an FM. Subjective information obtained from teacher questionnaires also showed positive changes in social behaviors, attentiveness, and in their hearing profile (Friederichs & Friederichs, 2005). These findings are promising, but the sample size was small; hence, further studies are needed to support the use of personal FM systems with children who have APD. The aim of the current study was to measure the benefits of personal FM system use in children with APD following a two-school term trial (5 months).

Methods

Participants

The participants were 29 children, 23 males and 6 females, aged 7, 3 to 12, 9 (mean 9.84, SD 1.80). All participants had pure tone thresholds ≤ 15 dB HL (250-8000 Hz), present acoustic reflex thresholds and transient evoked otoacoustic emissions (TEOAEs), non-verbal IQ scores ≥ 80 (TONI-3, Brown, Sherbenou, & Johnson, 1997), and English as the primary language spoken at home and school. Participants were referred to the study by educational psychologists, learning disability tutors, other audiologists, teachers, developmental pediatricians, and speech language pathologists. Prior to beginning the study seven of the participants had no other related diagnoses, four had Asperger's syndrome, 16 had learning or language disabilities (e.g. dyslexia, reading disorder), and eight had ADD/ADHD. All participants were diagnosed with APD utilizing a comprehensive behavioral APD assessment and New Zealand normative data (Kelly, 2007).

Auditory processing assessment

All tests were presented at 60 dB HL via a GSI-61 audiometer and insert earphones. The children were assessed in a double-wall soundproof test suite. The children received a practice phase for all tasks and this phase was repeated if necessary. The auditory processing assessment included Dichotic Digits Test (DDT) (Musiek, 1983), Frequency Pattern Test (FPT) (Musiek, 1994), Gaps In Noise test (GIN) (Musiek, Shinn, Jirsa, Bamiou, Baran, & Zaidan, 2005), compressed (65 %) and reverberated (0.3s) words (CRW, test of monaural low redundancy), and Masking Level Difference test (MLD). Scores greater than 2 SD from the mean were considered failures. The tests of auditory processing are described in detail by Musiek and Chermak (2007).

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For the DDT the ears are assessed at the same time and the child was required to verbally repeat all four numbers they heard in any order. The ears were assessed separately for the FPT and the child was required to verbally repeat the pattern back to the tester. The GIN test requires a non-verbal response and the ears are assessed separately. Ears were tested separately for CRW and the child was required to respond verbally. MLDs were obtained for 500 Hz tones, with the signal phase inverted.

Speech-In-Noise Soundfield Test

A 4-speaker array was set up in a soundproof booth. The Lexically Controlled Word (LCW) list Eisenberg, Martinez, Holowecky & Pogorelsky, 2002), re-recorded with a native New Zealand speaker, were presented via a loudspeaker located 1 meter, 0° azimuth from the participant. The noise was multi-talker babble presented simultaneously through three speakers located at 90°, 180° and 270° all 1 meter distance from the participant. The LCW were presented at 70 dB SPL at 0 dB SNR. The LCW list is divided up into "easy" and "hard" words. The easy words are words that are frequently heard and have few lexical neighbors while the hard words are infrequently heard and have many lexical neighbors (Eisenberg, Martinez, Holowecky & Pogorelsky, 2002). The children received 15 easy and 15 hard words for each condition (no FM and FM).

Listening Inventory For Education-United Kingdom version (LIFE-UK), Questionnaire

The LIFE-UK (Anderson & Smaldino, 1996) was administered to the teachers prior to the FM fitting and following the FM fitting. The teachers rated the students on a 5-point scale on various listening behaviors and then rated their improvements (or lack thereof) following the 5-month trial period.

Parent/Guardian Questionnaire

Pre- and post- questionnaires were developed to better understand how the parents' perceive their child's listening skills and other behaviors prior to and following the FM system trial. Open-ended questions and modified rating scale questions based on the LIFE-UK teacher's version were used to gain further information about each child and family.

FM System

The FM receivers were Phonak EduLinks, selected for this study due to their open fit. The transmitter was a Campus SX with the microboom microphone or mini mic 8 (lapel style). All of the children received bilateral EduLinks and teachers were given the Campus SX transmitters with the microboom microphone unless a mini mic 8 was preferred in situations with multiple teachers. The children were fitted with their FM systems following their initial and follow-up assessments at school at the beginning of the term. The parent(s), teacher and child were required to attend this fitting appointment and to display an understanding of the use of the FM system both technically and practically. The FM systems were utilized at school only. Teachers were given an information sheet to support their use of the FM system during the intervention period, and were contacted at the middle of, and prior to the end of, the trial period to monitor FM use and to check for any problems and to address any issues that may have arisen.

Teachers were given an information sheet to support their use of the FM system during the intervention period.

