

Spoken Language Processing: A Convergent Approach to Conceptualizing CAPD

Larry Medwetsky, Ph.D.
VP, Clinical Services
Rochester Hearing and Speech Center
lmedwetsky@rhsc.org (585-271-0680 x 245)

Overview of Presentation

- Contrast presenters' approach from other approaches
- Perception/processing mechanisms involved in spoken language processing
- Deficits subsequent to breakdowns in specific processes
- Using the SL-P model to develop a test battery that can lead to an individualized management approach to addressing deficit areas

Central Auditory Processing: What is it?

- much debate in audiology/speech & language fields as to whether there is such a thing as central auditory processing, and, if so, what is it?
- some have advocated examining only auditory mechanisms
 - may not always shed light into the difficulties an individual may encounter in everyday life
- (ASHA and AAA guidelines delineate discrete processes, such as localization, temporal resolution)
 - pure auditory processing mechanisms only occur up to maximum of 250 msec post-stimulus offset
- some have developed approaches focusing primarily on the underlying neurophysiologic mechanisms
 - however, this does not examine how the brain

Overview of the Spoken Language Processing (SL-P) Approach

- The underlying processes, breakdowns and treatment strategies are addressed in the context of what the listener faces in everyday listening situations
- The focus is on the individual's ability to process spoken language, thus, serving to bridge various auditory/ language processing models.
- The individuals that are assessed have normal hearing and cognitive development, yet, have difficulty processing and retaining the spoken signal accurately and easily (note that this model can also help to understand processing issues of hearing/cognitively impaired populations)

Presenters' Approach- continued

The processing of spoken language involve dynamic, interactive processes that include:

- *underlying auditory processes*
- *cognition*
- *language*

Presenters' Approach- continued

I refer to these processes as Spoken Language Processing.

By combining a knowledge of speech language processing mechanisms plus the strategic deployment of various tests, we can :

- understand how breakdowns in specific processes are manifested
- design a test battery that examines these processes, and, in turn, determine the deficits present and their severity
- design a management approach that addresses individual needs

Difference Between Hearing and Spoken Language Processing

Hearing

- Essentially is the awareness of presence of sound
- Normal hearing means one can hear sounds at very soft levels
- If one has normal hearing, an individual will hear all the speech sounds of his/her language at average speaking levels at a distance of six feet away (in quiet)
- Having normal hearing does not guarantee a person will be able to comprehend, retain and maintain the information presented
- For example, one can hear someone speak in a different language yet not understand what has been said. To do so one must know the linguistic code of that language

Specific Processes Engaged in Spoken Language Processing

Spoken language processing consists of many processes:

Transduction

The incoming acoustic stimuli undergo many conversions from sound waves to:

- mechanical vibrations (eardrum and bones)
- hydroelectric transmissions (fluid movements in inner ear)
- neuroelectric discharges (involving acoustic nerve and various brain substrates)
- neuronal regions extract different features (intensity, frequency, temporal, intonation/amplitude contours, phase- comparison between both ears)

Decoding

Decoding

Neuroelectrical patterns are relayed via various pathways to the:

- language centers in the brain (for @ 95% of population, this is in left hemisphere)
- rhythmic areas of the brain (for approximately 95% of population, this is in the right hemisphere)

The rapid, short duration information is processed/ analyzed by the left hemisphere (neurons specialized for rapid temporal sampling).

The slower, longer duration information is analyzed by the right hemisphere (neurons unable to sample at rapid rate but able to monitor slower temporal changes).

Transduction → Decoding

Decoding

Three types of decoding occur:

- **words**
 - often called lexical decoding
- **phonemes**
 - individual sounds that make up the words of a language

In discourse, phonemes and words generally do not exist in physical reality but within an individual's brain/consciousness

- **Suprasegmental patterns**
 - sentence stress, rhythms/inflections of speech, pauses (i.e., where occurs in discourse)

Decoding- continued

The speed and accuracy which these incoming patterns are identified depends on:

- i. clarity of input signal (speech-to-noise ratio; level above auditory thresholds; clear pronunciation)
- ii. accurate transmission and conversion of stimuli to neuroelectric patterns. This is affected by:
 - hearing ability
 - neural synchrony (leading to accurate temporal, frequency, intensity, and phase resolution)
 - organization of lexicon in long-term memory (phonologically, graphemically, semantic concepts, semantic relations, grammatical category, physical attributes)

Decoding Speed- continued

- iii. activation threshold of the stored percept: commonly occurring percepts (numbers, food, etc.) and those with high emotional content (individual's name) have lower thresholds (easier to activate) than percepts whose frequency of occurrence is minimal or of low emotional content
- iv. amount of attention allocated to target stimulus; this lowers the activation thresholds making it easier to stimulate the neurons
- v. (a) linguistic/social context preceding/following stimulus; (b) world knowledge; and (c) subject's expectations (these lower the activation thresholds of associated neurons)

Short-Term/Working Memory

Once the language pattern has been activated from long-term memory (neurons in active firing state), it resides momentarily in **short-term memory** (the only time the information is accessible to a person).

