The Buffalo CAPD Model: The Importance of Phonemes in Evaluation and Remediation

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Introduction

Years ago, an ASHA committee on Central Auditory Processing (CAP) was discussing diagnostic procedures. One member added, to the test list, a phonemic procedure and immediately another member said, "Phonemes are not audiology". So, the first audiologist asked the second, "Are sentences audiology?" to which the response was "yes". The response was also "yes" to each of these, "words, nonsense words, tones, noises, clicks". Then the first audiologist asked, "So why not phonemes?" There was no response.

In the Buffalo Model of CAP phonemes are vital considerations in evaluating, categorizing the problems, planning and carrying out therapy, as well as in determining the success of therapy (Katz, 2012). Phonemes are basic language (Kent, 1992) and fundamental to auditory processing.

Some History in Using Phonemes Clinically

In the past phonemic-based testing and training were used to aid those with speech and academic problems even in the absence of hearing loss. Marion Monroe (1932) studied a phonemic synthesis procedure in children with reading problems compared with those who had normal reading ability. She found that those with reading disorders had between half and one-third of the items correct of the control group. Samuel Orton (1937), a neurologist after whom the Orton Dyslexia Society and Orton-Gillingham therapy were named, spent years studying children with reading, writing and speech problems. He had numerous insights and an excellent understanding of these issues that has taken us a long time to relearn. For example, he pointed out that we should teach children with reading problems the sounds of the letters and how to blend them together to arrive at the spoken equivalent so they can understand the words (p 159). Mildred McGinnis (1963), at Central Institute for the Deaf, who worked with "Aphasic" children, taught them speech using a sound-by-sound method.

Charles VanRiper (1963), the famed pioneer in speech pathology, included a phonemic synthesis test (called vocal phonics) in his text because he knew little about it, but felt it was so important that he hoped it would encourage others to study it. Luria (1970, p 324) pointed out that, "investigation of reading and writing (i.e., spelling) should begin not with … the ability to read …words but with … (the) ability to carry out … auditory analysis and synthesis which are essential to both reading and writing". More recently we have found great benefit in using these types of tasks to improve auditory processing as part of the Buffalo Model.

Two audiologists, Arthur Boothroyd (1968) and Fredrick Berg (1976) have led the way for scoring phonemes in word recognition testing for those with hearing loss. Boothroyd pointed out that this approach is more reliable and specific than scoring whole words. This enabled him to develop a discrimination test with just 10 words in each of 15 lists that were carefully balanced for 30 phonemes. One or more lists could be used for each variable (e.g., an input-output function). Berg followed up on the work of Boothroyd and developed a word recognition test that was to be analyzed phonetically and extended this application by using phonemes in auditory training.

More and more audiologists have become involved in providing therapy. This is especially true in auditory processing. After giving the Buffalo Model tests; therapy is often recommended. Decoding training is the most basic category, using phonemes to improve the speed and accuracy of processing speech. This training is generally administered at the same time as other rather basic auditory tasks (e.g., speech-in-noise and short-term auditory memory). Improvement in Decoding will enable the person to develop their higher order auditory skills more quickly because they can apply their improved accuracy for processing speech.

Phonemic training is not limited specifically to those diagnosed with CAPD. Watson et al. (2008) indicated that just as in the case of those with normal hearing; those with hearing losses and cochlear implants differ in their “central recognition skills”. Importantly, they indicated that whether one has a hearing loss or not training can help them to greatly improve their auditory skills. The Buffalo Model procedures can be modified to help those with hearing loss and cochlear implants to improve their processing (Katz and King, 2000). Another important population is those who have intellectual deficits. We found that many of them had major phonemic challenges and major improvements with therapy (Katz, 1999, 2013).

