# Central auditory processing disorder: a literature review on inter-disciplinary management, intervention, and implications for educators

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# CENTRAL AUDITORY PROCESSING DISORDER: A LITERATURE REVIEW ON INTER-DISCIPLINARY MANAGEMENT, INTERVENTION, AND IMPLICATIONS FOR EDUCATORS

by

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# ABSTRACT

**Clinical Questions:** What top-down and bottom-up interventions across the psychology, audiology, educational, and speech language pathology domains are most effective for children and adolescents with Central Auditory Processing Disorder (CAPD)? What considerations for planning research and intervention might be offered to a classroom teacher to further support students diagnosed with CAPD, especially in relation to the Multi-Tiered System of Supports (MTSS), formerly known as Response to Intervention (RTI)?

**Method**: Inter-Disciplinary Literature Review

**Study Sources**: *PsycInfo, Linguistics and Language Behavior Abstracts, ProQuest, International Journal of Audiology, American-Speech-Language Hearing Association, Journal of Neurotherapy, Medline-Esbcohost, ERIC Ebscohost, Professional Development Collection Education, and What Works Clearinghouse*

**Number of Included Studies**: 16

**Age Range**: 2-13 years

**Primary Results**: 1) Phonological awareness training was the primary reading educational construct found among the included interventions in this literature review. 2) Most CAPD studies employed a combination of both bottom-up and top-down treatments in intervention. This finding may possibly indicate that in order for a CAPD intervention to be even more beneficial to the student, both bottom-up and top-down treatments should be considered and incorporated in relation to the student's individualized needs.

**Conclusions**: Results confirmed very little research and are few intervention implications on CAPD students within the educational research discipline, including special education. Search results primarily included methods to improve listening in the classroom environment, but did not specifically mention intervention in relation to CAPD and its implications. Results also confirmed that a multi-disciplinary effort is needed to provide clinical decision and effective intervention for the CAPD population.

## ACKNOWLEDGMENTS

First and foremost, I would like to give my sincere appreciation to Dr. Taylar Wenzel for her unyielding support, encouragement, and tremendous assistance in the preparation of all aspects of this project. Her expertise and background in the Educational Psychology field was indispensible in portraying the essence of the CAPD population and its implications for educators.

I would also like to thank my other committee members, Dr. Sherron Killingsworth Roberts and Dr. Alvin Wang, for encouraging me to initiate and conduct this project. I appreciate all of the time and effort that they have spent providing me feedback and support for the successful completion of this Honor in the Major thesis.

# DEDICATIONS

I would like to dedicate this project to Mom, Dad, and my sister Brooke for their unconditional love and support. Thank you for always believing in me, and encouraging me to "Reach For The Stars!"

## AUTHOR'S NOTE

I chose to conduct a research project on this particular topic because of my own diagnosis of Central Auditory Processing Disorder (CAPD). In second grade, I performed poorly on the Florida Comprehensive Assessment Test (FCAT), and my parents and teacher noticed that I was having trouble with multi-tasking and auditory processing. I was diagnosed with Central Auditory Processing Disorder and was given an Individualized Education 504 Plan (IEP). At first, I was discouraged by this academic and personal challenge. In both the home and school environment, it was difficult for me to remember verbal multi-task directions and discriminating subtle differences in sounds and words. However, over time, I developed my own learning strategies to compensate for my CAPD. Although I was able to develop my own learning strategies, I still have auditory and language processing difficulties. At times, this still does have an impact on my social and academic performance.

Changes in the current educational system and the Multi-Tiered System of Supports (MTSS) have started to require teachers to integrate specialized academic plans and interventions in the general education classroom. However, Not all general education teachers may have the professional knowledge of interventions that are appropriate to design an individualized classroom intervention and provide support for this particular subgroup of students. My own IEP provided preferential seating, which is a crucial component of environmental modifications for CAPD, but insufficient by itself for a 'true' CAPD intervention as found by the research in this study.

Next year, I hope to be able to take my proposed considerations for future research and implement and test an intervention case study for CAPD students in the School Psychology graduate program. As a future school psychologist and with my experience analyzing research and knowledge across a spectrum of disciplines which address the epidemiology of CAPD students, my hope is to provide intervention and consultation for teachers to assist students with Central Auditory Processing Disorder, as well as other learning disabilities.

