Auditory Processing Training with Children Diagnosed with Auditory Processing Disorders: Therapy Based on the Buffalo Model

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Audiologists are concerned with the outcomes of treatments for children identified with various audiological disorders, such as auditory processing deficits (APD). Questions arise whether treatments provided to children who have undergone training to improve auditory processing have significant outcomes.

The present study focused on 20 children who received auditory processing training from one of the authors (Kavita Kaul). The other author (Jay Lucker) completed all statistical analyses to study the outcomes of the auditory processing training provided. Therapy was provided using recorded information with controlled volume settings via the audiometer or through an iPad. Live voice was used to provide additional visual cues, only when recorded voice was difficult to process and understand.

Pre-and post-treatment scores were compared statistically. The tests and treatment batteries were the same for all children although treatment procedures were modified and customized for each child. The length of therapy depended on the age and severity of the APD as well as how the child responded to the treatments provided. Evaluation and therapy procedures were based on the Buffalo Model.

Seventeen different scores were obtained and compared before and after therapy using a battery of tests based on the Buffalo Model. Additionally, the Buffalo Model Questionnaire (BMQ) was administered pre-therapy and post-therapy and results were compared.

Results of the statistical analyses indicated significant improvements in auditory processing following therapy for 12 of the 17 measures used. Also, a trend towards significance was found for two additional measures. Typically, parents reported noticeable improvements in listening, auditory processing, learning, academic performance, and social communication interactions based on the Buffalo Model Questionnaire results. These results provide evidence that auditory processing training can positively impact auditory processing abilities in children, and direct treatment services can lead to improvements in auditory processing skills.

Introduction

Parents and professionals who work with children diagnosed with auditory processing disorders (APD) seek research demonstrating the outcomes of therapies to overcome problems in listening and learning for these children. Although there are resources to help people better understand APD with discussions of different intervention options, much of this material describes and recommends programs that may not have empirical evidence to support the outcomes of any specific treatments or therapies (ASHA, 2005; Bellis, 2011; Edell, Lucker, & Alderman, 2008; Geffner & Ross-Swain, 2012; Moore, 2006; Musiek, Shinn, & Hare, 2002). Often, the only recommendations made to help such children are environmental modifications (such as reducing the noise in the classroom), use of accommodations (e.g., FM systems), or preferential seating (such as having the child sit closer to the teacher). Review of the ASHA Technical Report on auditory processing and its disorders (2005) reveals a general discussion of treatments, but provides no specific data to identify therapy outcomes. Another source that discusses treatment is Moore's (2006) presentation of both environmental management and therapies, but he, too, does not present empirical research supporting their outcomes.

A literature review published on treatments for auditory processing disorders indicates very limited evidence demonstrating the outcomes from any specific treatments. Musiek, Shinn, and Hare (2002) discuss what are called deficit specific areas of auditory processing and some treatments recommended for each area, but their review of the literature on these treatments is more a discussion of the treatments and the general outcomes one would expect after using them rather than specific empirical evidence demonstrating changes in auditory processing after the use of such treatments. The same is found in Bellis' (2011) and Geffner and Ross-Swain's (2012) books in which treatments are discussed, but the chapters of these books looking at different treatments do not identify specific research analyzing the outcomes focusing on auditory processing disorder in children who have gone through these treatments. Actually, both Musiek, Shinn, and Hare and Bellis state that there is a lack of evidence supporting the efficacy and effectiveness of outcomes from the various treatments discussed. Furthermore, there are many online programs claiming to improve auditory processing skills. However, these programs lack well developed empirical research studies supporting their outcomes. It is felt that unless these programs are used in conjunction with direct therapy provided by a professional who understands auditory processing deficits, improvement may not carry over to other areas of real life situations such as communication, academic, and emotional development.

Looking at the research on treatments, Fey et al (2011) discuss a systematic review of evidence regarding treatment outcomes for computer based programs. They looked specifically at Earobics and Fast ForeWord, two programs discussed in Geffner and Ross-Swain's book (2012). They also discussed an internet search on publications focusing on treatment outcomes for children with auditory processing disorders. In the end, of the 192 studies initially identified, only 23 provided appropriate evidence to be analyzed systematically. In the end, after completing an analysis of these 23 publications, it was concluded that there was really "no compelling evidence that existing auditory interventions make any significant contributions to auditory, language, or academic outcomes of school-age children who have been diagnosed with APD or language disorder" and that "clinicians who choose to continue using auditory interventions should do so in conjunction with interventions that target specific language, communication, and academic goals" (p.254).