Anatomic–Physiologic-Behavioral Relationships to Phoneme Perception

The Buffalo Model is based on many years of research to determine the signs on the Staggered Spondaic Word (SSW) test (Katz and Smith, 1991) for various sites-of-lesion, to help localize brain dysfunction. These concepts and findings have been adapted and expanded to understand CAP disorders. The SSW is currently the most widely used CAP test by audiologists who work with CAPD (Emanuel et al., 2011). This may be because of the sensitivity of the test (Gallun et al., 2012) and its accuracy in identifying the diagnostic categories (Jutras et al., 2007). Seven of the 20 SSW indicators are related to the Decoding category (associated with phonemic processing).

Where do we process phonemes in the brain? The work of Alexander Luria (1966, 1970) enabled us to better understand the connection between brain functions and the processing of phonemes. Luria, the famous Russian neuropsychologist, evaluated hundreds of soldiers who sustained gunshot wounds and patients with other brain lesions. This enabled him to locate where brain damage caused impaired phonemic processing. He found that 95% of those who had disorders dealing with processing phonemic stimuli had lesions in the left auditory cortex (areas 42, 22 and likely 41 of Brodmann) with the remaining brain lesion cases involving the region immediately adjacent to it (see Figure 1).

Figure 1. The region of the left hemisphere of the brain that is associated with phonemic processing disorders in 95% of the cases. This phonemic zone of Luria (1970, p118) corresponds to the auditory cortex.

It is of interest to note that Luria (1970, pp 118-119) specifically mentioned phonemic analysis and synthesis skills as well as articulation to be functions of this brain region. Independently, in the Buffalo Model research we found the same area associated with Decoding.

Working with neurologists and neurosurgeons we have been able to map out much of the auditory brain with the SSW (Katz and Pack, 1975, Katz and Smith, 1991). With this dichotic listening task, we found that Heschl Gyrus (HG) was the most sensitive region in both hemispheres. The 1 cm square that the neurologists felt corresponded best to HG was E-9 in the Figure 2. The region immediately around E-9 is the secondary auditory cortex. We found that patients with lesions to this area had the most errors on the SSW with the major peak for the competing condition in the ear opposite the auditory reception lesion (Katz and Pack, 1975). The SSW Total-Ear-Condition (TEC) Analysis was moderate or severe in these cases. The test indicators associated with this region became the signs of the Decoding CAP category system when statistically supported by factor analysis results.

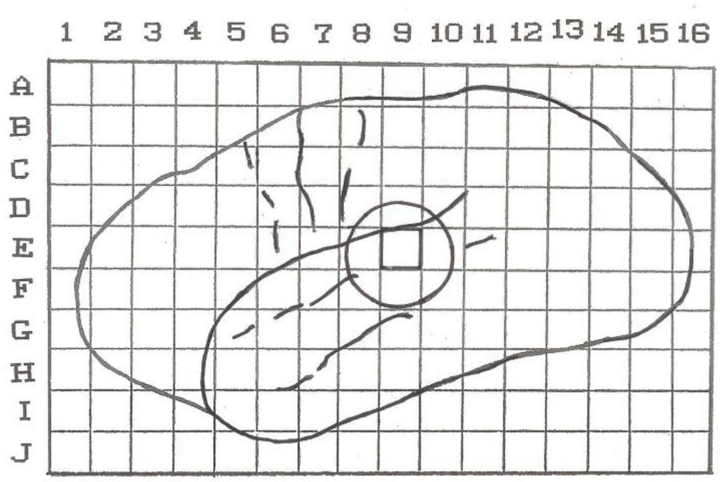

Figure 2. Figure used to record location of cortical lesions which were used to compare with SSW test results to identify Auditory Reception (AR) E-9, and auditory cortex (circle) lesions and the area immediately surrounding it.