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# CHAPTER ONE: INTRODUCTION

Children and adolescents who are diagnosed with Central Auditory Processing Disorder (CAPD) are studied in a variety of domains across academic literature, including but not limited to: elementary education, special education, speech-language pathology, audiology, and psychology. While the unique lens of each of these fields offers varied insights regarding potential interventions that have and could be used to support students with a CAPD diagnosis, it seems as though increased communication and collaboration across these disciplines is warranted (Bellis & Anzalone, 2008; Friel-Patti, 1999). Further, there remains great controversy regarding the components that should be included in a CAPD intervention and qualifying factors that make a CAPD intervention effective. Research further demonstrates a need for clinical consensus among the speech-language pathology field and related disciplines on how CAPD should be diagnosed, treated, and measured (Friel-Patti, 1999). According to Bellis and Anzalone (2008), "Formal consensus guidelines for diagnosing and treating/managing CAPD did not appear in the literature until relatively recently. Intervention for the disorder requires a multidisciplinary team endeavor. There remains to be a need for ecologically, valid intervention plans" (p.143). Friel-Patti (1999) states that "Clinical decision-making in central auditory processing assessment and intervention remains controversial" (p. 345).

This thesis will identify and synthesize interventional research and practices from the fields of elementary education, special education, psychology, speech-language pathology, and audiology in relation to Central Auditory Processing Disorder. All interventions will be organized and compared in a Speech-Language Pathology network model and Audiology pathway model. McFarland & Cacace (1995) argue in Friel, Patti (1999) that the network model is reflective of the information processing component within the nervous system, and the Audiology pathway model is reflective of the auditory nervous system and the centers along the pathway that processes auditory information. These two models will be related to the Select Organize Integrate (SOI) Informational Processing Model in terms of how CAPD students are processing and storing sensory and instructional input. These findings will appropriately inform and prepare educators to reach out and support students who are diagnosed with CAPD through research-based intervention. In addition, findings from this thesis will be applied to develop considerations for future research pertaining to educational protocols for students diagnosed with CAPD.

# CHAPTER TWO: BACKGROUND OF CAPD

According to the American Speech-Language-Hearing Association (ASHA) (2005), Central Auditory Processing Disorder (CAPD), also commonly known as Auditory Processing Disorder (APD), affects many individuals in their academic, personal, and professional lives. The clinical criteria for CAPD is not identified in the Diagnostic and Statistic Manual of Mental Disorders (DSM-IV, American Psychiatric Association, 1994); however, clinical criteria for evidence can be found in the research and articles presented by the American Speech- Language-Hearing Association (1999). The American Speech-Language-Hearing Association's CAPD research further state there is not a unique set of clinical characteristics or a pattern of deficits on test batteries that clearly define the behaviors and difficulties that are possessed by individuals affected by CAPD. Chermak and Musiek (1997) argue in Bellis and Anzalone (2008), the estimated prevalence of CAPD in the school-aged population is approximately 2 to 5 %, and the estimated prevalence of CAPD in the older adult population is 76 %. These percentages are higher than those affected by hearing loss. The majority of individuals that have been evaluated for CAPD have been found to possess one or more of the following characteristics: oral language impairments, reading disabilities, phonological disorders, learning disabilities, and/or low academic achievement that does not correlate with their normal or above-normal intelligence.

Central Auditory Processing Disorder may also be defined as difficulty for children with normal hearing to listen selectively in the presence of noise, to combine information from two ears properly, to process speech when it is slightly degraded, and to integrate auditory information when it is delivered faster than the individual with CAPD can process (Nelson

Textbook of Pediatrics, 2011). Tallal (2008) further states that children with CAPD can be characterized by severe deficits in higher order auditory processing, specifically rapid temporal integration of acoustically varying signals and serial memory. These children may also have difficulty in discrimination and sequencing rapidly presented auditory information, especially when the stimuli are short tones, short vowels, or short transition consonants in combination with brief interstimulus intervals (Tallal, 2008). In the classroom setting, educators may notice students with CAPD demonstrate the following behaviors: 1) having trouble following more than one direction at a time, 2) commonly verbalizing "huh?" or "what?" and needing information repeated, 3) poor memory for words and numbers, 4) difficulty with complex language such as word problems or a long story, 5) difficulty expressing complex speech, and 6) having trouble with reading, comprehension, spelling, and vocabulary related tasks. According to Ross-Swain (2007), "to learn, a child must be able to attend to, listen to, and separate important speech from all of the other noises at school and home. When auditory skills are weak, the child may experience information overload" (p.141).

