SSW Reports

Conceptualizing Integration: Assessment and Management

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Introduction

I would like to start off by presenting various definitions of Integration (INT) that have been used by others, and then share my definition. The following is what Jack Katz wrote relative to INT (Personal communication, 2007). "Auditory Processing Disorders are complex, with the Integration (INT) category being the most complex category (and having 8 sub-categories). Basically INT represents difficulty in connecting central functions, presumably between the two hemispheres. Forty years ago, I tested two patients with severe dyslexia who had highly asymmetrical SSW results (we called the pattern Type-A). The right hander had her competing-error peak in the left ear and the left hander had hers in the right ear. Type-A is the only SSW sign that seems to reflect laterality of language dominance. The Type-A could be explained if the R-handed case had a slow left channel and the reverse for the L-hander (this suggested corpus callosum {cc} involvement). Both cases had abnormal EEGs involving the posterior temporal/tempro-occipital region (?implicating the A-V integration center - angular gyrus). Twenty-five years ago I tested a group of patients with cc tumors. One-third had Type-A patterns; in addition, those with posterior lesions had the most severe SSW findings, the anterior cases had the best and both of these had different patterns of SSW/CES errors than the mid-cc cases. Finally, in 1992 we studied unselected APD kids and found that those classified (by the previous INT classification system) as INT+DEC (more posterior) had the most severe academic performance of the six groups and those with INT+TFM (more anterior) had the next most severe. I believe that INT cases generally have the most severe academic problems and are the most difficult to remediate. Many are labeled dyslexic. Over the years I have tried to expand the INT criteria beyond Type-A, but could never find sufficient evidence that the additional cases were truly INT cases. Perhaps Larry can accomplish this."

Background

Bellis describes Integration as the efficient interhemispheric transfer and interaction of information across both hemispheres (Bellis, 2003). However, integration involves not only inter-hemispheric transfer but interaction of information within the same hemisphere as well. For example, Autism is the most extreme example of an integration (inter-connectivity) disorder (Herbert, 2005; Schultz and Klin, 2002). Anatomical studies of those identified with autism reveal larger brain volumes of 5-10% relative to normal peers. However, whole brain enlargement likely is a marker for a disturbance in the fine structure of the brain that actually causes autistic symptoms. That is, increased brain size comes at the expense of interconnectivity involving white matter between specialized neural systems, giving rise to a more fragmented processing structure (both intra- and inter-hemispherically).

Auditory-Linguistic Integration (AL-I)

Because my focus is on the ability to process spoken language, I use the term "Auditory-Linguistic Integration", which is defined as "the ability to integrate information across different auditory/language processing regions". Examples include:

- the ability to process and integrate facial features and socio-linguistic context (important in pragmatics, such as being able to tell the difference between happy/sad)
- the ability to integrate suprasegmental information (typically processed in the right hemisphere) and its linguistic counterparts (typically processed in the left hemisphere)

For approximately 95% of the population, non-linguistic information such as facial features and suprasegmental information are processed within the right hemisphere, while linguistic features such as phonemes and lexicon are processed by approximately 95% of individuals within the left hemisphere (Musiek and Lam, 1994).

The following discussion will focus on two aspects of AL-I often examined by audiologists: binaural separation and the integration of nonlinguistic and linguistic information. Both of these assess the integrity of effective corpus callosum pathways. The corpus callosum is one of the last anatomical features to physiologically mature, with full maturation typically achieved by 13-14 years of age. Consequently, any task that involves inter-hemispheric transfer is likely to be influenced by a maturational effect.

Binaural Separation:
Binaural separation refers to listening situations whereby a listener is exposed to acoustic stimuli originating from various locations in space. Research has shown that spatial cues are the most effective in enabling individuals to selectively attend to "target" stimuli, while ignoring competing "irrelevant" stimuli originating from other locations (Medwetsky, 1994).

