## 2. WHAT IS THE SSW TEST?

### The Staggered Spondaic Word (SSW) Test

The SSW test is a procedure that is used to assess central auditory function. The person is asked to repeat the words they hear (i.e., one spondee to each ear). It is considered a test of dichotic listening because a different monosyllabic word is presented simultaneously to opposite ears. In addition, it is a complex listening task because it starts in one ear and ends in the other and the starting ear alternates from one item to the next. Another challenge is low level equipment/recording noises in the background, and each item is introduced with the carrier phrase, "Are you ready", which is not to be repeated. Currently, the SSW is widely used for evaluation of auditory processing disorders in children and adults (Emanuel et. al, 2011).

### Description of the SSW

The SSW test has 4 practice items followed by 40 test items. They alternate Right-Ear-First (REF) and Left-Ear-First (LEF). It is considered a dichotic test because 2 of the 4 words of each item are auditorily perceptually-centered on one another. That is, they sound highly or completely overlapped, if given just to one ear or loudspeaker. The items always begin REF (unless by mistake). This is because the central challenge is different if the same item is given LEF. Using spondees gives the listener an advantage in guessing the second monosyllabic word from the first or vice versa. To partially counteract that, the first word of the first spondee, and second word of the second spondee, form a third spondee. So, if the person would simply try to make a spondee by repeating one of the competing words, this "available word (AW)" will produce an error and reduce the likelihood of a correct guess. For example, the spondees 'up stairs' and 'down town' can form a third spondee, 'up town'. If the person misses 'down' they can say 'up stairs up town". If the person misses 'stairs' they can say "up town down town". Each competing word has this built-in AW to form a legitimate spondee, so the word will be wrong (as it should).

The test words are spoken rather slowly with a pause between the 2 monosyllables of each spondee. Before each item the person hears "Are you ready?" in one ear, to call attention to the first ear for that item. The person is not to repeat that carrier phrase, just the words that follow it. Each item is scored by writing, the error above the missed word, on the form. Knowing what the person said, vs. the actual word can provide additional information (e.g., showing the phonemic errors). We also pay attention, and mark down compensations and other characteristics as discussed in the section, "Giving the SSW Test". The test is usually presented at a fairly comfortable loudness level (about 50dB SL $\pm$ 5dB). The recording runs 10 minutes.

### Buffalo- Model Categories

There are 4 Buffalo-Model (B-M) categories. The categories are based on findings with patients with neurological lesions. This aids us in understanding, what types of problems are revealed by the SSW signs and the other B-M tests. When the same signs were noted in those with CAPD; years were spent by many audiologists in the U.S. and Canada to verify the implications and applications to the CAPD

population. In 1987-88 the Buffalo Model (Katz and Smith, 1991) was developed, and used effectively, since then, by hundreds of audiologists. SSW Workshops have been invaluable in teaching how to give the test, and how to interpret it effectively.

Most people we see have 2 or more weak categories. The more ways in which a person is limited in their auditory skills, adds considerably more difficulty to the person's challenge. We are usually able to compensate for one mild or maybe a moderate problem, but 2 or more significantly reduce our chances for success.

**Understanding the Four Buffalo-Model Categories**

Many signs on the SSW and the B-M tests are associated with the 4 categories. To help the person, it is important to determine their significant APD categories. This help includes what therapies to use and also what accommodations would be most helpful. Table 2-1 lists the categories, defines them and the problems with which they are associated.

| # | Category | Definition and Associated Problems |
|---|---|---|
| 1 | Decoding (DEC) | Inability to quickly and accurately process speech. It is associated with such problems as poor recognition of speech, phonics, reading accuracy, spelling and articulation. |
| 2 | Tolerance-Fading Memory (TFM) | It is associated with difficulty understanding speech-in-noise and short-term auditory memory. It is also noted with anxiety and attention problems. TFM can result in forgetful-ness, reading comprehension and, of course, difficulty understanding in noise. |
| 3 | Integration (INT) | Most importantly combining auditory and visual information. Typical problems are severe reading, spelling and dyslexia. |
| 4 | Organization (ORG) | Auditory sequencing and keeping things in order. |

Table 2-1. This table shows the 4 B-M categories, their abbreviations and description of each.