CAPD students are often clinically observed by educators as having Attention Deficit Hyperactivity Disorder (ADHD) due to the similarity of attentive, processing, and behavioral problems they exhibit (i.e., poor listening skills and difficulty remembering verbal information). Although these symptoms may be similar, the actual neural processing of auditory input in the central nervous system is intact for individuals diagnosed with ADHD, whereas the auditory input in the central nervous system is not intact for individuals diagnosed with CAPD (ASHA, 2005). It is important to note that individuals with CAPD have normal peripheral hearing and can successfully engage in one-to-one conversations, but have difficulty with multi-talker situations or in conversations with competing background noise. The level of severity of CAPD may vary, from moderate to severe. However, even mild CAPD can even result in significant impairment in adolescence (Heine, 2008).

According to Bellis and Anzalone (2008), CAPD is considered to be a **diagnostic** term rather than a **descriptive** one. Many individuals exhibit listening and related difficulties that mimic CAPD; however, only those shown to have central auditory nervous system dysfunction using sensitized tests designed for the purpose should be diagnosed with CAPD (Bellis and Anzalone, 2008). It is important to note that individuals that may benefit from a CAPD diagnosis are assessed and evaluated by a multi-disciplinary team that is composed of audiologists, speech-language pathologists, psychologists, and educators (Bellis and Anzalone, 2008). Individuals with CAPD are assessed by clinical observation, audiology batteries to determine the functional ability of the central auditory nervous system and central auditory processes, electrophysiological measures, classroom achievement, receptive and expressive oral and written language, behavioral tests, and the Wechsler Intelligence Scale For Children-Fourth Edition (WISC-IV) (Wechsler, 2004). Current CAPD research (Bellis and Anzalone, 2008) recommends that a diagnosis of CAPD be given only if abnormal performance persists on at least two tests of central auditory function and that the pattern of performance across tests is consistent with central auditory nervous system dysfunction (as cited in ASHA, 2005).

Research demonstrates the presence of great misunderstandings of CAPD and associated intervention among professionals that work with this population (ASHA, 2005). Controversy also remains as to whether CAPD is primarily an auditory impairment versus a language processing impairment. In 2005, the American Speech-Language-Hearing Association developed a Central Auditory Processing Disorder technical report and position statement for audiologists and speech language pathologists. This report provides the most recent information on CAPD including its most recent definition, screening and diagnostic criteria, and key intervention approaches. These approaches include bottom-up theory, top-down theory, treatment goal, management, and approach implication (baseline performance, measureable outcomes, and schedule of treatment). This technical report further supports that although there is clinical evidence and definition for the CAPD population, effective interventions are limited. (Friel-Patti 1999, ASHA 2005).

# CHAPTER THREE: THEORETICAL FRAMEWORK

CAPD research (ASHA, 2005) recommends that all interventions for this specific auditory processing disorder be based on a top-down as well as bottom-up treatment approach.

The top-down approach is teacher-centered and focuses on language and cognition. According to Friel-Patti (1999), speech-language pathologists support the top-down approach, commonly referred to as the network model. The network model "emphasizes the distributed nature of information processing within the nervous system… the integration of sound, meaning, and intention involves more than the auditory neural pathway" (Friel-Patti, 1999, p. 347).

Alternately, the bottom-up theory is supported by audiologists. This student-centered approach focuses on signal quality and environmental modifications. The bottom-up theory is commonly referred to as the pathway model. Friel-Patti (1999) states that "audiologists support the pathway model, which is based on the auditory nervous system and the centers along the pathway that processes auditory information. The focus is on specification of the stimuli and the level of the auditory nervous system being evaluated" (p. 347). In regards to the context of CAPD intervention, bottom-up or pathway model theory may include acoustic signal enhancement, auditory training, direct skills remediation, and environmental modifications. Environmental modifications for individuals with CAPD are preferential seating, visual aids, reduction of competing signals, reverberation time, and assistive listening systems. These modifications can be implemented in the classroom, workplace, and home (ASHA, 2005). Table 1 provides a summary of the bottom-up theory/pathway model, as well as the top-down theory/network model treatment approaches for the CAPD population. These intervention theoretical framework assumptions will be referenced in the following sections of this paper.