In a more recent publication, DeBonis (2015) reported concerns regarding the outcomes of interventions for APD. DeBonis stated that efficacy and effectiveness of therapies has not been established. As such, he questions the validity of the APD diagnosis in school-aged children. DeBonis' argument and review of the literature cited above reveals limited evidence supporting the specific outcomes of therapy for APD. Thus, the authors undertook the following retrospective study to determine the outcomes of treatments provided for children having auditory processing disorders (APD). The present article presents a discussion of an empirical analysis of the outcomes of auditory processing treatment in children.

METHODS

Research Design

The research design focused on obtaining answers for questions that asked if the treatments resulted in significant changes in auditory processing test findings, and how much improvement was found after treatment. Many procedures or approaches to answer these research questions could present with significant biasing errors. For example, if a group of children were provided with a specific therapy using a test-retest protocol, there is possibility of researcher bias to support the hypothesis that the particular therapy is effective in improving auditory processing abilities. In the present study, using a retrospective approach helped reduce such therapist bias.

The original purpose in collecting the data was to determine the presence of APD problems in these children. Based on the findings, therapy was provided to remediate areas of difficulties for these children. At the end of therapy, re-evaluation was completed to assess changes in auditory processing abilities. Additionally, feedback regarding the children's performance in school and at home related to listening and learning was obtained from parents. These results were then subjected to statistical analyses to determine the significance of the changes that occurred after therapy. In order to reduce further bias, all statistical analyses were completed by one of the authors (JRL) who was not involved in any of the data collection or therapies provided.

Participants

Twenty files were retrospectively chosen for the present study. All 20 subjects were diagnosed with auditory processing disorders (APD) based on the normative data for each test administered and were consequently provided therapy using the same treatment protocol. Their ages ranged from 5 to 15 years with a mean age of 8.4 years (standard deviation of 2.52 years). The length of therapy varied from 11 to 25 sessions with a mean of 15.1 sessions (standard deviation of 3.75 sessions).

One may question testing children for auditory processing at such young ages as 5 and 6 years. However, the research has demonstrated that (a) there is great benefit and need to evaluate children this age, and (b) there is no evidence to support waiting until a specific age to evaluate children for APD (Ackie, 2013; Bander, 2004; Geffner, 2011; Katz, 2005; Keith et al, 2014; Lucker, 2005a & b, 2015a & b; Tillery, 2005; White-Schwoch et al, 2015). Furthermore, both professional associations involved with auditory processing (i.e., AAA and ASHA) have guidelines and technical reports that neither limit the age at which children should be evaluated nor state that there is a specific age cut-off below which children cannot or should not be assessed for auditory processing (AAA, 2010; ASHA, 2005a & b). Furthermore, most assessments of auditory processing having norms for children down to five years of age (e.g., Auditory Skills Assessment, SCAN-3:C, SSW, Word Recognition in Quiet and Noise, etc.). Thus, including these young children is very appropriate based on these factors.

Approach to Auditory Processing

In this study, diagnosis and treatment of auditory processing skills included qualitative signs (delays in responses, impulsive quick responses, need for multiple repetitions, need for task simplification, etc.) and quantitative signs (low scores compared to norms). At the end of therapy, both the quantity and quality scores were used to assess improvement. The weaknesses in auditory processing were treated from a multi-system coordination of skills perspective. This included whole body focus, attention, ability to endure sustained attention for repetitive tasks, ability to stay seated for longer periods of time, decreased need for verbal reminders, improved eye contact, ability to wait for the information to be presented in full, ability to self-monitor and self-correct responses, ability to self-regulate body posture for active listening, ability to self-regulate emotional reactivity to simple tasks that were perceived as difficult or aversive, improved stamina and energy, ability to connect meaningfully to the task rather than mechanically completing task from rote memory, ability to connect to the task at a linguistic level to meaningfully process the information in connected speech, ability to self-advocate when the task is too difficult or to ask for clarification, etc.

Therapies Used

All of the children's files used for analyses in the present study included children who received the same treatments. Therapy was based on Jack Katz's Buffalo Model of Auditory Processing Therapy (Katz, 2007, 2009; Katz & Fletcher, 2004) which included phonemic synthesis training, phonemic awareness and recognition training, auditory attention, whole body active participation and listening training, endurance for auditory listening, short-term memory (repeating words, numbers, phrases, and sentences), working memory/organization training (ability to repeat longer units of numbers forwards and backwards), dichotic and monaural listening training, selective ear listening training, speech in noise training for each individual ear, ear separation listening, auditory ear lateralization, and auditory processing integration training. Therapy was provided using recorded information with controlled volume settings via the audiometer or through an iPad. Live voice was used to provide additional visual cues, only when recorded voice was difficult to process and understand. When recorded messages were incorporated, the volume level was set to provide a comfortable listening level via headphones or loudspeakers depending on the child's ability to tolerate wearing the headphones. The loudness level was typically set at 55-60 dB HL for all therapy sessions.