**Associated Brain Regions**

The analysis of the SSW is based on 3 decades of data gathering and analysis. Site-of-lesion and audiometric results were compiled with physicians, using radiological and surgical evidence, as well as their clinical procedures. This enabled us to match site-of-lesion and test abnormalities/peculiarities, mainly on the SSW. Because of the complex nature of the SSW, and a lot of good fortune, it was possible to identify various loci of lesion based on the specific test patterns. This is discussed in Associated Brain Regions, below. The relationship of the SSW and other test findings of those with APD tests was studied over 40 years. This is discussed below and reflected in this manual.

The basis for the B-M initially came from an NIH grant when I was teaching at Tulane Medical School and working with an amazing neurologist, Arthur Epstein (whose specialty was the temporal lobe). The grant was completed 2 years later at Menorah Medical Center, in Kansas City, MO. The research

continued there for 7 more years, mainly through the efforts of Bernard Abrams, Chair of Neurology and Neurologist Gary Pack. This continued at the University at Buffalo, for more than 25 years with primarily with Larry Jacobs, head of Neurology at Buffalo General Hospital and Anthony Avelanosa, head of Neurosurgery at Roswell Park Cancer Institute. Many other Neurologists and Neuroanatomists in Buffalo and Kansas City have also contributed to the anatomical-physiological interpretations of the SSW test and the subsequent B-M procedures.

The medical doctors were asked to draw the lesions on 12 photographs of 1cm vertical brain slices, to show its depth. For the NIH grant it was necessary to discuss the medical problems and the audiological findings in conference with the medical doctors. In the early days we thought we were testing the temporal lobe, but early on in the grant, Dr. Epstein reported that a patient's tumor involved the anterior temporal lobe. I protested that the SSW was pretty mild so I did not see how it could involve the temporal lobe. At that point he stopped me and said, "The SSW is not a 'temporal lobe test', it is an auditory reception test". That is, the very severe cases involved Heschl's gyrus. That opened up new possibilities for our central testing. The research continued for a number of years with Dr. Pack and Dr. Jacobs. The Neurologist and I would review those cases. Typically, the SSW results were consistent with the medical findings. On occasion, the SSW did not agree with the neurologist's findings. In such cases I sent them to Dr. Epstein at Tulane and, as I remember, his assessments almost always agreed with the SSW. The test did an amazing job, so one day Dr. Jacobs (mistakenly) said that I was the smartest person he ever knew. I just said what the SSW told me to say. For one interesting case I said that the data showed that the disorder involved the corpus callosum, but the X-rays did not support that. I assumed that I was wrong, but Larry had his colleague do a microscopic analysis of some sort. Sure enough, the SSW came through again.

**About the Buffalo Model Categories**

When CAPD came on the scene, in the middle 1960's and the SSW was used, the same types of signs showed up and the patterns were consistent for patients with brain lesions. One big difference was that many patients with brain/brainstem lesions had more extreme scores than those with APD. Long before the close association between short-term memory and speech-in-noise were known, the B-M put these two problems together in the TFM category (Katz and Smith, 1991, Brannstrom, et al., 2012, Yathiraj and Maggu, 2014).

One of the strongest signs for localizing brain lesions was Order Effect (discussed later). Order Effect Low/High (significantly more errors on the last 2 words of the items than the first 2 words) was associated with damage to the region of the auditory cortex. Order Effect High/Low was found in anterior temporal and frontal lobe cases. Initially, we did not know, or wonder, why. After working with CAP cases, we realized that poor DEC in the posterior temporal cases and poor memory in the anterior temporal cases helped to explain what the Order Effects were all about and why.

Paula Smith, Barb Kurpita and Susan Brandner, contributed 200 CAPD cases that were then Factor Analyzed to see which signs corresponded with each category. Each of the audiologists gathered their data in different clinical settings and in different locations which likely added to the validity of the

results. Each of these audiologists had excellent knowledge of the test, and then used the pre-cursor of, the SSW-Plus computer program to score the test. Table 2-2 shows the signs and the behavioral characteristics associated with each category.

