Topics in Central Auditory Processing

Volume 2 Number 3 **August 2017**

This About That: *Donna Geffner and Deb Ross-Swain will soon be coming out with their 3rd edition of their excellent book, Auditory Processing Disorders: Management and Treatment. Tom Zalewski and I and our ENT colleague, Michael Brennen, have written a chapter that will show what we have put together to show how otitis media can lead to aspects of APD, what are the signs of early otitis media to look for and what can be done to remedy the problem.*

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Auditory Processing and Language

Wayne J. Wilson Ph.D.

Following a 1999 study of twin pairs (aged 8 to 10 years) with and without language impairment, Bishop et al. (1999) and colleagues concluded that auditory temporal processing impairment was neither necessary nor sufficient for causing language impairment in children. Instead, these authors suggested that CAPD may be a synergistic risk factor for language impairment that exerts a moderating influence when children are already at genetic risk of language disorder.

In a recent study, Halliday et al. (2017) challenged Bishop et al's conclusion by examining the link between CAPD and language disorders in a different population: children with mild to moderate sensorineural hearing loss. The authors argued that the over-representation of CAPD in these children provides a natural experiment in which to examine CAPD and language outcomes. Two hypotheses were considered. First, if CAPD was necessary for language impairment then all children with language impairment should have CAPD, and no children with language impairment should have normal/good CAP. Second, if CAPD was sufficient for language impairment then all children with CAPD (with or without other disorders) should have language impairment, and no children with CAPD should have normal/good language.

Halliday et al. (2017) sampled children (aged 8 to 16 years) with mild to moderate sensorineural hearing loss and age-matched, typically developing controls. They then performed a range of CAP and language tests on these children. The CAP tests included simple and complex frequency discrimination, frequency modulation (FM) detection, rise time discrimination, complex amplitude modulation (AM) detection, and speech discrimination. The language tests included tests on non-verbal communication, phonological input/output, receptive and expressive vocabulary and grammar, and word and non-word reading. Factor analyses of these test results reduced the CAP testing to three factors – general CAP, complex AM detection, and speech discrimination; and the language testing to one, overall language factor.

Not surprisingly, the three different auditory processing factors were shown to have different relationships with the language component. Poor general CAP skills appeared to be a risk factor for poor language. This was because almost all children with poor language scores showed poor general CAP component scores (i.e. poor CAP appeared necessary for poor language), but not all children with poor CAP component scores showed poor language scores (i.e. poor CAP was not sufficient for poor language).

Poor complex AM detection skills appeared to be a single distal cause and/or a consequence of poor language. This was because while few children showed poor complex AM detection scores (i.e., poor complex AM was not necessary for poor language), those who did showed poor language scores (i.e., poor complex AM appeared sufficient for poor language in those children).

Poor speech discrimination skills appeared to mediate language development possibly by association. This was because the children showed a nuanced relationship between speech discrimination and language with no simple relationships identified.

Overall, Halliday et al. (2017) concluded that different CAPs related differently to language in children. This should remind us that when it comes to the relationship between CAPDs and language deficits, the devil is certainly in the detail!

Reference

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Test Early, Treat Early

Donna Turetgen, Au.D.

Recently, the IGAPS group has given quite a bit of attention to debunking the myth that children younger than seven or eight years of age, cannot be evaluated for auditory processing disorders. If you did not get a chance to tune in live to Dr. Donna Geffner's webinar, sponsored by Pearson, "Central Auditory Processing: What Age Should We Test?" be sure to catch the recorded version, as she gives us an overview of the various assessment measures that are available for children younger than seven years.

Slowly and steadily, there is some movement to the "bright side" from the "dark side" regarding the age for APD testing. I have seen a growing number of children in my practice who have been either evaluated or referred for an evaluation, prior to the age of seven years. But what about treatment? What happens after that early diagnosis? I can tell you what does NOT happen if there is no treatment; the child does not outgrow APD.