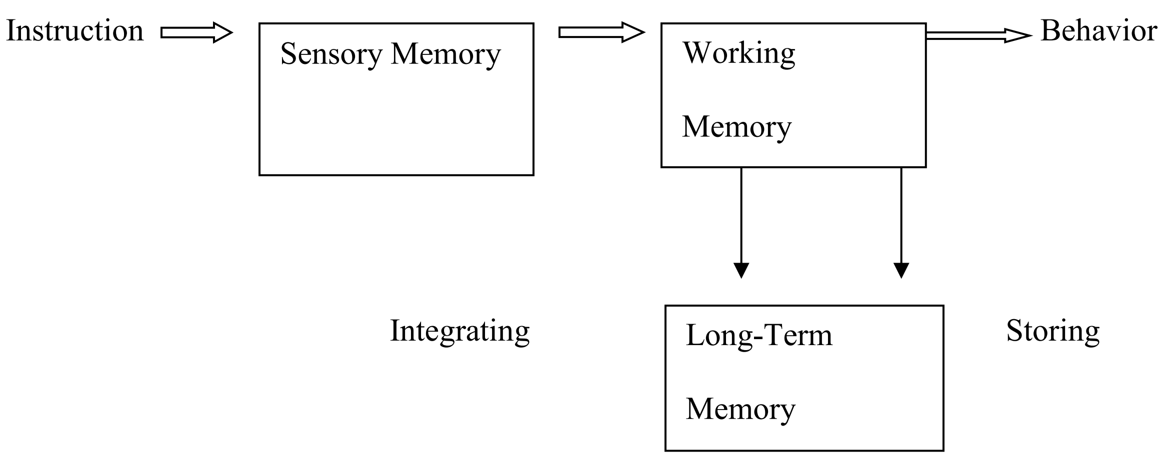
Table 1: Fundamental Theoretical Framework for CAPD Intervention

| **Bottom-Up Theory & Pathway Model** | **Top-Down Theory & Network Model** |
|---|---|
| Acoustic Signal Enhancement<br><br>*Focused on the "Equipment"* | Cognitive Strategies<br><br>*Teacher-prompted* |
| Auditory Training<br>(intensity, frequency, duration discrimination, phoneme discrimination, phoneme-to-grapheme skills, temporal gap discrimination, temporal ordering and sequencing, pattern recognition, recognition of auditory information presented within a background of competing noise or competition) | Language Strategies<br>(schema induction and discourse cohesion devices, context derived vocabulary, phonological awareness)<br><br>Classroom Learning Strategies such as reducing/minimizing distractions, flexible preferential seating, providing isolated area for independent work, speaking clearly and slowly, providing teacher notes, emphasizing critical information, extending time for task completion, teaching test taking strategies, allowing oral responses, providing alternative testing options, training students to "look and listen," organizing long term assignments into manageable, sequenced steps) |
| Environmental Modifications (preferential seating, visual aids, reduction of competing signals, reverberation time, and assistive listening systems) | Meta-Cognitive Strategies (self-instruction, assertiveness training, cognitive problem solving) |