Selective attention involving binaural separation is typically assessed under headphones via the presentation of dichotic stimuli, whereby the listener is directed to attend and recall stimuli presented to one of the ears, while ignoring "irrelevant", competing stimuli originating from the other ear. In dichotic tasks, stimuli are best transmitted to the cortices via the contralateral pathways. The ear to which the listener is told to recall stimuli, in turn, guides "automatic attentional direction". In the case of selective attention tasks involving dichotically presented stimuli, attentional direction (a) increases the likelihood of neural firing in the auditory receptive areas in the hemisphere contralateral to the designated ear, while (b) either ignoring stimuli or engaging inhibitory processes in the opposite hemisphere (Nager et al., 2003; Petkov et al., 2004). Thus, if an individual is told to recall stimuli presented to the right ear, he or she will automatically (subconsciously) direct attention to the left hemisphere, and, vice versa if told to recall stimuli from the left ear. Because the pathway from the right ear to the left processing region is direct, it does not entail corpus callosum transfer. However, information presented to the left ear must first access the right hemisphere for initial processing, then cross the corpus callosum if it is to access the language processing region in the left hemisphere. For younger individuals, this typically results in a "right ear" dominant effect, whereby, the individual typically recalls more information from the right versus left ear. This effect typically diminishes with physiological maturation. However, in individuals with auditory-linguistic integration deficits, the right-left ear difference is significantly greater than their "normal" peers and still may be present even as an adult.

Linguistic and Non-Linguistic Integration:
Another way of assessing AL-I is to examine an individual's ability to integrate non-linguistic and linguistic information. Examples include assessing: (1) an individual's ability to process, and, in turn, verbally label various tonal patterns; and (2) an individual's ability to utilize suprasegmental aspects of speech to enhance linguistic processing. In both instances, the non-linguistic information processed in the right hemisphere must somehow be integrated (via the corpus callosum) with the linguistic information processed in the left hemisphere. This is characterized in everyday life by:

- distinguishing declaratives from yes/no sentences, even though wording is the same (e.g., That's an airplane! versus That's an airplane?)
- distinguishing nouns from verbs for trochees of the same spelling, based on where the stress is placed- stress on first syllable is a noun, while stress on the second syllable indicates a verb; for example, per'-mit (license) versus per-mit' (to allow)
- determining the meaning in ambiguous sentences based on the particular stress, pausing, etc. (e.g., "The farmer **out** standing in the field" versus "The farmer out-**standing** in the field").

Impact of AL-I Deficits

AI-L deficits can be manifested in a number of ways:

- in competing listening situations, such as in a group setting with many talkers, an individual with an AI-L deficit will experience greater difficulty processing information originating from the left side
- an individual may experience greater difficulty utilizing prosodic information, such as: (1) difficulty perceiving differences in ambiguous sentences dependent on correct perception of suprasegmental cues, (2) difficulty with figurative language; and (3) in the most extreme case, such as someone with Autism, individuals may exhibit flat voicing patterns
- the ease/speed in which information is integrated across processing regions; in turn, this can impact on reading/writing speed, reading comprehension, organization of written material, and problem solving tasks- depending on the abstractness of the concepts and language used and the amount of time allotted to the task

Assessment of AL-I

Assessment of AL-I can be broadly characterized within two domains: (a) binaural separation and (b) ability to integrate suprasegmental/linguistic information.

1. **Binaural Separation**

There are a number of binaural separation (dichotic) tests that are commercially available. These include tests that assess either selective attention (attend to and recall stimuli presented from one ear, while ignoring stimuli from the opposite ear) or divided attention (attend to and recall stimuli from both ears). Stimuli that have been typically used include digits, single syllable words, spondees, and sentences. Stimulus length and novelty enhances the sensitivity of a test. For example, if the clinician were to assess selective/divided attention, dichotic tasks involving digits (short duration, high familiarity) are the least likely to reveal a deficit. Tasks that utilize spondees (compound words of equal stress- such as the Staggered Spondaic Word (SSW) test, with somewhat longer duration and less familiarity than digits) would more likely ascertaining an AL-I deficit than digits, while tests utilizing sentence stimuli would be even more sensitive (due to the greater amount of material that must be transferred across the corpus callosum). In this article, I focus on only those tests I utilize in my own clinic.

<u>SSW Test:</u>

The hallmark of an AL-I deficit is a significant Left-Competing (LC) condition (unless the language processing region is located in the right hemisphere- which really does put a crimp in analyzing the results; in this case, I rely on the overall test battery results). Experienced clinicians may be asking, "Is a significant LC not finding a fading memory sign?" The literature concerning other dichotic tasks attributes a significant left ear finding to inefficient corpus callosum transfer, thus, an integration sign. Second, in an analysis of data from my clinic, of 99 individuals with a significant LC condition, only 8.1% revealed a significant hi/low order effect, while 10.1% revealed a low/hi ear effect. Thus, 81.8% of the patients with a significant LC condition did not reveal one of these fading-memory signs, nor did they reveal fading-memory signs on other tests (such as more errors on the earlier portions of sentence recall, digit span, or the Phonemic Synthesis Test).