The 5 basic scores are Total NOE, RNC, RC, LC and LNC. A student (in the very first SSW study) noted a strange response - the words were repeated correctly, but not in the correct order. I assumed it was "response biases" which is what psychologists called idiosyncratic responses. Pretty soon, we saw more and more of these peculiarities and realized that they were not idiosyncratic. Later on, when we tuned-in more we saw such things as delayed responses and perseverations. These were referred to as 'Qualifiers' because it related to the quality of the response.

| # | Category | Abbrevi-ation | Description | SSW Measures |
|---|---|---|---|---|
| A | Decoding | DEC | Inability to quickly and accurately processing speech | RC, LNC, X, (XX), EE H/L, OE L/H, P, QR, [SM-2, IW, BTB] |
| B | Tolerance-Fading Memory | TFM | Speech-in-noise, short term auditory memory & attention, anxiety | LC, EE L/H, OE H/L, Q, SM, Y, AYR, TTW |
| C | Integration | INT | Getting parts of brain to communicate, especially R & L hemispheres | Type-A, SIR and 2 supportive signs (XX)/IX, *2B3* |
| D | Organization | ORG | Keeping things in order, reversals | Rev |
| E | Various (CAP) | Var | APD severity regardless of category | Total NOE, RNC |

Abbreviations spelled out and shown in the order of significant findings. 2B3 (all 3 tests) shown below SSW signs.

| | | |
|---|---|---|
| **1. Total NOE**, Total Number of Errors | **10. XX**, Extreme Delay | **19. Q**, Quick |
| **2. RC**, Right Competing | **11. SM**, Smush | **20. TTW**, Tongue Twister |
| **3. LNC**, Left Non-Competing | **12. OE H/L**, Order Effect High/Low | **21. OE L/H**, Order Effect L/H |
| **4. LC**, Left Competing | **13. Type-A** | **22. EE H/L**, Ear Effect High/Low |
| **5. X**, Delay | **14. SIR**, Standard Integration Ratio | **23. QR**, Quiet Rehearsal |
| **6. P**, Perseveration | **15. AYR**, Are you ready | **24. IW**, Intrusive Word |
| **7. Rev,** Reversal | **16. Y**, Yes | |
| **8. RNC**, Right Non-Competing | **17. SM-2**, Smush-2 | *All 3 Tests Combined:* |
| **9. EE L/H**, Ear Effect Low/High | **18. BTB**, Back-to-Back | **2B3**, 2-By-3 |

*Table 2-2. Shows the Buffalo Model categories and the SSW indicators for each. While no sign is perfectly associated with a category, 2 of the signs are too mixed to associate with just one category. Extreme delays (XX) are associated with INT, but in some cases, when the person is working very hard to figure out the item there is a very long delay. The latter is a DEC characteristic. Three measures in brackets are clearly strong measures but have not been fully vetted (as discussed elsewhere). But, Sm-2 is especially important.*

**Associated Brain Regions**

The diagnostic findings on the SSW test, are associated with each of the 4 lobes of the brain. For purposes of APD assessment, it is also helpful to think about the regions associated with the B-M categories.

**Decoding (DEC):** Decoding speech is processed primary in the auditory reception areas (41 and 42 of Brodmann) and adjacent auditory cortex (area 21). These regions are in the posterior superior region of the temporal lobe. It is shown in Figure 2-1 as the light purple area, labeled 'DEC'. When this is damaged in either hemisphere (not a functional disorder such as APD) there is a moderate or severe peak of errors on the SSW for the competing condition in the opposite ear. When, it is in the dominant hemisphere there are usually errors in the ipsilateral competing condition as well (and often some noncompeting errors). Because this is where auditory information enters the cortex, and then proceeds to the secondary auditory region of the auditory cortex, it is not surprising that this showed up as the Decoding region in patients with brain lesions. Luria (1966) noted that this is the phonemic region of the brain and where phonemic synthesis and analysis take place.