In 1986-7 when we developed the Buffalo Model of CAP it was based on what we had learned in 25 years of site-of-lesion/dysfunction work primarily using the SSW test and 20 years of CAP study with the three Buffalo-Model tests (Katz and Smith, 1991). Three powerful signs on the SSW were chosen as exemplars for a factor analysis that was based on 200 CAP cases that were collected by three well trained audiologists who performed the three CAP tests using the same protocols and criteria. A wide range of CAPD cases was assessed because each audiologist had a different work setting and were in different states and a Canadian province. These results enabled us to determine which test signs loaded on Decoding as well or the other categories of the model. We could also see which SSW Decoding signs correlated significantly with the subtests of the other basic tests of this model (to be discussed later). Most of the speech-sound analyses deal with Decoding. Not surprisingly, most of the phonemic signs are on the Phonemic Synthesis test.

Phonemic Measures and Questionnaires in Buffalo Model

Presently, most audiologists do not record the verbal response when a word is in error on their tests. Often a dash or an 'X' shows there was an error, but not what the error was. It could be just the omission of a final S-sound or a response that bears no resemblance to the test word. It could be "blue" for "green" or "tack" for "cat". There may be an H-sound in front of words beginning with vowels or a complete omission of the word. Those of us who enter the spoken error have much to gain and little to lose. Those who record the errors know how helpful this is in understanding a person's auditory problems and can take this information into account in the diagnostic and remedial phases. On all three of the Buffalo Model tests we indicate the error word/s so that we can make better sense of the difficulties and can later construct a Phoneme Error Analysis (PEA) (Katz, 2012) to tailor-make a therapy program for the person. Below is a list of SSW and Phonemic Synthesis subtests; most of which depend on the specific phonemic response. We use phonemic information from the speech-in-quiet/noise tests, which are used in the PEA, but they do not have other phonemic indicators, at this time.

There are 4 major categories in the Buffalo Model (Katz, 1992, 2012). The first and most common one is Decoding. It is defined as the speed and accuracy of processing speech. Everything of importance that we hear must be processed and those who have poor building blocks (phonemic accuracy) are much more likely to misunderstand what is said and take longer to figure out the meaning. Decoding of speech is very heavily dependent on accurate processing of phonemes. It is more likely for children with poor phonemic accuracy to have speech, language, reading and/or spelling difficulties. On the Buffalo Model Questionnaire-Revised (Katz and Zalewski, 2012) there are 9 Decoding questions. Each question is clearly related to phonemes (see Table 1).

	May have a problem with	If Difficulty with Phonemes
1	Speech (saying sounds)	Speech sounds not clearly heard; likely their speech not clear
2	Understanding language	Words/sentences not understood well if poor processing
3	Understand verbal directions	(as above)

4	Oral reading accuracy	Need quick-accurate sound-symbol & visual recognition
5	Phonics	(as above)
6	Spelling	(as above)
7	Responds slowly/delayed	Slow to understand what was said/asked. Slow to respond
8	Foreign language learning	Sound & symbol associations poor with weak phonemes
9	Speaks slowly	More successful when processed/spoken slowly

Table 1. Nine Decoding-category items on the Buffalo Model Questionnaire-Revised (Katz and Zalewski, 2012) and their relationships to phonemes. This reinforces the understanding that many important functions in communication and academics relate to phonemic difficulty.

Buffalo Model also has a questionnaire (APD: Characteristics in Young Children) for problems seen primarily in pre-kindergarten children. These Decoding signs can relate to phonemic problems (see Table 2).

Item #	May have a problem with	If Difficulty with Phonemes
1	Slow to learn to talk	Babbling/words etc. develop slowly if poor phoneme processing
2	Poor articulation	Poor encoded models & slow processing of rapid signals
3	Limited vocabulary	Poor incidental learning & poor understanding of speech
4	Poor receptive language	Foundation is poor and so is everything depending on it
5	Has had speech therapy	Because speech-sound production poorer than age peers

Table 2. APD: Characteristics in Young Children (Katz, 2015) items that relate to the Decoding category and show a clear association with poor phonemic processing.