In the literature, STM generally refers to passive processing, while working memory refers to active processing (engagement of various processes such as entailed in problem solving, math calculations, etc.).

Neuronal regions fire (information can reside) for @ 1-2 seconds. The neural firing pattern (residing time in working-memory) can be extended through the processes of various forms of attention (rehearsal, reauditorization, visual imagery).

Transduction → Decoding → STM

Short-Term/Working Memory Span

There is a limit to how many neuronal regions can remain active at any one point in time, dependent on how quickly can shift attention from one region to other to maintain neuronal firing. Thus, STM span is primarily about time (though also relies on good sequencing ability).

Research shows this to be approximately 4 regions, though through chunking, one can recall more units. For adults (@ 7 for numbers, 5-6 for familiar words, and 3-4 for unfamiliar words).

This is called an individual's **short-term/working memory span**.

STM Span- cont'd

STM span is affected by:

- **Attentional allocation**
 - Rote-memory span tasks (i.e., tasks with minimal context such as digit/unrelated word recall) include strategies such as internally repeating on the fly and periodically going back to repeat earlier items, imagery, chunking, mnemonics); usually involves serial recall of exact information
 - Sentence/Discourse recall include active processing strategies such as visualizing, analyzing content/relationships, summarizing information internally; generally involves memory of semantic content (also syntax for sentence recall)
- Articulatory difficulty of items (affects rehearsal)
- Familiarity of input (affecting how easily the prototype can be activated/retrieved from LTM)
- Organization of information in long-term memory, which affects the speed of processing/retrieval of information

Integration

The segmental information processed in the left hemisphere is integrated with prosodic information (as well as with body language/facial cues) in the right hemisphere on the fly (how/where in brain I don't know).

The rhythm/amplitude & intonation contours/pauses, allow for some of the following:

- ◆ coincide with grammatical clauses
- ◆ help to chunk information
- ◆ provides stress to key words/syllables
- ◆ assists in differentiating yes/no clauses
- ◆ help determine mood of talker (angry, happy, sarcastic, etc.)

Transduction → Decoding → STM → Integration

Sequencing

Includes various neuronal regions such as:

- ◆ Lateral Pre-Frontal Cortex (formulating and holding representations of events in working memory)
- ◆ Sub cortical regions, such as the Basal Ganglia
- ◆ Posterior portion of Broca's area (sub-vocalizations to maintain information in phonological store of working memory) helping to preserve the order in which information has been presented.

There are different aspects to sequencing, including:

- ◆ formulating and carrying out sequences of events and actions
- ◆ processing and output of speech sounds/syllables

Transduction → Decoding → STM → Integration → Sequencing

Attention

Attentional Processes allow the listener to focus on a limited amount of information at any one point in time, and, in turn, maximizes the extent to which the target information will be processed and stored.

Attentional processes play role in initial activation of prototypes from long-term memory. Recent research by Hillyard and colleagues using Evoked Response Potentials indicate that attention can enhance electrophysiologic responses as early as 20-50 milliseconds (likely involved in filtering process).

Neurophysiologically, the process of attention destabilizes neurons (i.e., lower the activation thresholds) of the "target" receptors and can also involve inhibition of nearby "competing" neurons.

Attention- cont'd

Attentional direction allow neurons to be in a "primed" state, allowing for:

- lower activation thresholds
- increased ease to which corresponding/ associated neurons can be stimulated

In addition, attention maintains neuronal firing of "target" percepts so they can continue to "fire" and be retained in short-term memory (STM). In general, signals that are not attended to fade rapidly from STM (example, think of misplacement of keys).