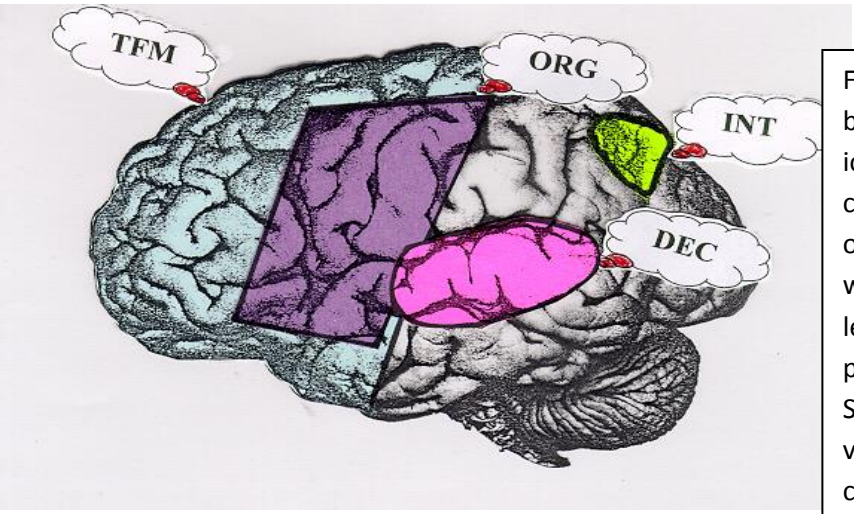


Figure 2-1. This figure of the brain shows the approximate regions, associated with the 4 B-M categories. It is based on 30 years of research, with patients who were diagnosed with brain lesions, which showed consistent patterns on the SSW test. Statistical analyses grouped the various signs into the specific categories.

**Tolerance-Fading Memory (TFM):** TFM covers the anterior portion of the brain including the frontal lobe and importantly the anterior temporal. It is shown in light blue in the figure. In fact, it involves just a little more than the tip of the temporal lobe (shown in the figure). Deep in the anterior temporal lobe, sits the famous hippocampus, which is the important memory center. It involves both short- and long-term memory. Right above it is the amygdala (part of the limbic system, which is closely connected to the hippocampus) this has particular significance for us, as it is associated with speech-in-noise (and unpleasant/frightening memories). The Buffalo Model linked, speech-in-noise and short-term memory, long before it was known by scientists. Anxiety was also associated with the TFM region long ago. The prefrontal cortex involves some short-term and working memory functions, in the TFM region.

**Integration (INT):** This category, primarily involves neural connections between the two hemispheres, for combining auditory and visual information. Specifically, this includes the corpus callosum (CC) and a small pathway, the posterior portion of the anterior commissure. In addition, an important cortical region is the angular gyrus of the parietal lobe, which is the site or auditory-visual integration.

From our research with patients who had corpus callosum lesions, we found a somewhat different pattern on the SSW and Competing Environmental Sounds (CES) tests, depending on where the damage was located. We looked at anterior, middle and posterior CC lesions. Those with the posterior lesions had large peaks of errors for the LC condition on the SSW and a large percentage of errors on the CES test in the right ear. That made sense, as the posterior region lies between the left auditory language region and the right visual parietal region. In the posterior region this pattern on the SSW and CES tests was noted across age. Involvement of the anterior portion of the CC showed the same crossed pattern on the SSW and CES tests, except that in children, up to the teens, tended to have normal or relatively normal results. However, by the 30's, patients with lesions in this region had rather similar crossed patterns as seen in the posterior CC group. In their 60s and 70s patients with anterior CC lesions were just like the posterior group. We did notice age effects with anterior commissure lesions, but they appeared to have the severe scores similar to the posterior group. However, the middle CC group cases were quite different than the other cases. What was clear is that both SSW and the CES peaked on the left side. There was no crossed pattern (Katz, Avelenosa and Aguilar-Marculis, 1980).

**Organization (ORG):** Anatomically, this category overlaps TFM and somewhat with DEC. At first, I did not consider it a separate category, thinking it a general APD sign. When we considered the specific loci of these lesions (primarily the motor cortex, and the inclusion of the pre-motor area (for motor planning) it made more sense, as a separate category (Katz and Pack, 1975). It is not clear how much the sensory strip functions might contribute to reversals. We found the most reversals toward the top of the Reversal Strip and the fewest at the bottom of the strip in the anterior temporal lobe. Both Luria (1966) and Efron (1965) independently located auditory sequencing lesions overlapping different parts of our reversal region. Interestingly Efron located the visual sequencing area primarily in the posterior-superior region of the temporo-occipital lobe. Sometimes we have seen a few cases, with auditory sequencing problems who had lesions in this area as well. But we did not test their visual sequencing.

The SSW test is surely the most studied central auditory test. A book by Arnst and Katz (1982) gives a glimpse of the depth and breadth of the research. It is the oldest central test in continuous use, and is widely used here, and in many counties around the world. The SSW is brief and provides over 20 signs that reveal information about all 4 B-M categories. It can be used for CAPD evaluations for those seen for site-of-lesion testing, hearing impaired, intellectually challenged, those on the Autism spectrum etc. The important question is AYR?

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