I would like to introduce you to TJ. Today, he is an adorable eight year old male with APD.TJ was born full term without any complications and his developmental milestones were age appropriate. He has a history of environmental allergies for which he takes over-the-counter allergy medication, daily. Additionally, he had repeated respiratory and adenoid problems when he was younger.
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He received early intervention services between two and three years of age. Then, he transitioned to the local school district's early childhood education program where he continued to receive speech and occupational therapies. His astute preschool team suspected auditory processing deficits. TJ's mom eventually sought out an APD evaluation with a private provider; TJ was five years old at that time. TJ was subsequently diagnosed with decoding and tolerance-fading memory types of APD. The recommendations at that time included: RedCat speaker system, noise cancellation headphones, closed caption, text-to-speech assistive technology and self-advocacy and assertiveness training.

Then, he transitioned to the local school district's early childhood education program where he continued to receive speech and occupational therapies. His astute preschool team suspected auditory processing deficits. TJ's mom eventually sought out an APD evaluation with a private provider; TJ was five years old at that time. TJ was subsequently diagnosed with decoding and tolerance-fading memory types of APD. The recommendations at that time included: RedCat speaker system, noise cancellation headphones, closed caption, text-to-speech assistive technology and self-advocacy and assertiveness training.

TJ continued to receive school-based and private speech-language and occupational therapies, but the specific recommendations from the APD evaluation were not implemented into the school or home schedule. TJ continued to struggle academically. He had a difficult time remembering what he was told and he needed things to be repeated frequently. He mixed up sounds and words and did not like being in the gym or lunch room. By the middle of second grade, he had to leave his mainstreamed elementary classroom, because he was having multiple incidents that required seclusion and restraint. Additionally, self-harm behaviors had emerged. Therefore, he had to enroll in the school district's specialized program for students whose primary needs are emotional or behavioral in nature.

While in the special program, he met a new speech-language pathologist who had experience working with deaf and hard of hearing students. She also noticed APD signs during speech therapy sessions at school. TJ's mother confirmed that he was diagnosed with APD at the age of five years. TJ's Individualized Education Plan (IEP), which he had since preschool, did not reference APD in the documents and there were no service plan goals for APD; his special education eligibilities were speech-language disorder and emotional disturbance. The school speech-language pathologist suggested an APD re-evaluation as the triennial review of TJ's IEP was coming due.

This is where I come on the scene (*enter Dr. Donna*). On referral from a friend, TJ's mom called me and we scheduled the APD testing. When TJ arrived at my office, we began the basic hearing testing as usual. Tympanometry showed a flat tracing in one ear and a normal tracing in the other ear, but both ears showed a moderate degree of hearing loss. Pure tone testing was halted and I pulled out my otoscope to have a look in the ears. I could not decipher if what I was seeing was a Fruit Loop or a Gummy Bear, but it was clear to me that TJ's ear canals needed attention from someone with not only a better otoscope, but also a headlamp, a curette, alligator forceps, irrigation and possibly suction. So, off TJ went to the ENT, while I eagerly waited to hear the report. "*String and a whole bunch of other things"* was the text that I received later that day from TJ's mom. *"I am so glad you found this,"* she wrote.

We arranged to meet the next morning to complete the testing, so long as the canals were clear and the eardrums were healthy. I asked TJ's mom, *"How long do you suspect his ears were clogged with those things?"* She responded, *"Well, we used that string about a year ago."*

TJ returned the next day with clean ears and normal peripheral hearing tests. Table 1 summarizes the Buffalo Model central test results.