Attention- continued

Neurophysiologic postulate to selective attention:

- ◆ listener makes conscious decision to who/what to listen to (corresponds to certain region in auditory space, and, in turn, corresponding neuronal region in Auditory Cortex). In presence of competing stimuli, this primarily involves contralateral neuronal region.
- ◆ pre-frontal cortex directs stimulation to that region and to either ignore or inhibit firing in other regions
- ◆ the further apart the talkers, the easier it is to allocate attention effectively, and the more successful the individual will be in listening to the target talker

Attention- continued

There are many kinds of attention:

- preparatory attention choosing what to attend to
- selective attention attending to target & blocking out competing stimuli
- divided attention attending to two or more targets
- vigilance attending to an intermittent target
- sustained attention maintaining attention to a target over time

Long-Term Memory

Long-Term Memory refers to the neuronal representations of words, concepts, etc., that reside in a resting state (i.e., inaccessible to the client). It is analogous to the hard drive of the computer. As mentioned earlier, it becomes accessible to the client when the neuronal representations are activated into short-term memory.

Acoustic stimuli are stored or can be integrated with input from other modalities as percepts (schema) and stored in long-term memory. In general, the more organized/comprehended, the more readily accessible they are for processing/activation and retrieval.

Central Executive System

Central Executive System (CES) refers primarily to the Pre-Frontal Cortex (also includes Basal Ganglia, Anterior Cingulate Cortex, Striatum). The CES is often referred to as the "Internal gatekeeper" and believed:

- to be key to self-regulation, planning/organization and short-term/working memory
- accomplishes above by allocating attention to, inhibiting and integrating information across the various processing regions

Roles of CES:

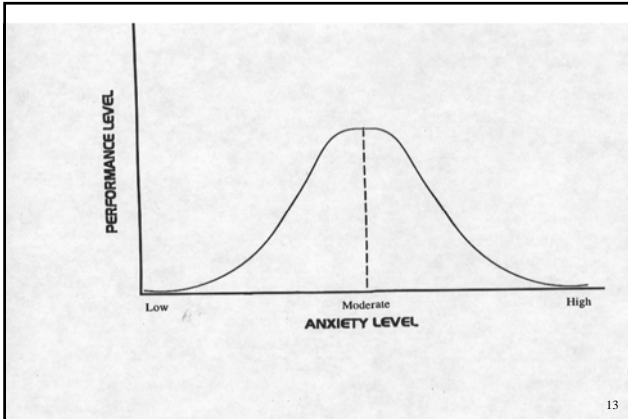
1. Attentional Allocation
2. Self-Directed Actions
3. Organization of behaviors across time
4. Critical player in sequencing events over time

Central Executive System- cont'd

Performance varies with the degree of arousal level. It is believed that arousal level affects speech processing by interacting with the Central Executive System.

When arousal level is low or high, the arousal level system (via the Reticular Formation) can not regulate the central executor effectively. That is, performance is best at moderate arousal levels:

low ----- moderate ----- high
(fatigue) arousal level (anxiety)



Central Executive System- cont'd

Recent research has shown:

- some children with sleep disorders can resemble children with ADHD.
- individuals who are sleep deprived/stressed can momentarily display ADHD-like symptoms
- exercise can improve the focusing ability of children with ADHD by optimizing arousal level
- arousal level affects speech processing by interacting with the CES. That is, if the CES is under/over aroused, then it can not direct attention effectively
- in turn, this makes it harder to retain information in short-term memory and possibly even impact initial activation of prototypes from LTM). Thus, attentional deficits (e.g., ADHD) can impact on spoken language processing in specific ways

Central Executive System- cont'd

Central Executive System-att'n

Transduction → Decoding → STM → Integration
→ Sequencing

The Relationship of Capacity to Mental Load (Spoken Language Processing)

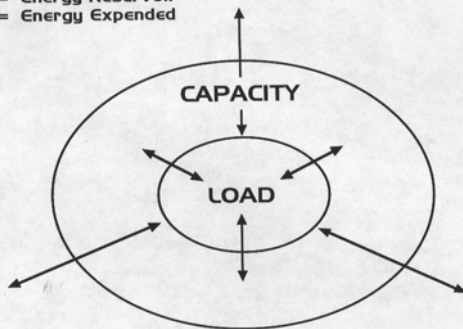
Capacity is determined by:

- ◆ Innate/developmental factors
- ◆ environmental influences (exposure, training, etc.)
- ◆ arousal level

Mental load is determined by:

- ◆ quality of stimuli processed (e.g., distortions present, sensation level, etc.)
- ◆ complexity of task (automaticity, # of simultaneous tasks)
- ◆ familiarity of stimuli
- ◆ amount of information (chunks)/time

Capacity = Energy Reservoir
Load = Energy Expended



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Summary Overview of Spoken Language Processing