It should be noted that the presence of a significant finding in the LC condition does not necessarily imply an AL-I deficit. As I discussed in SSW Reports (2005), if both RC and LC conditions are significant, it is possible that the significant LC finding may be due solely to a lexical (i.e., word) decoding speed deficit. That is, regardless of which ear the spondees are presented, ultimately they must be processed in the language processing region (as mentioned earlier, for 95% of individuals this is located in the left hemisphere). If a lexical decoding speed deficit is present, it will impact the processing of spondees from either ear. To be able to state that an AL-I deficit is also present, there must be significantly more errors in the LC versus RC condition, over and above the RC-LC 'normal limits" difference in their normal peers (i.e., the difference that can be attributed to corpus callosum immaturity at a particular age). For example, the normative RC-LC difference (i.e., boundaries of normal limits for each condition) for someone seven years of age is 5 (RC = 7; LC =12). In ascertaining if a significant LC condition is due to an AL-I deficit, one must add the # of errors in the RC condition and the normative RC-LC difference. If the LC # of errors is greater than this total, then an AL-I deficit can be said to also be present; if less, one can not come to this conclusion. The only caveat to this assumption is if a significant RC score is due to a deficit specific to the contralateral pathway prior to the language processing region. In this case, one would have to look to the other test battery findings to ascertain the true nature of the LC deficit. Using my criteria applied to 140 individuals (10 per age group for ages 6-11 as well as adults, both males and females), 76/140 (54.3%) individuals exhibited an AL-I deficit. Interestingly, the percentage was identical for both genders suggesting gender does not influence the presence of an integration deficit, measured by the SSW test.

Please note the presence of a Type-A does not negate the presence of a generalized AL-I integration deficit also being present. When a Type A is present, I also examine the number of LC errors in column C and then multiply by 2. If this results in a greater NOE than the normal limit, I assume that a generalized AL-I is also present.

Competing Sentences Test (CST)

The CST consists of 6-8 words presented dichotically. In this test, the target sentence is presented at 35dB sensation level (SL) re the SRT in that ear, while the competing sentence is presented at 50dB SL re the other ear's SRT. Scoring can be done in either of two ways:

- *linguistic meaning*; is the sentence recalled identical to or essentially similar in meaning to that of the sentence presented?, thus, an all or none score is obtained for each sentence (Willeford and Burleigh, 1994)
- the use of a quadrant scoring method (Bellis, 2003); if the words are correctly recalled within a quadrant, the listener receives a score of 2.5 points per quadrant up to a maximum of 10 points per sentence

In modifying the scoring procedure for this test, Bellis's rationale was that the original scoring method was too subjective (i.e., one tester might score a sentence correct based on the meaning, while another examiner might give no credit for the same sentence). Bellis has derived norms/ lower limits of two standard deviations for those 7 years or older. I still use Willeford's scoring method for 5-6 year olds with the goal of determining how the child is doing in their better ear. That is, even in 5-6 year olds the lower limit of the normal range in the better ear is quite high-above 88% with standard deviations that are quite small; however, the standard deviations for this age group in the poorer ear is so large that it negates the ability to examine performance in the poorer ear. For individuals 7+ years of age, an AL-I deficit is deemed to be present when (a) there is a significant finding for only the left ear; or (b) there are significant findings in both ears, but significantly poorer results in the left ear relative to the norms.

2. Integration of suprasegmental cues and linguistic information

One popular central auditory processing test that assesses this skill is the Pitch Pattern Sequence

Test (PPST; Pinheiro, 1983). Each test item consists of two high and one low frequency tones, or vice-versa, presented in any sequence. Subjects respond by humming, tapping on designated objects, or verbally (e.g., saying high-high-low); note that tapping requires verbal mediation, thus, it taps the same skills as verbal labeling. There are two versions of this test, one for 9+ year olds and one for 6-8 year olds. The 9+ version presents the tonal stimuli with shorter inter-stimulus intervals and smaller frequency separations than the 6-8 year old version. Perception of the tonal pattern is reliant on adequate right hemisphere function, and is assessed by asking the listener to hum back the pattern (i.e., a non-linguistic response). In order to verbally label the tonal pattern, the perceived tonal pattern must somehow be transferred to the left hemisphere, whereby verbal labels can be applied. A discrepancy in performance between the non-verbal and verbal test findings is indicative of auditory-linguistic integration difficulty. I have recently begun to administer the younger version of this test to individuals 9+ years who revealed a non-verbal/verbal test score discrepancy. In most patients, the verbal task score improved greatly (the exception being those with severe integration difficulties as determined by performance on the other integration tests). This suggests that one of the major impacts of an integration deficit is to impede inter-hemispheric transfer speed of information.