Table 1. Central Auditory Test Results at Age 5 Years Compared to 8 Years

Test	***Measure***	***Results Age 5 yrs***	***Results Age 8 yrs***	***APD Category***
SSW				
	Total # errors	31, NL=23	34, NL=16	Various
	RNC	5, NL=2	WNL	TFM,DEC
	LC	14, NL=11	21, NL=7	TFM
	LNC	WNL	5, NL=3	DEC
	X, QR, Yes	Significant	Not significant	DEC,TFM
	P,BTB,SM	Not significant/reported	Significant	DEC,TFM
Speech in Noise				
	RE-Diff	36, NL=27	44, NL=22	TFM
	LE-Diff	16, NL=30	36, NL=22	TFM
	RE-Noise	36%, NL=72%	56%, NL=75%	TFM
	LE-Noise	52%, NL=68%	48%, NL=73%	TFM
Total # findings		14	15	Various

Do you see what I see? Three years have passed since TJ's initial APD diagnosis and his central auditory test results remained significantly abnormal. In fact, most of his test scores were worse at age eight years compared to age five years. When I recently asked a group of audiologists for a list of reasons for not testing children for APD before the age of seven years, the top two reasons were: 1) younger children cannot perform the tasks and 2) the brain is not mature/they may outgrow it. Unfortunately, in this case, TJ performed as well or better at age five compared to age eight. If anyone is still wondering if TJ outgrew APD, no he did not. We cannot know with certainty if TJ's communicative and mental health issues could have been avoided or resolved years ago, if he had received therapy for his APD when he was first diagnosed. However, there is no doubt that early intervention drives better outcomes.

The take home, or perhaps I should say, "take to work" messages are:

1. Never presume that peripheral hearing is normal, even if the patient or the family insists, "he has passed every hearing test he has ever had." Hearing testing should be completed on or near the day of the central testing. *TJ had a moderate conductive hearing loss on the day he presented for his APD evaluation.*

2. Testing and diagnosing APD early (i.e. before seven years of age) is only half the battle. Treatment needs to follow an early diagnosis. The "wait and see" method will only make the situation worse for the child. *TJ's APD test scores were the same or worse 3 years after his initial diagnosis, in the absence of treatment.*

3. Speech-language therapy is not the same as auditory therapy. While some individuals with APD may also need speech-language therapy, conventional speech-language therapy programs do not remediate auditory processing deficits. *TJ had been receiving speech-language therapy since early childhood.*

4. An auditory training therapy program that is configured by a competent provider with expertise and experience in treating APD, is expected to 1) improve listening skills so that fewer repetitions are needed; 2) improve most initial decoding concerns and decrease the number of phonemic errors; 3) improve speech clarity and improve some, but not necessarily all, articulation errors and 4) improve self-confidence. *TJ was not offered auditory training therapy when he was first diagnosed at age five.*

5. The team approach is best but only effective when the team members are working in collaboration and communicating with one another. *TJ was fortunate to have astute team members who recognized his APD, including his classroom teachers, parents, speech-language pathologist and audiologist, yet there was no unified intervention plan.*

As for TJ, I hope that now he will get the help he needs for his APD. When I spoke to TJ's mother recently, she was hoping that his educational team would be able to offer him auditory processing services when school resumed in the Fall. She was reluctant to enroll in therapy with me immediately due to scheduling, travel and financial constraints. I suggested that I participate in the school meeting in the Fall to advocate for TJ and explain the appropriate therapy for him. In my experience, some local schools have contracted for my services, as a "private vendor." I have provided therapy for a couple of students this way, either during their school day, or in my office, after school. The team approach is best and schools are important team members for these children. TJ's case demonstrates the undeniable necessity to test early and treat early.

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Analysis of Changes in Auditory Processing After Therapy

Christa Reeves, Au.D. & Jay R. Lucker, Ed.D.

The lack of empirical data has led some researchers, such as DeBonis (2015), to state that the effectiveness of therapies for APD has not been established and to question the whole notion of APD as a diagnosis in school-aged children. In contrast, Kaul and Lucker (2016a & b) provided a statistical analysis of 20 children with APD finding very significant changes after completing Buffalo Model based therapies.