Results

Pre-intervention LIFE-UK teacher ratings revealed that children in APD group (N=28, mean age 9.8, SD 1.8) had significantly greater classroom listening difficulties than a control group children (Morgan, 2008) with no suspected APD (N=83, mean age

9.9, SD 1.3) [z test, p<.0001] (see Figure 1).
Results for 22 children that have completed the FM trial indicate that the MLD, DDT, and GIN tests showed practice effects and no clear FM effect. Compressed and reverberated word scores did not show an FM effect. The FPT and LCW in noise tests showed stable baseline scores and statistically significant improvements after FM trial.

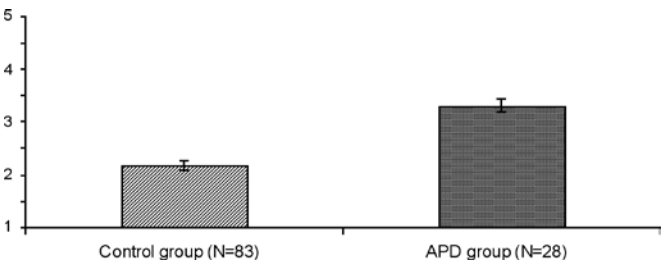

Figure 1. Pre-intervention LIFE-UK ratings for group with APD (N=28) compared to a control group of children with no APD (N=83). Higher ratings on the LIFE-UK questionnaire indicate poorer listening abilities.

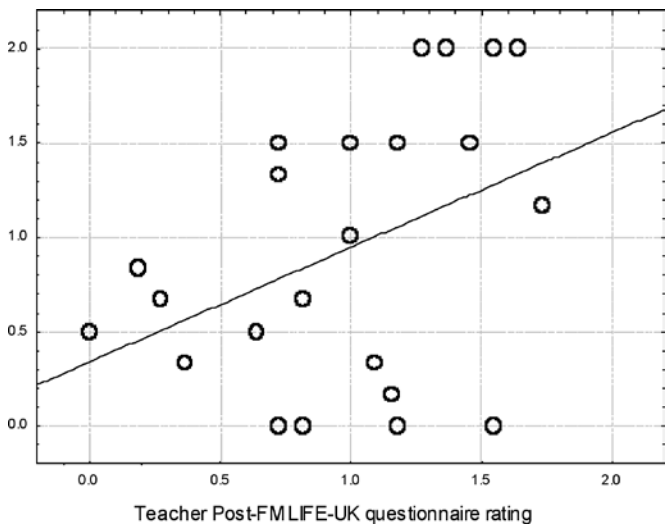

Figure 2. Teacher LIFE-UK average ratings versus parent average ratings (based on six LIFE-UK questions), showing a significant positive correlation. The solid line is the linear regression line (r=0.54, p=0.008).

Post-intervention summed teacher ratings (n=24) on the LIFE-UK indicated that 79 % of participants were perceived by their teachers to have an FM system trial that was "successful" (n=16) or "highly successful" (n=3). Four children were rated as "minimally successful" and one child was rated as "unsuccessful". The ratings of success were defined by criteria on the LIFE-UK post-intervention questionnaire. Figure 2 shows that, in general, the LIFE-UK ratings for the teachers and the parents (6 questions extracted from the LIFE-UK teacher) agree, as indicated by the significant correlation between post-intervention teacher and parent LIFE-UK average ratings (Pearson's r=0.54, p=0.008).

Case Examples

The classroom teacher's perceptions of a child's success (or lack thereof) with a personal FM system are often requested by parents and/or funding agencies. Therefore it is helpful to examine individual cases to determine factors that contribute to success of FM fittings. Two cases are described here, one child perceived as "minimally successful" by their teacher and one perceived as "successful" according to the LIFE-UK teacher rating scale. Case 1 is a child perceived to be "minimally successful" with the FM system, and case 2 is one of the 79 % of children perceived by teachers as successful or highly successful users of the FM systems.

Case 1

A male aged 7 years 10 months with normal birth history presented to the study with concerns in the areas of reading, writing, and spelling. His parents noted that he has difficulty doing more than one task at a time and difficulty following verbal instructions. Additionally, they noted that he often complains about the noise in the classroom and is easily distracted by it. An educational

psychology report from a year earlier identified that he was a visual spatial learner and noted some dyslexic features but the psychologist was reluctant to label him at the time.

At his initial appointments Case 1's peripheral auditory system was assessed and results on all audiologic tests (pure tone screening, speech discrimination, tympanometry, ipsilateral and contralateral acoustic reflexes, and transient evoked otoacoustic emissions) were within normal limits. His TONI-3 score was 121 indicating no difficulties identifying patterns in a minimal non-verbal situation.