When we consider the selective ear training, it could be confused with some other therapies. However, for the present therapy provided, selective ear training was conducted using the "Differential Processing Training Program Acoustic Tasks" CD program from LinguiSystems (http://www.linguisystems.com/products/product/display?itemid=10474). This training involves a variety of listening tasks including, but not limited to, repeating numbers or words presented in the right ear or left ear only (selective ear listening), repeating numbers in the right or left ear while ignoring items presented to the opposite ear at the same time (ear separation using dichotic presentations), and repeating numbers, words, or phrases presented in both ears (dichotic listening). The children were also asked to point to the ear in which a specific number, word or phrase (ear lateralization) was presented. This helped develop lateralization, selective listening, and auditory attention. Accuracy was determined by correct responses provided, and training continued until the child was accurate on all practice items.

Although the same types of therapies were provided, the tasks were customized to suit the needs of the child based on frustration level, endurance, stamina, level of difficulty, age, their specific areas of weaknesses related to the Buffalo Model Auditory Processing Categories (Katz, 2007, 2009; Katz & Fletcher, 2004).

Although these therapies were provided for all children, the specific number of treatment sessions and amount of therapy provide varied. All children completed 15 Phonemic Synthesis lessons in which progress was based on the child's accuracy of response in blending the phonemes into words. The speed of blending as well as any qualitative methods the child used for obtaining a correct response were used as a guide to determine when a child was identified as having met the criteria for each Phonemic Synthesis activity before the next, more difficult, activity was introduced. Thus, the number of sessions differed depending on the accuracy and how quickly a child met the criteria for correct identification of the words when blending phonemes into words.

Eight lessons consisting of 80 monosyllabic word were used for the speech in noise training. The children were asked to repeat the monosyllabic words presented via headphones with varying degrees of noise from signal-to-noise ratios (S/N) of +15 down to +5. The speech and noise were presented to the same ear. Cafeteria noise was used as the background noise. All training started with the easiest S/N of +15. Therapy progressed to a level where the noise was louder (S/N+5). Ten monosyllabic words were used for each S/N level. The words were repeated at each level along with therapist assistance as needed to achieve accurate recognition of each word presented at the various S/N ratio. The goal in this therapy was to improve decoding skills at word level, in the absence of contextual cues, while ignoring extraneous and distracting background information (desensitization to background noise).

Dichotic Offset Training or DOT was another training provided for 6 children to further improve dichotic listening skills. Not all children were able to tolerate this task. Each of the 8 lessons had a specific offset time for presentation of information between the 2 ears simultaneously (500 ms; 400 ms; 300 ms; 200 ms; 150 ms; 100 ms; 50 ms; 0 ms). Each lesson consisted of 10 right ear first presentation (REF) and 10 left ear first presentation (LEF). Each item was repeated during the lesson until the child was able to repeat the 4 letters in the same sequence accurately (2 letters in each ear). Reversals and any errors in recognizing the letters accurately (V for Z ; P for B, etc.) resulted in repeating that item until accuracy was achieved. At times the child was made to listen to each ear individually and then then dichotically to achieve success in repetition of the task.

EVALUATION MEASURES

All 20 children received a battery of tests to measure auditory processing skills before and after therapy. The test battery was based on the Buffalo Model for APD diagnosis and treatment developed by Jack Katz (Katz, 2007; Katz & Fletcher, 2004). The list of tests are as follows.

Speech Understanding in Quiet and Noise

Speech understanding in quiet and noise was assessed for all children using word recognition measures in quiet and noise and comparing the differences between quiet and noise (called the Quiet/Noise difference). The specific word recognition measure used for all children was the W-22 Word Lists presented at 40dBSL for each child. Initially, the children were given the W-22 recognition task in quiet and then in noise at a signal-to-noise ratio (S/N) of +5dB in which the speech (words) was 5dB more intense than the noise in the same ear. The test in quiet and noise was conducted for each individual ear according to the standard method for assessment of auditory processing based on the Buffalo Model (Katz, 2007; Katz & Fletcher, 2004). Thus, four measures were able to be obtained both pre-treatment and post-treatment. These four measures included right ear in quiet, left ear in quiet, right ear in noise and left ear in noise. Additionally, the quiet/noise difference was computed for each individual ear. These were also computed for each individual ear. As such, six measures of speech understanding in quiet and noise were obtained.