The present study looked at a large group of children who received therapy after being diagnosed with APD by one of the authors (CR). The purpose of the study was to show the effectiveness of therapy using empirical, quantitative, statistical analyses of the pre- vs. post treatment scores.
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Summary of the Methods Used

Participants

Subjects included 125 children ranging in age from five to sixteen years, with a mean age of 9.4 (standard deviation of 2.73) years. All participants met the criteria for one or more categories of APD based on The Buffalo Model (Katz & Fletcher, 2004): Decoding (Dec) (N = 114), Tolerance-Fading Memory (TFM) (N = 25), Integration (Int) (N = 30), Organization (Org) (N = 18). None of the children had hearing losses or any physical problems that would interfere with the therapies provided.

Diagnosis of APD was made via administration of the following tests: Speech in Noise (SIN) for each individual ear, the SSW test (only used the SSW total errors score for statistical analyses), the Phonemic Synthesis Test (PST) (quantitative analysis), NU-6 Filtered Words (FW) for each individual ear, and the Pitch Pattern Sequence Test (PPST).

Equipment and Treatment

Therapy was based on the Little Listeners Therapy (LLT) program. The LLT program typically consists of 15 to 20, 30-minute therapy sessions that consist of rhythm training with Interactive Metronome (IM) (www.interactivemetronome.com), Phonemic Synthesis Training, and "headphone" training with pre-recorded tracks for Auditory Figure Ground (speech-in-noise), Auditory Closure (Filtered Words, and Dichotic Listening (Dichotic Words). This headphone training was comprised of specific tracks from the Integrated Listening Systems' (iLS) (www.integratedlistening.com) Language Program recordings or using more difficult tracks that are custom recordings created by Little Listeners in 2016. Phonemic Synthesis Training focused on teaching participant to blend phonemes together to form whole words. Thus, in all, participants were provided with iLS listening and earphone training, IM, and Phonemic Synthesis Training.

Procedures

All children were initially seen for auditory processing testing to determine their specific APD problems. After completing therapy, the same auditory processing tests were re-administered. The changes in test scores were compared statistically.
The course of treatment was determined based on the child's age and assessment outcomes. The plan of therapy was individualized based on the specific needs and test results.