## CAPD & Information Processing Model

Central Auditory Processing Disorder (CAPD) refers to how the central nervous system processes auditory information. According to Tallal (2008) and ASHA (2005), individuals diagnosed with CAPD do not have an intact auditory input in the central nervous system, have severe deficits in higher order auditory processing, and have poor serial memory. The central nervous system assists with a wide variety of functions including: memory, attention, and language. Chermak & Musiek, 2007 argue that neurobiological mechanisms and relayed processing of sensory and auditory input in CAPD students indicates that CAPD management and intervention can also be based off of an information processing model framework (as cited in Sharma, Purdy, and Kelly, 2012, p. 506). The authors further state “this approach emphasizes the complex, multileveled nature of auditory processing, involving parallel and serial processing of information” (p. 506). One way that perceptual processing of auditory information in CAPD students can be described is by the Select-Organize-Integrate (SOI) Information Processing model (Alexander & Winne, 2006). The SOI model is comprised of three memory stores-sensory, working, and long-term memory. The model begins with instructional input, including auditory and verbal stimuli. The pictures, printed images, and spoken words used during instruction are broken down and stored into the sensory memory. If the individual is fully attentive throughout instruction, he or she may then transfer the stored information in sensory memory to working memory. Working memory allows the individual to execute verbal and non-verbal tasks and make the information available for further processing. Since children with CAPD have difficulty with language and auditory input, as seen by the sensory and instructional input in the beginning of the information processing model, their working memory may not be able to function as well as other individuals who do not have an CAPD diagnosis. Chermak and Musiek (2007, p. 507) argue in Sharma, Purdy, and Kelly (2012) that working memory in children with APD may be developed through language-based activities involving formulation sentences, sentence assembly, and sentence completion. Since clinical characteristics of CAPD include difficulty combining auditory information, needing information repeated, and with following verbal multi-task directions, one of the language tasks in a top-down theory intervention approach may include “following and directing instructions” (Sharma et al., 2012). This involves both attention and working memory. As a result of a possible deficit in working memory, verbal and sensory information may not be conveyed, stored, or retrieved to/from long and short term memory, as seen in Figure 1, the SOI Information Processing Model.

**Figure 1: Conceptualization of the SOI Processing Model**




The SOI Processing Model demonstrates how one processes, organizes, and integrates information. Children diagnosed with CAPD have difficulty with language and auditory input. In relation to the classroom environment, these students are not effectively processing the instruction and sensory input that is being delivered by the teacher. As a result, this information is not being transferred to the working memory, which in turn affects the ability of CAPD students to store long and short term information

# CHAPTER FOUR: MULTI-TIERED SYSTEM OF SUPPORTS AND RELATION TO CAPD

During the past several years, many significant changes have occurred in the nation's educational system. This includes the Response to Intervention (RTI) Model, which has been recently adopted through the nation's special education law, Individuals with Disabilities Education Act (MTSS, 2012). According to the National Center on Response to Intervention (2012), the main goals of the RTI model, also known as Multi-Tiered System of Supports (MTSS), is to decrease the number of students who may be referred to special education for additional services, provide high-quality research-based instruction with progress monitoring and adjustments based on students' needs, and increase the number of intervention and prevention opportunities available to students. One unique subgroup of the student population that may benefit from increased intervention and progress monitoring is comprised of students who have been diagnosed with Central Auditory Processing Disorder (CAPD).

Students that are consistently demonstrating poor academic and/or conduct performance in the classroom, may be referred for testing and evaluation by a school psychologist. Depending upon the severity of the student's classroom performance, they may receive additional academic support and intervention with appropriate documentation and testing. The special support and intervention is currently referred to as the Multi-Tiered System of Supports. The Multi-Tiered System of Supports is based on a three tier system, where Tier I is the core instruction that the student receives. Students placed in Tier II receive supplemental services in small groups, in addition to core instruction. Students who are academically and/or behaviorally struggling below their grade level are placed in Tier III. These students receive specialized academic interventions, 180 minutes a day of instruction based on their particular academic needs, alternative education plans, and behavior intervention plans if applicable. Tier III students are monitored more frequently and may be referred to special education services if progress is not met within the six week time frame.

If a student is struggling academically and/or behaviorally, and is suspected of possibly benefitting from a CAPD diagnosis based on CAPD clinical characteristic criteria, he or she may be referred for CAPD screening and evaluation by a multi-disciplinary team. Depending upon the pattern of results on the students' CAPD screening and the level of diagnosis, the student may be placed in either Tier II or Tier III of the MTSS model. It is important to also note that since children with CAPD may also manifest a language impairment, the student may receive Speech services in addition to the Tier II or Tier III services being provided in the classroom. In performing the literature review for this thesis, knowledge of RTI or MTSS is important in order for educators to understand and be able to employ appropriate supplemental intervention for CAPD students in these particular tiers.

# CHAPTER FIVE: METHODOLOGY

This multi-disciplinary literature review will identify and examine what top-down and bottom-up interventions across the psychology, audiology, educational, and speech language pathology domains are most effective for children and adolescents with Central Auditory Processing Disorder (CAPD). Furthermore, this thesis will identify considerations for planning research and intervention that might be offered to a classroom teacher to further support students diagnosed with CAPD, especially in relation to the Multi-Tiered System of Supports.