SSW Test

The second formal, standardized measure of auditory processing was the SSW Test (Katz, 2007; Katz & Fletcher, 2004). This test has a number of measures, but only the individual condition scores and the total error scores were included in the statistical analyses. The individual scores were for the right and left ears for the non-competing items (RNC and LNC) as well as for the right and left ears for the competing items (RC and LC).

Dichotic Listening Measures

Katz (2015) identified two additional measures that examine dichotic listening. The first is the Standard Integration Ratio based on the competing message scores (RC and LC) on the SSW. Standard Integration Ratio or SIR compares left and right ear response errors in the presence of competing messages. SIR score of +1.0 or greater is significant and an indication of the Auditory Integration problem. Second is the Dichotic Offset Measure or DOM. In this dichotic task, letters of the alphabet are presented at different offset times of 0 milliseconds to 400 milliseconds. The offset time indicates the time gap between the competing signals going into each ear. A 0 millisecond gap means the competing signals to the right and left ears arrive at roughly the same time during the presentation of the items. Here two letters of the alphabet are presented to each ear. Each ear hears one letter of the alphabet without competition, i.e., non-competing signals, and two letters with competing signals at different offset measures. The results for the DOM and SIR were also collected and analyzed.

Phonemic Synthesis Test

The Phonemic Synthesis Test in the APD test battery looks specifically at phonological processing. This test has two methods of scoring called Quantitative and Qualitative. The PST has 25 items and one scoring method is merely to identify whether each item is correct or incorrect. This is the numeric or quantitative score. However, sometimes a correct response is provided with much effort using many coping strategies that impact the efficiency of the response. This would be counted as a PST qualitative error. Norms for both Quantitative and Qualitative results are available so that APD findings can be identified based on both scores.

Phoneme Recognition and Phoneme-Word Association Test

The Phoneme Recognition Test from the test battery was presented via speakers at comfortable level (55-60 dB HL). The subjects were asked to recognize, identify, and repeat the phonemes heard. Additionally, they were also asked to associate the phoneme to a meaningful word (/p/ - POT; /d/- BAG; etc.). The test was presented pre and post therapy. Therapy included exercises to recognize and identify phonemes as well as match the sound to symbol as well as to match sound to word each session. The goal in therapy was for both effective and efficient responses. Delays in phoneme-word association were also noted before and after therapy for response efficiency.

Thus, a total of 17 measures were used for APD assessment both before and after therapy (6 speeches in quiet and noise measures; 5 measures related to the SSW; 2 measures for Dichotic Listening; 2 for PST, 2 for Phoneme Recognition and Word Association Test).

All 17 measures were subjected to the initial statistical analysis to determine significance of the differences before and after therapy. Then, those measures found to have significant differences or trends towards significance were subjected to another statistical analysis to determine the effect size of the change after treatment.

Buffalo Model Questionnaire

Parents were asked to complete a questionnaire to report areas of weakness related to Auditory Processing Deficits for various listening and learning tasks at school and at home. These skills are organized under the specific Buffalo Model Categories of Auditory Processing Disorders (Decoding; Noise Tolerance; Short-Term Memory; Integration; Organization). Additionally, there are a list of questions related to generalized processing difficulties which do not fit any specific Buffalo Model classification. Thus, an additional category called OTHER was included for analysis. The last factor is the overall or TOTAL SCORE which is merely the sum of the number of items identified for all categories on the BMQ.

Each of the Auditory Processing Deficits categories is described below:

- Decoding (DEC) refers to the ability to quickly and accurately hear, listen, and process speech.
- Tolerance-Fading Memory (TFM) refers to a combination of poor understanding of speech in the presence of background of noise as well as difficulty with short-term auditory memory. This category is divided into two sub-categories called auditory noise Tolerance (TOL) and Short Term Auditory Memory (STM).
- Integration (INT) refers to a wide variety of symptoms and problems that differ from child to child. The basic characteristic appears to be difficulty in bringing information together.
- Organization (ORG) refers not only to the ability to organize one's thoughts but also to sequence information. But, ORG is a labor-intensive problem requiring a great deal of monitoring of both information that is heard or seen (likely because we say things to ourselves) as well as what the person says and writes. This takes away brain capacity from other important tasks. ORG, when combined with other APD problems, reduces the person's capacity and increases frustration and confusion.