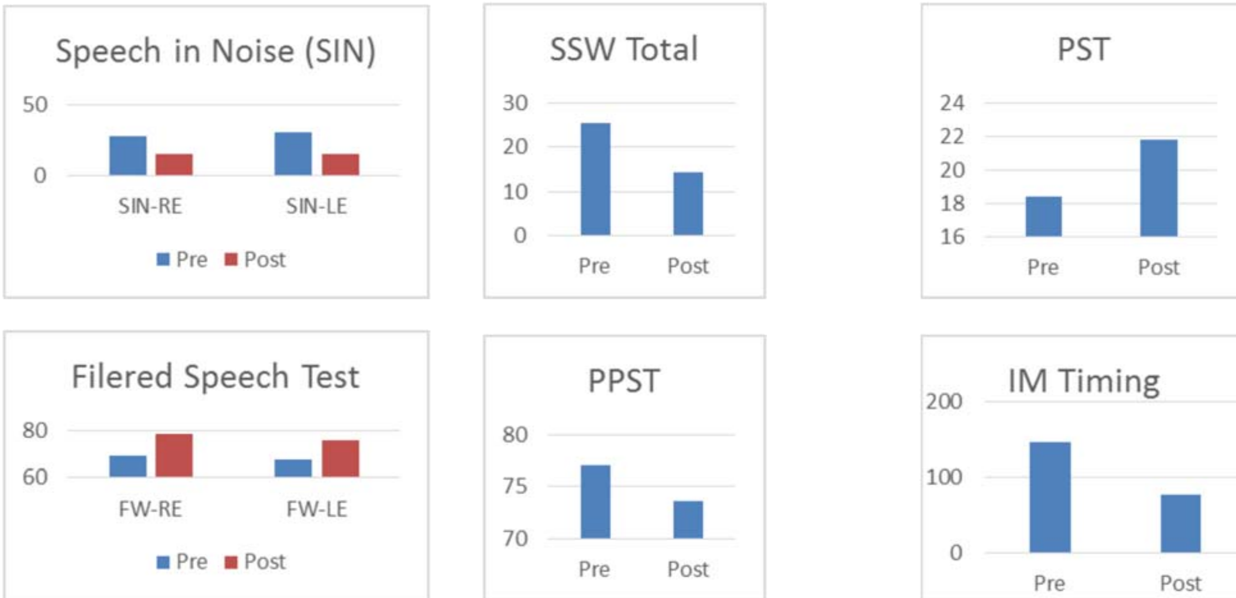
Analyses

Each measure of auditory processing used to diagnose the children having APD problems, along with a special measure of timing from the IM program related to response time were completed. Paired Sample t-tests were used to see if significant changes occurred for each measure comparing pre- and post- treatment test results. Significance was determined via a two-tailed value for p less than 0.05 ($p<0.05$).

Results

Changes in APD Test Scores After Therapy

Results of the t-tests for all APD measures and the IM timing indicated highly significant findings $p < 0.000$ for all measures.



Figures. Comparison of pre- and post- treatment measures on all APD tests. (SIN RE and LE = Speech in noise Right Ear and Left Ear; SSW = Staggered Spondaic Word Test; PST = Phonemic Synthesis Test; FW RE and LE = Filtered Words Right Ear and Left Ear; PPST = Pitch Pattern Sequence Test; IM = Interactive Metronome).

To determine how much improvement was made, Cohen's d was calculated for each measure used. This statistical method looks at the number of standard deviations that have changed between the post-treatment versus pre-treatment raw scores. Cohen's d is viewed as a measure of the "size" of the change known as the effect size. Effect sizes of 1.000 or greater reveal improvement of one standard deviation or more. These measures revealed significant effect size improvements greater than 2 standard deviations for SIN, SSW, PST, and IM Timing, while greater than 1 standard deviation improvement was noted for FW, and close to a .9 standard deviation improvement was noted for PPST.

The above measures looked at absolute scores for each specific measure. However, this does not reveal whether the results were normal or not normal. Thus, the data were re-analyzed looking at whether results were normal (value of 1) or below normal (value of 0) for each measure used. These normal and below normal results were statistically analyzed via Chi-Square tests comparing pre- and post-treatment results. Results revealed significant findings for almost all measures ($p = 0.000$), with only two measures (PST and PPST) around $p = 0.010$. As such, both analyses (using raw scores and age level normative data) indicated significant improvements after therapy for this group of participants.

Were Changes Related to the Specific APD Category?

To see whether the type of APD was a factor which would indicate that the treatments provided were more helpful for some categories of APD compared with others, a correlation between the post-treatment test findings and the specific APD categories was completed. Participants were identified as having met the criteria for a category (1) or not having that criterion (0). The 1 and 0 were then correlated for each individual category of APD with each of the measures used based on post-treatment findings.

Results indicated that there were no significant correlations between improvements in APD and IM Timing on post-treatment measures and the specific Buffalo Model categories of APD except for participants identified with Integration type APD, and only for two measures. These two tests were PST and FW only for the right ear. Overall, the findings indicate that significant improvements in auditory processing can be found in all areas of auditory processing regardless of the specific category of APD identified for the child.

Conclusions

Results indicated that the use of iLS and the LLT headphone training along with IM therapy can significantly improve all Buffalo Model categories related to auditory processing skills in children from five to seventeen years of age. These results are similar to those found by Kaul and Lucker (2016a & b) who found significant improvements in auditory processing using a Buffalo Model approach to treatment. Both studies also revealed significant effect size changes after completing the therapies provided. It is hoped that more empirical studies will be completed so that professionals can have the evidence base they need to support the use of therapies for children with APD.

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Do You Address Short Term Memory?

Jack Katz, Ph.D.

As you know short-term auditory memory (STAM) is an important feature of the Buffalo Model. It is one of three aspects of the Tolerance-Fading Memory (TFM) category. While nothing that is heard is useful if not decoded; it won't make much difference if we can't remember it. This column deals briefly with evaluation of STAM and then therapy for this problem.