In order to examine 1) Central Auditory Processing Disorder, 2) Relation of bottom-up and top-down interventions to CAPD disorder and 3) CAPD language and auditory deficit in relation to the SOI Informational Processing Model, an interdisciplinary, multi-phase literature review was conducted. First, the epidemiology of individuals diagnosed with Central Auditory Processing Disorder was examined. Articles and studies were drawn from books and academic journals across the fields of educational, psychology, communication of sciences and disorders, and audiology that best highlighted CAPD in terms of its language, auditory, and processing components. The specific databases of this multi-disciplinary literature review included: *PsycInfo, Linguistics and Language Behavior Abstracts, ProQuest, International Journal of Audiology, American-Speech-Language Hearing Association, Journal of Neurotherapy, Medline-Esbcohost, ERIC Ebscohost, Professional Development Collection Education,* and *What Works Clearinghouse*. The search terms that yielded the most valid and significant results were "Auditory Processing Disorder and interventions," and "Auditory Processing Disorder and case studies." An even greater yield of positive results was found when the audience was limited to school age or adolescence and peer-reviewed. It is important to note that only studies were included wherein the participants were native English speakers, normal hearing, and no former diagnosis of reading disorder or ADHD.

After all CAPD interventions based on sixteen sources were compiled, reviewed, and synthesized, a further analysis of these interventions was conducted to determine a pattern of effective bottom-up and top-down treatment approaches for individuals with CAPD. Initially, these interventions were going to be aligned with the WISC-IV (Weschler, 2004). However, after further research in this area, results concluded that there was a lack of evidence and validity between a correlation with cognitive CAPD deficits and the various sub tests on the WISC-IV including Front and Backward Digit Span, Arithmetic, Letter Number Sequencing, and Comprehension (Weschler, 2004). Further research also suggested that organizing the interventions by pattern of academic weakness was not relevant, due to the lack of support for comprehension and fluency constructs. Instead, the data suggested that the most effective and reliable CAPD interventions were based off of a bottom-up, top-down, and information processing theoretical framework. The sixteen intervention studies that were included for analysis contained the criteria for effective intervention as outlined by the current ASHA technical report (2005). This includes: baseline performance prior to starting intervention, regular intervals during course of treatment, termination of intervention, repeated measurement, and measureable outcomes (ASHA, 2005). A literature map (Creswell, 2003) was also created to list and compare the CAPD-related intervention studies across the speech- language pathology, educational, audiology, and psychology disciplines (Appendix B).

# CHAPTER SIX: INTERVENTIONS REVIEW

CAPD interventions that have been found to be most effective are deficit specific, multi-disciplinary, employ bottom-up and top-down approaches, and are designed based on diagnostic test results and presented academic and behavioral complaints (ASHA, 2005). Sixteen article reviews that support the top-down approach and network model, as well as the bottom-up and pathway model are listed and categorized in this manner.

### Network Model & Top-Down Interventions

According to the Special Education *What Works Clearinghouse* database, the three language intervention programs that are commonly used among educators and speech language pathologists are Fast ForWord (FFW), Lindamood Phoneme Sequencing (LIPS), and Phonological Awareness Training. The underlying cognitive, language, and auditory skills that are incorporated in these training programs are evident in all of the currently practiced CAPD and APD research and interventions mentioned in the four article reviews that follow.

Fast ForWord (FFW) (Tallal, 2008) is a computer-designed cognitive reading program. This program is intended to be used between 30 to 100 minutes a day, five days a week. The usual duration of FFW is between 4 to 16 weeks. Fast ForWord focuses specifically on the following cognitive skills: memory, attention, processing, and sequencing. It is also focuses on language and reading skills, listening accuracy, phonological awareness, and language structures. According to *What Works Clearinghouse* Fast ForWord Intervention Report, Fast ForWord helps to increase participants' processing efficiency, sound-letter association reading skills, word recognitions, vocabulary, and comprehension. The question and skill complexity adjusts based on the participants' responses. Fast ForWord has been found to positively effect fluency and comprehension among children and adolescents (Tallal, 2008).