Prior to the FM system trial, his teacher reported the following behaviors as *poor* on the LIFE-UK questionnaire: following class directions and rate of learning. The teacher also noted that he is "less inclined to volunteer ideas, or to persist with tasks at hand" than his classroom peers.

Case 1 was diagnosed with APD at the initial assessments based on test scores for the FPT and DDT being more than 2 SD below the normative mean for his age group. His MLD score was within normal limits at both pre-FM trial assessments. Results from these assessments immediately pre- and post- FM system trial can be seen in Table 1. Case 1's listening in noise abilities, in soundfield, were also assessed pre- and post- FM system trial. Case 1's listening in noise scores were very variable (range 53-100 %) and consequently showed minimal improvement with the FM compared to the no-FM condition (76 % *versus* 83 %).

Following the trial period with the FM system the child reported that he thought the FM system was "good" and that it was most helpful when "the classroom was loud". He showed improvements for FPT after the FM trial. His teacher noted the following areas of improvement: following class directions, following individual directions, overall attention span, on task behavior, rate of learning. The teacher perceived a deterioration of his performance in his "involvement in class discussions".

Although the teacher noted areas of improvement, overall she felt that the FM system trial was "minimally successful" as judged by the LIFE-UK questionnaire. She reported that "... the device was hugely successful initially as it was new and exciting. As [his] attitude changed (I can't instead of I can) he forgot to wear the device and even when wearing it his attitude let him down." In this case the child's attitude towards school may have been the barrier to FM success.

Case 2

In the second case a female aged 8 years 4 months was referred to the study due to difficulties in all school subjects, especially reading. This child was also diagnosed with dyslexia and ADD/ADHD. Her mother and father noted that she had difficulty following directions, staying on task and often responds inappropriately to questions both at home and at school. Initial assessment of her peripheral auditory system revealed results within normal limits on

Table 1. Results for Case 1 on behavioral APD assessments pre- and post- FM system trial. Scores more than 2 SD below the normative mean are identified in bold. FPT=Frequency Pattern Test, DDT=Dichotic Digit Test, GIN=Gaps In Noise test, CRW=Compressed & Reverberated Words (65 % compression, 0.3s reverberation).

	Results pre- FM system trial				Results post- FM system trial			
	FPT	DDT	GIN	CRW	FPT	DDT	GIN	CRW
Right	**13.3 %**	80 %	5ms	50 %	**33.3 %**	82.5 %	5ms	50 %
Left	**13.3 %**	**65 %**	6ms	57 %	60 %	**70 %**	4ms	54 %

all audiologic tests (pure tone screening, speech discrimination, tympanometry, ipsilateral and contralateral acoustic reflexes, and transient evoked otoacoustic emissions). Her TONI-3 score was 102 indicating that she does not have any difficulties identifying patterns in a minimal non-verbal situation.

Prior to the FM system trial, the teacher ranked the following behaviors as *poor or very poor* on the LIFE-UK questionnaire: following class directions, following individual directions, overall attention span, on task behavior, rate of learning, involvement in class discussions, contributes when working in a group, paying attention to multimedia, willingness to answer questions, answering questions in an appropriate and relevant manner, and amount of repair behavior. The results from her behavioral APD assessment pre- and post- FM system trial can be seen in Table 2. Case 2's MLD was within normal limits but she had poor scores on the FPT and DDT prior to the FM trial. The results from these assessments can be seen in Table 2.

Table 2. Results for Case 2 from behavioral APD assessments both pre- and post- FM system trial. Scores more than 2 SD below the normative mean are identified in bold. FPT=Frequency Pattern Test, DDT=Dichotic Digit Test, GIN=Gaps In Noise test, CRW=Compressed & Reverberated Words (65 % compression, 0.3s reverberation).

	Results pre- FM system trial				Results post- FM system trial			
	FPT	DDT	GIN	CRW	FPT	DDT	GIN	CRW
Right	**26.7 %**	65 %	5ms	47 %	80 %	**72.5 %**	4ms	42 %
Left	**13.3 %**	70 %	6ms	44 %	93.3 %	90 %	3ms	63 %

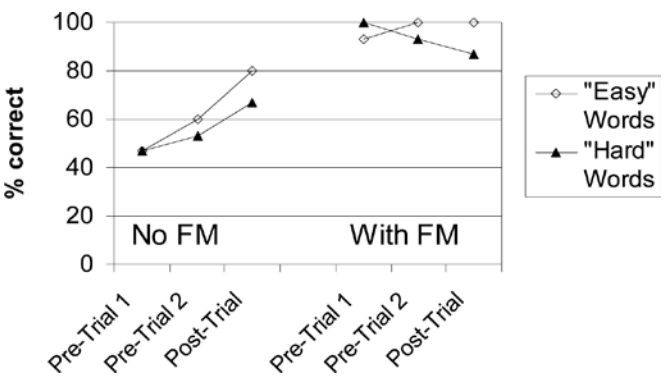

Figure 3. Results for Case 2 from speech in noise soundfield test both pre- and post- FM system trial.