PROCEDURES

The 20 children whose files were used in this retrospective study were evaluated by the first author (KK) and identified as having auditory processing deficits. This same professional then provided the therapy (describe earlier) and retested each child after therapy was completed. The files were arbitrarily selected so long as they met the selection criteria previously discussed.

The raw data for each of the measures pre- and post- treatment along with the children's ages, number of treatment sessions, and the various treatments provided were then given to the author (JRL) who did not provide the testing or therapy. That author conducted the statistical analyses as follows.

Since the raw data (see Table 1) varied between measures, an analysis of variance was determined not to be appropriate. For example, high scores on measures such as the PST indicate response accuracy whereas high scores on the SSW indicate response errors. Additionally, the Quiet and Noise measures use a percent correct compared with the absolute number of correct responses for the PST quantitative analysis and the number of errors for the SSW. Thus, it was determined that paired sample t-tests would be most appropriate for the analysis to see if any changes after therapy were significant. Table 2 presents the results of these analyses.

Table 1. Descriptive data (ranges, means, and standard deviations (SD)) for the pre-treatment and post-treatment auditory processing test results for the 20 participants used in the present study.

APD Test	Measure	When Tested	Range	Mean	SD
Speech in Quiet	Right Ear	Pre-Treatment	80 - 100%	92.2%	5.27
		Post-Treatment	80 - 100%	94.2%	5.11
	Left Ear	Pre-Treatment	80 - 100%	89.8%	5.69
		Post-Treatment	84 – 100%	92.4%	5.93
Speech in Noise	Right Ear	Pre-Treatment	36 - 84%	65.8%	13.39
		Post-Treatment	44 - 88%	73.2%	11.25
	Left Ear	Pre-Treatment	36 - 84%	61.8%	13.45
		Post-Treatment	2 – 92%	68.1%	19.96
Quiet Noise Difference	Right Ear	Pre-Treatment	8 - 52%	26.4%	12.87
		Post-Treatment	8 – 48%	21.0%	10.69
	Left Ear	Pre-Treatment	8 - 52%	28%	12.67
		Post-Treatment	0 – 98%	24.3%	20.79
SSW Test	RNC	Pre-Treatment	0 – 15	4.2	4.05
		Post-Treatment	0 – 5	1.6	1.40
	RC	Pre-Treatment	1 – 32	10.2	7.62
		Post-Treatment	0 – 16	5.2	3.82
	LC	Pre-Treatment	6 – 32	17.8	8.58
		Post-Treatment	1 – 29	11.4	7.25
	LNC	Pre-Treatment	1 – 20	6.0	5.10
		Post-Treatment	0 – 9	3.3	2.69
	Total NOE	Pre-Treatment	11 – 96	38.1	22.86
		Post-Treatment	4 – 56	21.4	13.87
	DOM	Pre-Treatment	4 – 41	14.9	11.98
		Post-Treatment	1 – 30	8.0	12.35
	SIR	Pre-Treatment	-1.73 - 5.53	1.5	2.34
		Post-Treatment	-4.01 – 3.93	0.6	1.76
Phonemic Synthesis Test	Quantitative	Pre-Treatment	11 – 24	18.7	4.28
		Post-Treatment	16 – 25	22.7	2.72
	Qualitative	Pre-Treatment	4 – 24	13.4	6.15
		Post-Treatment	10 – 25	19.7	5.16
Phoneme Recognition Test		Pre-Treatment	50 – 87	75.0	11.21
		Post-Treatment	80 – 86	61.5	22.77
Word Association Test		Pre-Treatment	76 – 100	90.0	6.00
		Post-Treatment	79 – 100	91.6	7.47

Table 2. Results of paired sample t-tests for each of the measures comparing results post-treatment vs. pre-treatment.