A second task examining the integration of suprasegmental cues and linguistic information is one I have developed. The task involves assessing digit span serial recall via: (1) the traditional format, whereby digits are presented one/second in a monotone voice and the listener is asked to wait until all of the digits have been presented and then recall the numbers in the same order; (2) a modified version, whereby I utilize a rhythmic format, including a strategically placed two second pause, with the goal of making it easier to chunk the item into two units (e.g., /4-8-2/ /6-1-4/). My research on 5-11 year olds has shown that almost all non-LD individuals find the rhythmic task easier and, on average, recall one or two more digits versus the traditional, monotone format; adults anecdotally indicate it is easier, though I have not done any research to determine if, in fact, they recall any more digits. In examining the pattern among children suspected of CAPD, approximately 80% of the patients obtained the same performance on both tasks, 10% did better with the rhythmic information, 10% did worse. For those who did worse, they either consisted of individuals with a diagnosis of Autism or Asperger's Syndrome, or, displayed pervasive integration difficulties (significant difficulty across all of the integration tasks I use in my clinic). The implication of these findings is that the vast majority of LD individuals have difficulty using the suprasegmental cues to enhance performance.

Management of Auditory-Linguistic Integration Deficits

A promising approach for addressing inter-hemispheric differences in dichotic listening (yet not commercially available at the present time) is Dichotic Interaural Intensity Difference (DIID) training (Weighing and Musiek, 2007). In DIID training, listeners are presented with competing speech stimuli (be it competing numbers, words, sentences, or even words/sentences presented to the target ear and a story in the competing ear) that are matched for onset and best presented dichotically under headphones; the stimuli do not have to be identical in nature. The goal is to reduce the amount that the weaker contralateral connections (i.e., left ear to right- hemisphere to left-hemisphere language processing region) is suppressed by the stronger direct contralateral connections (right ear to left-hemisphere language processing regions), and strengthen the weaker connections under progressively more challenging listening conditions.

The first step entails finding the comfortable listening level in the left ear. To reduce the amount of suppression, the presentation level in the better (right) ear is decreased until left ear performance exceeds right ear performance (i.e., the crossover point). To then strengthen the weaker connections, the presentation level in the right ear is gradually increased over time (the competing level is increased when a performance of 80% in the poorer ear is achieved at a particular level). Training is deemed successful, when a patient achieves similar performance in both ears. A typical training schedule involves the patient engaging in DIID training in the clinic for 15-30 minutes, 3-4 times a week. Please note there is a caveat to this training. The listener must be able to obtain near normal level performance at the crossover point (i.e., at some point when the irrelevant, competing ear level is decreased, the listener must be able to achieve normal performance).

A second approach to addressing auditory-linguistic integration deficits entails improving the listener's ability to utilize and integrate the suprasegmental information with the linguistic information being presented. This entails ascertaining the specific difficulties being encountered and then implementing a program to address these deficits. The major problem is that there is no available test that assesses in a hierarchal fashion an individual's ability to process and utilize suprasegmental information, nor, is there any methodic approach to addressing these difficulties. Thus, the treating clinician must engage in an ad-hoc fashion to address these deficits, though one based on an understanding of hierarchal levels of complexity. The following is a recommendation that I include in my report when an AL-I deficit si deemed to be present:

" [Name's] ability to integrate and use suprasegmental information for understanding the intent of spoken language at different levels should be assessed, such as by [Name's] ability to: (1) differentiate Y/N questions from declarative statements on the basis of intonation contours, (2) perceive syllabic stress for differentiating meaning (such as stress patterns within words- per' MIT versus per MIT'), and (3) perceive and use stress in sentences with ambiguous meaning. If [Name] reveals difficulty, then tasks that work on the meaningfulness of suprasegmental patterns in linguistic context will be of benefit. These measures will also facilitate improved prosodic perception (as well as appropriate voicing patterns if this is also an area of concern)."

Summary

It is clear from the findings I have presented that integration difficulties are very prevalent among LD children. It is incumbent upon us to derive a comprehensive test battery that allows us to accurately ascertain the presence of this deficit and its extent, and, in turn, develop management approaches that will best ameliorate its impact in daily life activities.

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