The Buffalo Model tests use multi-dimensional scoring (as seen in many psychology tests but not many in audiology). In this way we can look at test results from various standpoints. There are approximately 40 factors that we can consider for studying specific features/categories instead of obtaining a combined- single score for each test. As you will see phonemic scoring can indicate not only the Decoding, but also two of the other categories of this model as well.

Table 3 shows the phonemic-based measures for SSW and Phonemic Synthesis tests. An error can relate to one or more measures.

Test	Measure	Category	Brief Description
SSW	Perseveration	DEC	Giving same response incorrectly as previously given correctly or incorrectly (could be nonsense word)
	Smush-2	DEC	Combining a spondee into a third word or nonsense word (e.g., out side = tide or south)
	Smush	TFM	Combining 2 competing words (e.g., bed spread mush room = bed smush room – thus the name *smush*)

Phonemic Synthesis	Quantitative Score	DEC	Number of errors when combining individual speech sounds (skill mentioned above by Luria, Orton etc.)
	O for L	DEC	Substituting a vowel for an /l/ or adding a vowel before the /l/ (e.g., child = chiod)
	Non-Fused	DEC	Saying the sounds back with 1 or more pauses between them or elongating connected sounds into a word
	1st Sound	TFM	Omitting first sound (e.g., paper = aper, or train = race)
	Reversal	ORG	Saying the sounds out of order (e.g., sky = psych, or gift = fig or gitf)

Table 3. Phonemic measures associated with Decoding (DEC), Tolerance Fading Memory (TFM) and Organization (ORG) Buffalo Model CAPD categories.

The Use of Phonemes Before, During and After Therapy

Our first step, prior to therapy, is to make a PEA based on the person's test performance. There are 926 phonemes on these three challenging tests, which gives us a pretty good idea of which sounds are poorly processed and what the phonemic confusions are. This is much more informative than counting how many of the 309 words were missed on the three tests. A person might have had a problem distinguishing between similar sounds (e.g., m/n, f/θ) or not so common (e.g., ʊ/æ). We also count phonemic omissions and additions. Figure 3 shows portions of the PEA that was just finished for a child who will begin her first therapy session.