APD Test	Measure	t	df	p
Speech in Quiet	Right Ear	1.697	19	0.106**
	Left Ear	1.740	19	0.098**
Speech in Noise	Right Ear	3.832	19	0.001*
	Left Ear	1.119	19	0.277
Quiet/Noise	Right Ear	-2.220	19	0.039*
	Left Ear	0.597	19	0.558
SSW Test	RNC	-3.510	19	-0.002*
	RC	-4.355	19	0.000*
	LC	-5.819	19	0.000*
	LNC	-3.739	19	0.001*
	Total NOE	-6.693	19	0.000*
	DOM	-4.389	3	0.022*
	SIR	-1.179	19	0.253
Phonemic Synthesis Test	Quantitative	5.226	18	0.000*
	Qualitative	4.783	18	0.000*
Phoneme Recognition Test		6.471	19	0.000*
Word Association Test		6.024	19	0.000*

*significant at $p<0.05$ **trend at $p<0.10$ but >0.05

RESULTS

Table 1 presents the ranges, means, and standard deviations for the 20 subjects on each of the 17 pre- and post- therapy measures (not including the results on the BMQ). It was decided to consider the BMQ data separately since it was not a formal test, but a questionnaire completed by parents. Review of table 1 indicates pre- and post-therapy differences, where some tests showed increased scores to indicate improvement (such as speech recognition in quiet and noise and the PST quantitative measures), while others showed decreased scores to demonstrate less errors as a result of therapy (as in SSW measures and for the PST qualitative analysis)

Since post-therapy changes suggest improvement as a result of intervention, paired sample t-tests were conducted for each of the 17 measures. Table 2 presents the results of these t-tests. Review of that table indicates that significant ($p<0.05$) differences occurred for 12 of the 17 measures (Speech in Noise for the Right Ear, Quiet/Noise Difference for the Right Ear, all SSW measures except for SIR, both Phonemic Synthesis Test measures, Phoneme Recognition and the Word Association Test). In addition to these 12 significant findings, a trend towards significance (i.e., $p<0.10$ but $p>0.05$) was found for two measures (the Right Ear and Left Ear Speech in Quiet measures). In addition to the SIR measure for the SSW test, a lack of significance was also found for the Speech in Noise for the Left Ear as well as the Quiet/Noise difference for that same ear. Since the SIR is not a common measure used by audiologists who administer auditory processing tests, the lack of significant findings does not detract from the high number of significant findings. However, the lack of significant findings for the Noise Left Ear measure and Quiet/Noise Left Ear measure is important because speech understanding in quiet and noise is often used by audiologists.

Results of therapy used in the present study revealed a significant difference in auditory processing abilities for most of the measures (12 of the 17 with a trend towards significance for two additional measures). In order to determine the magnitude of the improvement found, effect size measures were calculated using Cohen's d analysis.

Cohen's d is a statistical method for evaluating the effect of change when comparing factors tested before and after therapy. The value calculated indicates the number of standard deviations change.

Cohen's d determines the magnitude of the effect of the treatment. According to the description of Cohen's d, magnitudes and effect sizes can vary. Effect sizes less than .20 are considered to be insignificant factors. Effect sizes greater than .20 are predominantly used when studying positive improvement as a result of therapy. Effect sizes from .21 to .49 reveal a small change while effect sizes from .50 to .79 reveal a medium change. Large effect sizes are identified for values from .80 and higher. Table 3 presents the results of the Cohen's d effect size measures.

Table 3. Results of Cohen's d effect size statistical analysis comparing results post-treatment vs. pre-treatment for each measure having significant t-test findings.

APD Test	Measure	Cohen's d	Effect
Speech in Quiet	Right Ear	0.385	Small
	Left Ear	0.447	Small
Speech in Noise	Right Ear	0.598	Medium
Quiet/Noise	Right Ear	-0.456	Small
SSW Test	RNC	-0.868	Large
	RC	-0.821	Large
	LC	-0.812	Large
	LNC	-0.662	Medium
	Total NOE	-0.886	Large
	DOM	-0.564	Medium
Phonemic Synthesis	Quantitative	1.107	Very Large
Test	Qualitative	1.097	Very Large
Phoneme Recognition Test		-1.669	Very Large
Word Association Test		-1.717	Very Large

As stated earlier, only measures that revealed significant findings or trends were subjected to the Cohen's d effect size analyses. Three measures (Speech in Quiet for both ears and Quiet/Noise Difference for the Right Ear) revealed a small effect size. Medium effect sizes were identified for three other measures (Speech in Noise Right Ear, and SSW LNC, and DOM). All other effect sizes revealed large changes with the Phonemic Synthesis measures and the Phoneme Recognition and Word Association results revealing very large effect sizes greater than 1.00.

Results for the Buffalo Model Questionnaire

In addition to the above quantitative analysis of change after therapy, results from the Buffalo Model Questionnaire (BMQ) were used to look at changes reported by parents. Table 4 presents the summary data from the pre-therapy and post-therapy BMQ results.

Table 4. Descriptive data (ranges, means, and standard deviations (SD)) for the pre-treatment and post-treatment Buffalo Model Questionnaire (BMQ) results for the 20 participants used in the present study.