Assessment of STAM

To my way of thinking there are two types of STAM that are surely associated with CAP. Both digit and word memory are basic processing functions, but I pushed my comfort zone to include working memory which includes more higher-level functions. When I referred out to professionals in the community for memory work the feedback was not good. Therefore, I started to do this myself. I am so happy that I did.
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At the present time I use Woodcock-Johnson (WJ) #17 to test for word memory and WJ #9 for working memory. I pay some attention to the Age Equivalent score, but pay primary attention to if it's a reasonable memory span for that person. For digit memory I made my own Short-Term Auditory Memory Test (STAMT, Katz, 2009). For older children and adults I usually expect high performance for 5 units (as my own span was only 4 units for digits and words). STAMT has 10 items for each number of memory- span units, so it has depth to give reliable scores for each level (e.g., 3 digits, 4 digits).

The purpose of this testing is to determine if digits, words and/or working memory training is needed and if so where to start. Usually we suspect if memory work is needed or not from the Buffalo Model Questionnaire (BMQ). Table 1 shows an illus-tration of the percent correct for each stimulus (e.g., digits, words) for the levels tested.

Units	3	4	5	6		Start Tx at Units
Person 1						
Digits	100	100	40	0		4 to 5
Words	100	90	20			4 to 5
Working Memory	100	20	0			3 to 4
Person 2						
Digits	100	100	100	0		none?
Words	90	100	80	0		likely 4 to 5
Working Memory	0					not ready

Table 1. Illustration of results for 2 patients on 3 memory tests that were used to evaluate STAM. Units= number of digits (words etc.) in each item. Data are presented in percentage correct.

Therapy

Usually those who need training with memory are those who actually have memory issues (e.g., forgetful, need reminders, and/or reading comprehension) and have shown difficulty on your memory tests. I don't usually try to improve memory beyond 5 units. Usually, if the family thinks it is important to improve further I will give them the work sheets and show them how to give and score the results. They can bring back the sheets so I can advise them further.

In testing or therapy some people do quite well despite memory issues at home, school or work. If so watch to see if they are, for example, using their fingers or looking up. Looking up suggests that they are doing the task visually. If so tell them that ordinarily that's okay but you are trying to find out how well they remember auditory-only.

Where to begin: Looking at Table 1 you will see typical starting points for the 3 tasks for person 1 above. Digits are the easiest; followed by words and then working memory. In therapy we work from a level that is pretty good (usually 100-90%) and the next level that is weak/er. Table 1 (last column) shows where I would be inclined to start. The idea is to start at a level that is not too hard and to edge the person up by one unit.

Person 2 shows a number of findings that may be a bit more challenging to figure out. For digits the person had 100% from 3-5 units. In such a case I would not worry about 6 units. Perhaps the family would like to work on that if they indicate concern. For words you might want to spend some time strengthening from 4 to 5 units. If the person had some better results for working memory than this fictitious person you might want to work with e.g., 3 to 4 words to help later with working memory. However, in working memory person 2 is likely having executive function problems. If so it would be important to train the person how to do the task.

Working memory is a major challenge, as it seems to be in this case. The task I use is giving numbers and words and having the person say the numbers first from smallest to largest and then the words in the order they were given.

Start with digit memory work, if needed, and then words and working memory. Of course, not everything will go smoothly for each person. Below we will discuss what you can do if there are problems right away or if they show up later. For working memory you could start with 2 numbers and build up or perhaps show the task visually.

In my therapy book (www.edaud.org), it has examples of therapy sheets. For each level they start with Sublist-A, the easiest sublist for that level (e.g., 4 to 5 digits). In that sublist the items are easier than the following 3 sublists. That is, the units and combinations are easier to remember. Sublist-A is also easier because the first 4 items have 4-digits and there are only 6 items with 5-digits. Sublist-B has 10 somewhat harder items and there are only 3 items with 4-digits and 7 with 5-digits. Each sublist has harder items and more at the harder level as the person improves.