- incoming auditory stimuli are converted to neuroelectric patterns that are compared to patterns stored in long-term memory (LTM)
- if there is a match and there is sufficient attention to the signal, then the LTM representation is activated, called short-term memory (conscious memory). This process, known as decoding, must be done quickly/accurately "on the fly"
- information can reside in short-term memory for a very short period of time (maximum of two seconds) unless attention is directed to the stimuli (i.e., the process whereby the pre-frontal cortex directs flow to neuronal areas of focus to keep firing)

Summary of Spoken Language Processing - continued

- linguistic (sound, word, meaning, grammar) representations are represented in the left hemisphere in most individuals
- at the same time the incoming linguistic information is processed in the left hemisphere, the suprasegmental patterns (syllabic information, rhythm, stress patterns, etc.) of speech (as well as body language/facial cues) are processed in the right hemisphere
- the suprasegmental patterns are integrated with the linguistic representations and must be done "on the fly"

Summary of Spoken Language Processing - continued

- ◆ the processed information must be maintained in the same order as presented
- ◆ individuals often must listen in the presence of competing noise; in order to attend to "target stimuli" in noise, the brain must filter as well as direct attention (i.e., excite the neurons for the stimuli of interest, while ignoring/inhibiting the neurons corresponding to the "competing stimuli")
- ◆ a separate process over time involves the establishment of individual sound families (phonemes), develop phonological awareness skills (ability to manipulate phonemes), and, learn/memorize their symbolic (alphabetic) representations

Spoken Language Processing Disorders (SL-PD)

Individuals may break down in any of the processing skills discussed earlier:
- commonly referred to in the field as a central auditory processing disorder (CAPD)

SL-PD may impact on an individual in many different ways, depending on the specific, underlying deficit processes:

- ◆ in more severe disorders, it can affect the development of speech/language skills
- ◆ listening, especially in noisy environments, when information is novel, or, if presented quickly

Spoken Language Processing Disorders (SL-PD)- cont'd

- ◆ ability to process information over sustained period of time (often misinterpreted as ADHD)
 - different underlying causes may show similar behaviors
- ◆ ability to comprehend and/or retain verbally presented information
- ◆ ability to follow directions/organization
- ◆ reading, spelling, writing
- ◆ ability to perceive social cues/context appropriately

Categorization of Possible Processing Breakdowns

Phonological Awareness Deficits (hierarchical representation below)

- Rhyming
- Syllable Blending/Segmentation
- Phoneme Isolation
- Phoneme Blending (phonemic synthesis)
- Phoneme Deletion
- Phoneme Segmentation
- Phoneme Manipulation

Sound-Symbol Associations (Phoneme- Alphabet)

- Deficiencies will affect reading, writing, spelling

Depending on task, difficulties may arise because of related issues (e.g., fading-memory, higher order sequencing, problem solving)

Lexical Decoding Speed Difficulty

Lexical (word) decoding speed difficulties are manifested by increased processing time/mental load and is associated with word retrieval difficulty and prolonged response time:

- especially when the stimuli are novel, consist of more complex grammatical construction, and, when presented quickly

Lexical decoding speed difficulties may be due to:

- disorganized neuronal connections/pathways
- poorly organized percepts (phonemic, semantic, syntactic, etc.)

Fading-Memory

Individuals with fading-memory exhibit a tendency to forget earlier presented items and to retain what was heard most recently.

- often have difficulty following/retaining conversation and instructions, especially if the information is novel and if competing stimuli are present
- also tend to exhibit reading comprehension problems (due to forgetting details)-with or without spelling difficulties, the latter possibly due to difficulties in retention of visual orthographic representations of words

Fading-memory is likely due to inability to allocate attentional resources effectively.

Deficiencies Affecting Short-Term Memory (STM) Span

Deficiencies in STM span limit the amount of information that can be held/retained at one time.

STM span is affected by:

- A. Deficiencies in rehearsal/active processing strategies
- B. Articulatory difficulty of items
- C. Stimulus familiarity
- D. Organization of information and efficiency of retrieval in long-term memory

Problems in A-B will likely result in forgetting of earlier items, while problems in C-D will likely result in later items being forgotten.

Deficiencies Affecting Short-Term Memory Span- cont'd

Deficiencies in STM span can vary with the stimuli presented. For example, at RHSC, the pattern noted for approximately 75% of the students seen is: significantly reduced STM span for digits and unrelated words (rote-memory) tasks and within age norms for sentence stimuli.

This pattern is likely due to the fact that most of the children seen at our center have good basic language skills but have some form of processing deficit. In the absence of context, rote-memory span tasks are reliant on good processing skills and strategies (latter, especially applying to digit span recall).