A second language intervention reported by *What Works Clearinghouse* is The Lindamood Phonetic Sequencing (LIPS). Lindamood (2008) is a language processing program for children ages five to nine or struggling readers that teaches students the necessary skills to decode words and identify individual sounds in words. Lindamood Phonetic Sequencing is based off of Lindamood bell research which serves students with learning difficulties and students who have been previously diagnosed with Autism Spectrum Disorder, Dyslexia, ADHD, and Central Auditory Processing Disorders. LIPS teaches children about the lip, tongue, and mouth actions to form and produce specific sounds and then practice applying this knowledge to sequencing, reading, and spelling. This program is deficit-specific, and designed to meet individualized students' language, reading, and learning needs. Based on the *What Works Clearinghouse* intervention effectiveness standards, LIPS has potentially positive effects on alphabetic, reading fluency, and math, no significant effects on reading comprehension, and potentially negative effects on writing for students with learning disabilities. The Lindamood Phonetic Sequencing may have a potential positive impact on students diagnosed with CAPD, due to its emphasis on discriminating subtle differences in sounds and words, which is an area of academic concern commonly seen in most CAPD students. As LIPS also assists with language and sensory input, this program may assist students with CAPD in storing this input in their working memory, and later short and long-term memory storage.

Phonological Awareness Training, an intervention report provided by *WhatWorks Clearinghouse*, measured phonological awareness training by “any practice targeting young children’s phonological awareness abilities” (US Dept of Education, 2006). This includes teaching children to identify, delete, detect, or produce rhyme or alliteration. The four studies in this intervention report included seventy eight children with disabilities or developmental delays attending preschool in four locations across the United States. Although this intervention report did not specifically look at and conduct research related to CAPD and phonological awareness, a large focus of phonological awareness training uses auditory and language skills, both of which areas CAPD individuals have a large difficulty with. An integration of these skills in a future CAPD study may provide beneficial as an intervention to this population. Additionally, according to the *What Works Clearinghouse* intervention report on phonological awareness training (US Department of Education, 2006), this intervention was found to have potentially positive effects on communication/language competencies for children with learning disabilities.

Veale (1999) provides an overview and analysis of the design, implications, and efficacy of the Fast ForWord Language Intervention training. Fast ForWord utilizes computer games to train auditory and phonological skills to improve speech and language deficit. The Fast ForWord program consists of five games the child must complete each day. These games are automatically determined by the software based on previous response. The child must also play a total of 100 minutes of the game per day. When the child demonstrates mastery of the skills necessary for the first level of the game on successive turns, he or she is automatically advanced to the next level. In each level, the duration and intensity of the acoustic signal increases to train the child in how to appropriately process signals that are similar to the level of adult speech.

Each level is comprised of a game. The specific skills embedded in the games are the following: processing and temporal sequencing skills, distinguishing phonemic sound changes, identifying specific phonemes, reinforcing memory and reasoning skills within nonsense syllables that differ by a single phoneme, teaching listening comprehension and syntax through simple sentence structures, and higher level language skills (complex sentences, morphology, syntax, and grammar). The time of completion for this program is between four and eight weeks.

According to the Veale (1999) study, the Fast ForWord program has proved to be very successful. Approximately 90 % of all children with language impairment improved in auditory discrimination abilities, following directions, listening and speaking, and overall language development. This program also yields significant results in overall language abilities, auditory processing speed, working memory, phonological awareness, listening and comprehension skills, and syntax usage. This particular intervention would be best categorized under the top-down approach, due to its language focus. From the conclusions of this article it appears that students with CAPD may especially benefit from a combined language and auditory program, as seen by the auditory and phonological skills in the Fast ForWord program. This finding may apply to in-classroom use and teaching educators on the combination of accommodations (in this case, both auditory and language) for students diagnosed with CAPD.