Case 2's scores for FPT, DDT, and GIN improved following her 5 month trial with the personal FM system. As illustrated in Figure 3, improvements for the LCW in soundfield also occurred for the no-FM system condition after the 5-month FM trial. Scores improved from 59 % to 96 %, on average, for the no-FM versus FM conditions. Case 2 reported that she really liked her FM system and the teacher reported specific improvements following the FM system trial and listed examples for each. The teacher noted improvements in following class directions and noted that "[She] was beginning to show awareness of classroom. In group writing she didn't need as many prompts to join her group having her pencil and book on the mat ready." The teacher reported improvements with her ability to attend stating that "[she] was more attentive in class, especially whole class situations." The teacher also reported that she was more involved in class discussions and was able to ask questions to her peers when they were sharing news. In addition to these specific comments the teacher noted improvements on the LIFE-UK questionnaire in the following

areas: following class directions, following individual directions, overall attention span, on task behavior, rate of learning, involvement in class discussions, contributes when working in a group, paying attention to multimedia, willingness to answer questions, answering questions in an appropriate and relevant manner, amount of repair behavior. Overall the teacher found that for this child the FM system was "successful" as judged by improvements on the LIFE-UK questionnaire.

Discussion

In general, the personal FM systems were perceived by teachers and parents as providing benefit to this group of children with APD. It is clear that the FPT and LCW in soundfield were the most effective behavioral tests for measuring FM benefit following a stable baseline period. The use of questionnaires with both the parents and the teachers provided additional subjective data and insight into FM benefits or barriers to success. The positive correlation between the teacher post-intervention ratings and the parent post-intervention ratings indicates that benefit (or lack thereof) was observed consistently at school and at home.

To increase acceptance and benefit of personal FM use it is important to note the barriers that were encountered during the study. One of the important concerns when implementing rehabilitation is a child's self-esteem (ASHA, 2005). Some of the children in this study were concerned about the appearance of the earpieces and reported that other children perceived the device as looking like a hearing aid. In all of these cases appropriate counselling and teacher intervention occurred. Another problem encountered was lack of teacher insight into their student's listening difficulties, which has been reported in the literature for children with hearing loss (Blair, EuDaly & Benson, 1999). Efforts were made by the researchers to educate the teachers about APD and to specifically discuss their student's difficulties. Another problem that was encountered was the initial resistance of some teachers to using the FM system. Some teachers felt burdened by the addition of another piece of technology. In all but one case this was addressed with information and support from the audiologist and parents. Unfortunately, one child and his teachers did not inform anyone that he was not wearing his FM system until after the trial period ended and therefore it was too late to address the issues for this student and his teachers.

There are some steps that the audiologist can take to increase the opportunity for success with the personal FM system. Having a positive attitude about the FM system will reflect onto the child, parent and teacher. It is important to discuss FM system use with child, parent, and teacher when possible, and to ensure all the people involved understand how to use the system before leaving the fitting appointment. Most teachers found it helpful to receive a letter size one-sided sheet of paper with relevant information and troubleshooting tips for the FM system, plus contact details so that they could contact the researchers directly if there were any questions or equipment difficulties. The fitting audiologist should also make sure that the teachers are informed about the child's needs (auditory processing disorder, hearing loss, etc.) in a simple letter or information sheet, since a detailed report describing assessment results is often not read or understood (Blair, EuDaly & Benson, 1999). During the study the researchers sent an email or called the parents 1-2 times throughout the trial period in an attempt to identify any problems (e.g. equipment difficulties, teacher resistance or reluctance, issues with child's self-esteem or motivation). The pre- and post-trial questionnaires from parents and teachers were helpful and provided valuable insight into the child's difficulties and the impact of the FM system.

Children with APD are a very heterogeneous population but they can be successfully fitted with personal FM systems if each child's auditory processing, academic, emotional, and personal needs are addressed. The teacher plays an important role in the success (or lack thereof) of the FM system and therefore creating a working relationship with the child's teacher is necessary.

In two of the unsuccessful or minimally successful cases the children were in special classrooms for children with special needs (e.g. Asperger's syndrome). In these two

cases it appears that problems arose because there were too many teachers and other children's needs to attend to and the FM system was perceived as a burden by the teachers. It may be preferable for children with APD in special classrooms to trial a team teaching FM system or a soundfield FM system or another type of rehabilitation. Poor attitudes on behalf of the teacher and/or the student contributed to the other three cases of minimal success. Despite these difficulties, overall the results from this study indicate that personal FM systems are usually a beneficial rehabilitation choice for children with APD.

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