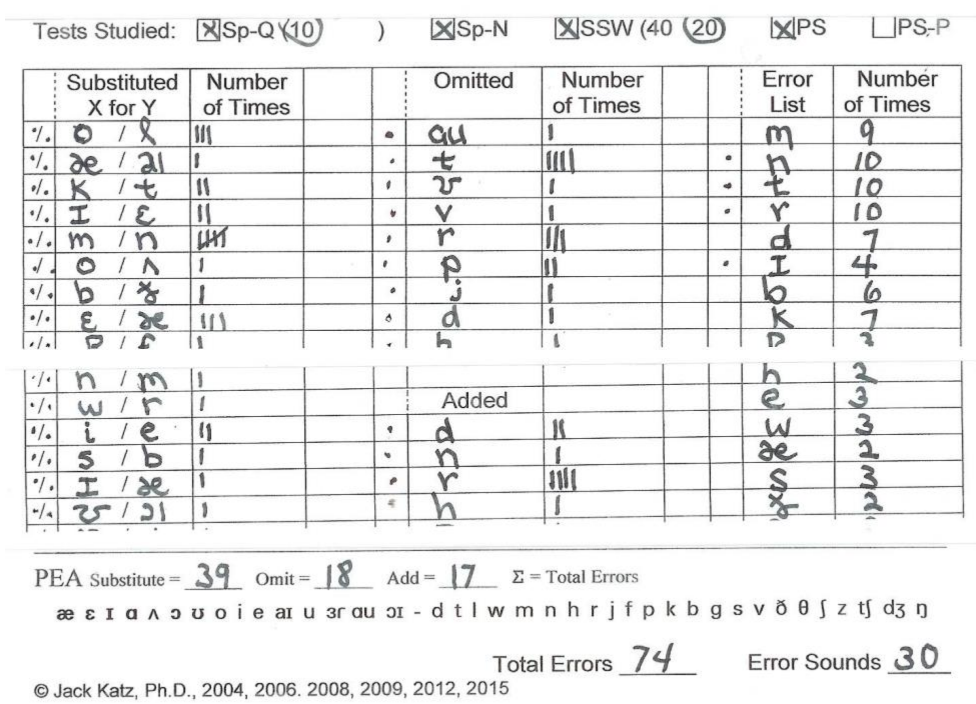

Figure 3. Phonemic Error Analysis (PEA) form of the Buffalo Model tests for a child with CAPD. It shows the specific phonemic confusions, omissions and additions. The total errors for each of the sounds are in the right column. PEA is used to guide the introduction of sounds in the Phonemic Training Program.

Because training for ‘auditory perception’ was relatively unheard of; Katz and Burge (1971) introduced their program with, “The auditory training program evolved because of empathy with children with learning pains and empathy with their parents. (It) is geared not only to improve…their auditory perceptual skills…but also to provide positive rewards…from successful learning (p 20). The most basic therapy procedure in the Buffalo Model is the Phonemic Training Program (PTP) (Katz, 2013). Training generally begins with the most difficult sounds for the individual, but the specific ones we use are not confused with one another (e.g., d, ɛ, l, m). The person begins with just one sound (/d/) and after some training the next one (/ɛ/) is presented individually and after further training the first two sounds are contrasted etc. In this way we can start to improve the ones that need the most help with repetition for as many sessions as needed. This phonemic training is quite quick and easy for the individual, but it is very effective and appears to be long lasting. One parent asked when I would start challenging her child. I tried to explain that teaching the brain is like physical therapy in which we gradually increase the listening task along with lots of repetition to teach the brain. In all our activities we try to make even the repetition as much fun as possible (and sometimes reverse rolls with the child). The results are most gratifying in relatively short periods of time (Katz and Cohen, 1985; Katz, Ferre, Keith and Alexander, 2015). For each of the therapy procedures we have effective remedies when a person hits a bump in the road.

The second Decoding therapy is the Phonemic Synthesis program (Katz and Harmon, 1985). The purpose is to support PTP and to move the process ahead by connecting sounds into words. We have been using this training procedure for almost 60 years and the current recorded program has been in continuous use for three Decades. Based on the PS pretest results an appropriate starting lesson is chosen. In this program individual phonemes are presented and the person is to say the word they form. The lessons gradually increase in the number of phonemes (e.g., 3 to 4) in the words, the difficulty level of the phonemes, or introducing consonant blends. The results have been very good especially when PTP is also given (Katz, 2012).

When the first round of therapy is completed (as many as 14, 50-minute sessions) there is a retest and the parent-teachers fill out a questionnaire dealing with any changes in the original concerns (most often involving Decoding) following therapy. Three measures are used to determine if the training has been successful, as it almost always is. Progress is monitored by studying improvements in test accuracy and noting the speed in identifying and distinguishing phonemes. We also compare test-retest results and improvement reported by the family/teacher in oral reading etc., communication and daily activities over the therapy period. To determine the phonemic improvement with training a second PEA is completed on the retests and supported by the results of the post-therapy questionnaire.

Summary and Conclusions

Phonemes are a crucial aspect of the Buffalo Model from the questionnaires and tests before and after therapy, to understanding the real-life problems, to categorizing CAPD, to plans for therapy, a vital part of the therapy itself, and at the end to determine the benefits of training. In therapy, the early lessons most heavily address phonemic difficulty, because this helps to improve all of the listening tasks that require decoding of speech. Phonemic skills are equally important for determining the person’s status following therapy. Increasingly, audiologists have realized that phonemes are an important part of Audiology, and surely basic to CAP. Gradually, more audiologists have ventured into recording phonemic errors and using phonemic tests and therapy materials. Because of the success in using phonetics there has been a much greater appreciation of the importance of phonemes/phonetics in audiology.

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