Area	When Tested	Range	Mean	SD
Decoding	Pre-Treatment	2 – 8	4.7	1.66
	Post-Treatment	0 – 8	3.5	2.11
Tolerance	Pre-Treatment	0 – 4	2.4	1.10
	Post-Treatment	0 – 4	1.85	1.18
Short-Term Memory	Pre-Treatment	0 – 6	3.2	1.79
	Post-Treatment	0 – 5	2.35	1.73
Integration	Pre-Treatment	0 – 4	1.2	0.9
	Post-Treatment	0 – 4	1.40	1.12
Organization	Pre-Treatment	0 – 3	1.5	1.36
	Post-Treatment	0 – 3	1.1	1.25
Other	Pre-Treatment	0 – 11	6.0	3.51
	Post-Treatment	0 – 11	4.8	3.14
Total	Pre-Treatment	6 – 29	19.0	14.45
	Post-Treatment	4 – 29	7.17	6.68

Review of this table indicates that the mean scores after therapy were different from the initial scores. In order to determine whether these differences were significant another series of paired sample t-tests were calculated. Table 5 presents the results from these analyses.

Table 5. Results of paired sample t-tests for each of the BMQ areas post-treatment vs. pre-treatment.

Area	t	df	p
Decoding	3.387	19	0.003*
Tolerance	1.718	19	0.102**
Short-Term Memory	2.904	19	0.009*
Integration	1.241	19	0.230
Organization	2.027	19	0.057**
Other	3.335	19	0.003*
Total	4.344	19	0.000*

*significant at p<0.05 **trend at p<0.10 but >0.05

Results for the seven paired sample t-tests indicated significant (p>0.05) differences for 4 comparisons. The greatest change was for the TOTAL score difference (t=4.344, df = 19, p=0.000). The specific categories identified having significant improvements included: DEC (t=3.387, df=19, p=0.003), STM (t=2.904, df=19, p=0.009), and OTHER (t=3.335, df=19, p=0.003). Two other categories (TOL: t=1.718, df=19, p=0.102; ORG: t=2.027, df=19, p=0.057) revealed a trend towards significance, with one category (TOL), very close to revealing a significant difference. BMQ findings indicate a decrease in observed weaknesses in auditory processing and listening skills as a result of APD therapy provided. Thus on the whole, parents identified significantly fewer concerns for auditory processing problems after therapy.

DISCUSSION AND CONCLUSIONS

Results of the present investigation support the hypothesis that therapy for auditory processing can and will make significant improvements in children's auditory processing abilities. Of the 17 measures of auditory processing investigated in this study, 12 revealed significant differences after the specific therapies used. In addition to these 12 significant findings, two other measures revealed a trend towards significance.

Thus, future research might look into the effects of longer therapy or different therapy focusing on the measures in which trends were found (Speech recognition in Quiet for each ear). Interestingly, basic speech understanding (in quiet) is usually not used as a measure to evaluate APD; rather it is used as a baseline measure to indicate the child's ability to recognize and repeat words heard at a comfortable listening level with no interference (i.e., noise) or distortion of the message. Possibly a significant finding might also have been found in the present study if children with low scores (i.e., below age level norms) on speech understanding in quiet were not included as subjects. Future research can be performed looking more closely at these measures and therapy for speech understanding in quiet.

It could be possible that lack of consistent and focused therapy in the specific areas that did not show a significant change were prominent factors. For example, the SIR scores may have improved more with therapy focusing on improving dichotic skills. Of the 20 subjects only 5 received Dichotic Offset Training to improve dichotic listening skills (therapy recommended by Jack Katz in which 10 items of each offset measure for right ear first presentation followed by left ear first presentation is provided. Each therapy session includes a total of 20 items for 1 offset measure. Beginning at 500 millisecond offset difference decreasing to 0 millisecond offset difference). Also, there was no formal therapy for speech in quiet. Providing speech in quiet listening therapy specifically may have improved the ability to decode monosyllabic words in quiet. Of the 14 measures that revealed significant differences or trends, a majority of the measures resulted in good effect sizes following therapy for auditory processing deficits. For 11 measures, the effect sizes revealed medium or better results. Of these 11 measures, 4 had large effect sizes and 4 additional measures revealed very large effect sizes. Thus, large and very large effect sizes were found for 8 of the 11 or for two-thirds (67%) of the measures of auditory processing.