Other patterns are likely associated with other types of difficulties and include:

STM Span Patterns

- ◆ Good digit span and sentence recall but poor word recall- likely decoding speed difficulty
- ◆ Poor digit span but good word and sentence recall- likely poor use of strategies
- ◆ Good digit span and poor word/sentence recall- likely language deficit or pattern of an autistic individual
- ◆ Good digit and word recall but poor sentence recall- likely language disorder (I am not sure if I have ever seen this one in over 1,000 cases)

Auditory-Linguistic Integration Difficulty

These individuals tend to exhibit:

- prolonged delays on expressive tasks
- may exhibit difficulty in tasks requiring coordination of skills across different modalities
- possibly impact on problem solving (subsequent to difficulty comparing/analyzing content)
- may exhibit difficulty in using prosodic information in language processing
- dominant ear effect (almost always right ear)- due to direct contralateral pathway dominance in the presence of competing stimuli (direct route from right ear to left-language processing hemisphere)

Prosodic Deficit

These individuals will have significantly increased difficulty perceiving/using the suprasegmental information in speech. This may be manifested by:

- a flat voicing pattern, poor ability to replicate melodies
- increased difficulty with chunking
- decreased processing speed (unable to use prosodic information effectively to facilitate perception of grammatical clause junctures)
- difficulty in cases of semantically ambiguous sentences/words
- increased difficulty listening in noise

**Note at RHSC, prosodic deficits have been observed only in rare instances (pure prosodic deficit would be observed in children non-verbal LD).

Sequencing/Organization Difficulty

Sequencing and organizational difficulties might be manifested by difficulties with:

- following/carrying out directions or tasks
- organizing thoughts/actions
- spelling or writing reversals
- writing (no logical order)
- imitating sequence of behaviors

Difficulty likely involves the Central Executive System.

Deficiencies in Attention

A. Preparatory Attention

If one is unable to correctly determine the "target", then all subsequent processing will be erred.

B. Selective Attention

Selectively attending to a target may be difficult because:

- of an inability to perceptually separate different stimuli (deficits in brainstem/auditory cortices), thus, unable to allocate attention exclusively to the target while ignoring competing message
- mental load to attend to target and block out competing stimuli exceeds person's capacity for that task
- inability to allocate attentional resources effectively

Deficiencies in Attention- continued

C. Divided/Shared Attention

Because of mental load and/or any processing inefficiencies, the individual may not have adequate resources to attend/recall more than one stimulus (e.g., note taking).

D. Sustained Attention

Individuals may differ in the amount of sustained time to which they can attend to target stimuli.

Inability to sustain attention may be due to different underlying difficulties (decoding speed, fading-memory, sequencing, etc.) that may add significantly to the mental load over time. In addition, those with ADHD may not be able to stay on task.

Central Executor System (CES) Deficiencies

One well known defect of the CES is ADHD-H/I disorder (now called Behavioral Inhibition Disorder by some).

Possible CES deficits on speech processing include:

- Difficulty with sustained attention/vigilance
- Fading-Memory
- Decreased short-term/working memory span
- Selective attention difficulties (unable to block out competing noise/messages)
- Sequencing deficiencies
- Possible impact on initial decoding speed

ADHD and SL-PD

Presenters' Synopsis

If an individual is suspected of having ADHD, we would expect at least one of the following processing difficulties:

- fading-memory (most likely sign)
- sequencing
- sustained attention (depending on reinforcing qualities of stimuli/task), inattention, and possibly impulsivity (ADHD H/I type)

It is also possible that other processing issues are present (decoding speed, integration, phonological awareness signs).

However, one would not expect a person with ADHD to have only decoding speed, phonological awareness, and/or integration signs.

Spoken Language Processing Testing- Audiology Perspective

RHSC uses tests that allow us to determine if a SLP disorder is present, the specific difficulties, and, in turn, the severity of the various underlying problems. In turn, we use the findings to guide individualized management.

This approach contrasts with other facilities that may use CAP tests for pass/fail and implement general strategies, or, that try and focus on "pure auditory deficits", which I feel is difficult to do in clinic setting and is self-limiting.

**SL-P Testing: Audiology Perspective
cont'd**

The tests done through the RHSC Audiology Department are relatively independent of "basic level" language influences, either because the stimuli involve minimal linguistic complexity (digits, phonemes) or involve words/sentences that are of early level language (e.g., 5 years or younger).

As a result, it is felt that the deficits that are diagnosed are primarily due to an interaction of underlying CANS, cognitive processes, and higher order/interfacing language mechanisms.