Therapy procedure

As in testing we say each word clearly. So if the word is 'hat' then each sound should be audible. In therapy I often ask the person if I was too fast or too slow. Going at their rate would be an effective way to build the person's memory span. As itimproves you could try to get them to do it more quickly. On the longer items it is a good idea to leave a little less time between units so they can take it in as 'one snapshot'. I usually show the error on my form so when I do it again I might say the problem unit a little louder or leave a little time before or after that unit.

Mark each item as correct (I use a dot) or for an error (a dash) and show the error/ incorrect sequence on the form. If given again I put a slash and then a dot or dash. For a reversal circle the 'R'. Repeat a sublist the next time if the performance was not as good as it could. If necessary go back to an earlier sublist and come forward again. If there is a very big challenge use a modified (MOD) procedure to help the person progress. The easiest thing to do is e.g., if 5-words are very hard, in MOD give the first 4 words and after successful completion, then give all 5. Pretty soon you will be able to go back to the regular presentation. In desperation provide some other items for the person to test you or give them written or visual cues.

Results

Usually we try to get the person to improve by 1 level in a round of therapy. If they had 0-20% for 4 units try to get them up to 90% or 100% for 4 units. I don't usually get retest scores because most of the tests have no depth (usually just 3 items) and one test is live voice so they would not be as useful for retest compared to the therapy data.

Here are the results for an 11 year old girl who I saw yesterday. She began memory therapy 3 months ago and had 9 sessions of memory training to date. Table 2 shows good digit skills. This was important because when you see that she could do so well at 5 units and had some skill at 6 units it suggests that she would be able to improve her word and working memory skills more rapidly. She sure did improve her word memory in just 2 tries.

We worked on working memory for a total of 7 therapy session. Four were from 3 to 4 units and 3 were 4 to 5 units. You can see from Table 2 that she improved by about 60 points with 100% at 4 and 90% for 5 units. What amazed me was yesterday she just zipped through the last several 5-unit items as though as though they were easy!

	Units	3	4	5	6
Digits	Pre	100	100/1r	100/5r	40/4r
	Post	DND	DND	DND	DND
Words	Pre	100	67	33	
DEMO	Post	100/1r	100/3r	4-5 @home	
Working Memory	Pre	100	33	0	
	Post	100	94/1r	91	

Table 2. Percent correct for 3 memory tasks, 3-6 units, pre and post therapy. Reversal = r.

She did so well that I wanted to make sure that she really had really had memory difficulty. So, I checked her BMQ and the greatest problems listed were Organization with 3/3 problems and for Memory 4/6 were noted (reading comprehension, speaks quickly, forgets thing told and remembers oral direction). At retest we will see if her mother notes improvement in these problems as she has shown in the auditory training.

Final Thoughts

Memory is a very important auditory skill. It is neither very difficult nor complicated to train. Families can often get involved in providing memory training at home. An added incentive that I found out about is that giving the therapy to others can help the tester improve his/her own memory.

Improving skills can increase from digits to words and then to working memory. This goes from easier to harder to hardest. It is amazing how working on the easier task/s can facilitate the next level challenge. Like speech-in-noise (SN), memory is subject to obvious problems when the person has fatigue or inattention.

A number of years ago one APD professional thought that memory and sequencing were not part of APD. I hope that by now that has been corrected or ignored. Also, a few years after that someone was convinced that the Buffalo Model concept that SN and STAM are part of the same category; was not correct. The world must have heard that. Suddenly there were 4 studies with different populations and different languages that found a close association between STAM and SN (Brannstrom et al. (2012), Coleman, 2012, Parbery-Clark (2011) and Yathiraj and Maggu (2012)).

I hope that if you do use STAM in your CAP work that you have gotten one good idea or two from this column. If you don't use it, whether you are in Audiology, Speech-Language, Psychology or Education, I hope that you will think about how memory work can help the people you serve.

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