Results from the present study refute the claim that suggests that there is insufficient data to conclude that treatments for auditory processing disorders really make a significant change in children's auditory processing abilities (DeBonis, 2015). Two-thirds of the measures used in the present study revealed significant improvements in auditory processing abilities following therapy. Thus, there is evidence that therapy can significantly improve auditory processing abilities in school-aged children.

In addition to these quantitative analyses, a qualitative analysis was conducted on the input from the Buffalo Model Questionnaire. Improvements in test scores also seemed to impact a variety of communication and academic skills. Parents completed the Questionnaire both pre and post therapy. Results revealed that parents identified fewer concerns for listening and APD problems for their children following therapy. More than 50% of the factors analyzed showed significant changes with two additional areas showing a trend towards significance. Typically, parents reported noticeable improvements in listening, auditory processing, learning, academic performance, and social communication interactions.

Following auditory processing therapy, often children were referred to a Speech-Language Pathologist, Reading Specialist (e.g., Orton Gillingham approach), Occupational Therapist, and for Visual Processing Therapy to improve other areas of weakness (Speech-Language; Reading; Sensory-Integration, Visual Processing). Some of these professionals who were familiar with these children pre-therapy and had initially recommended evaluation and therapy to improve auditory processing noticed improvements in the ease of listening and focusing skills post-auditory processing therapy when the children resumed specific interventions. The professionals often remarked that therapy for auditory processing skills had facilitated improved listening skills which helped the children progress more rapidly in the therapy being provided by them.

The objective of this present study was to provide empirical evidence supporting the use of auditory processing therapies to improve auditory processing skills in children. The outcomes from the present study revealed that the greatest improvements (i.e., very large effect sizes) were found for measures of auditory phonological processing. Large improvements were also seen in some areas of dichotic listening (SSW measures). Further research can provide even greater evidence to support which therapies to use with specific types of APD.

A limitation of the present study is that the evaluation of auditory processing and the therapies used were those specific to the Buffalo Model. Not all professionals hold to this model. Thus, further research needs to look at improvements in auditory processing when other therapies are used. Additionally, the therapist providing therapy for the children in the present study made the determination regarding what therapies to provide and when to stop each of the therapies based on the decision that the children had reached their goals. Thus, the present study did not incorporate the same amount of and types of therapy for each subject. Further research is needed in which the same exact therapies are provided to all subjects for the same length of time.

Another limitation of the present study is that there was no control group. This is because the study was retrospective in nature and not a standard experimental research study. Since this was an initial investigation to see what changes occur in individual subjects when they undergo treatments associated with the Buffalo Model, it was decided that looking at absolute change in raw score performance would be used. Now that there is evidence that significant changes can occur in the overwhelming number of measures of auditory processing used in the present study, future research can compare the pre- versus post- treatment scores on the norm-referenced tests used to see if significant changes occurred based on these results. Another approach could be to perform a standard experimental study in which a control group of children with APD who did not receive therapy would be compared with a group that did receive therapy to see what changes in performance on the APD tests occur and determine if the two groups differ. However, the present study was conducted as an initial look at changes in auditory processing abilities for a group of children who received specific therapy and evaluation based on the Buffalo Model of auditory processing. The results are felt to provide strong support that therapy for auditory processing makes significant changes in the children undergoing such therapy.

Another limitation of the present study is that the children in the study had a wide age range from 5 years to 15 years. It is possible that changes pre- versus post- could be thought to be due to the older age groups performing better than the younger groups, or vice versa, and, thus, balancing out the change. This is possible, but, one control for this was that paired sample t-tests were used comparing the pre- versus post- test findings for all subjects. Thus, the difference between the post-therapy and pre-therapy test performances was calculated and t-tests were run on the difference values obtained. These t-test findings led to the results and conclusions drawn from the analyses of the test data. Additionally, the individual responses from parents on the BMQ led to themes as to what changes parents noted in their individual child. Thus, future research could look at changes specific to the age of the subjects to see if therapy for auditory processing makes significantly greater changes for specific age groups compared. Additionally, the specific themes identified on the BMQ can be analyzed in future research.

Future research can also evaluate changes that auditory processing therapies might have on factors related to, but not specific with, auditory processing. The present investigation looked at changes on auditory processing measures, but children are often referred for auditory processing evaluations and therapy because of learning problems in school, such as problems with reading, spelling, and understanding lessons presented in class. Parent input on the BMQ indicated observed improvements in their children that relate to academic and learning factors. Thus, there is a need to look further into specific changes in school related skills following APD therapy (such as changes in the measures of academic performance in children such as grades, classroom performance, formal academic achievement tests, etc.).

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