Marler, Champlin, & Gilliam (2001) conducted an empirical study on using a computerized based intervention with children who have been diagnosed with language learning impairments. Similar to Veale (1999), Marler et al., (2001) tested the effectiveness of the commercialized Fast ForWord computerized language intervention program. He compared participants' changes in auditory processing abilities between FFW and Laureate Learning Systems, another language based training software. Typically, children who have language-learning impairments also have an auditory processing deficit. Both programs are designed to help train and improve temporal processing, speech perception, and comprehension skills; however, the Laureate Learning Systems computer training does not contain modified speech and is not specifically designed to improve auditory processing. There were seven total male participants in this study, ranging from six to nine years of age. Four of these participants had been diagnosed previously with Language-Learning Impairments, and three participants did not have a language impairment. The two Language-Learning Impairment participants received the Fast ForWord Program. Participants who were not diagnosed with a Language-Learning Impairment received the Laureate Learning Systems computer-assisted instruction. The Fast ForWord and Laureate Language Systems intervention were presented on the same four week schedule. Marler (2001) measured temporal processing through signal thresholds in backward and simultaneous masking conditions. The treatment participants attended the study center five days per week. The daily session consisted of five exercises, each lasting for a minimum of five minutes and a maximum of twenty minutes. Each participant worked under the supervision of a speech language pathologist. The no treatment condition came to the study center for a baseline session and four weekly visits. They attended regular education classes during the study.

In accordance with previous research, it was hypothesized that the language learning impaired children would perform significantly lower than their peers with typically developed language tasks requiring discrimination of brief sounds. Results indicated that there is no support for one type of a specific program that helps to improve temporal processing. Result patterns also indicated that auditory memory and maintaining attention is needed for successful temporal-auditory improvement in training. Limitations included lack of gender difference, limited amount of baseline monitoring before and after treatment, and differentiation of acoustic environments (completing program with competing background noise versus no background noise).

Based on study results, it appears that there may not be one particular and most effective intervention for CAPD students. It may just be important that CAPD intervention contain language and auditory treatment components.

Hutchinson (1998) provides an interdisciplinary assessment procedure and criteria for diagnosis of central auditory processing disorder (CAPD). For the purpose of this experimental case study, a CAPD test battery was selected consisting of the Staggered Spondaic Word test, the Pitch Pattern Sequencing Test, the Phonemic Synthesis test, and the Auditory Figure Ground subtest of the screening test for Auditory Processing. This research stands out because it provides a comprehensive, interdisciplinary approach for assessing and diagnosing children with CAPD through a case study design for purposes of remediation and classroom placement, which is the focus of this paper. The study states that, "Because auditory skills are basic to the language learning process, effective listening skills are necessary for scholastic success. In the academic environment, children must continuously attend to, comprehend, store internally, and retrieve auditory data while simultaneously monitoring their own understanding of the signal" (Hutchinson, 2008, p. 235).

Participants with educational and behavioral characteristics consistent with CAPD were chosen to highlight the importance of interdisciplinary procedures for accurate identification and intervention directions. Three children participated in this study. They were referred to the Miami (Ohio) University Speech and Hearing Clinic by teachers or county educational service providers because of classroom learning problems. The Children's Auditory Processing Performance Scale (CHAPPS) was administered by teachers or tutors for each child at the school before the CAPD evaluation at the clinic. The three children were comprised of two males and one female, and ranged from seven to eleven years old. Each participant had intelligence and speech-language within the normal range for their age. However, two of the children received special education services in speech-language or learning difficulties because of parental concern. Traditional hearing assessment was administered to rule out peripheral hearing loss and traditional word identification was measured within the two lists of the Kindergarten Phonetically Balanced word test. All tests were performed while subjects were sitting in a hearing test booth. The test battery consisted of the Staggered Spondaic Word test, the Pitch Pattern sequencing test, and the Phonemic Synthesis test. These tests were used to confirm functional deficits to determine appropriate management strategies. Case Study I was performed on a nine-year-old female named K.T. who was referred for central auditory assessment. Reports from her teacher and parents indicated poor attention and distractibility in most listening environments and difficulty in sorting and organizing information. K.T. performed about one year below grade level on standardized achievement tests. Comprehensive educational diagnostic testing suggested deficits in learning comprehension, auditory sequencing, and auditory/visual integration. Additionally, K.T. demonstrated deficits in processing, reproducing, and organizing orally presented information at the discourse level, and difficulty with comprehension questions that required her to analyze information. According to K.T.'s testing and perceived deficits, recommendations included classroom modifications designed to reduce the effects of noise and increase visual cues and specific remedial and compensatory strategies. Management emphasis was placed on improving her ability to process, recall, and execute multistep instructions, and to process information in a "noisy" environment.

Case study II focused on a seven-year-old male named D.K. This student was referred for CAPD testing because of his reading comprehension and spelling deficits. Reports from the parent, teacher, and Children's Auditory Processing Performance Scale indicated inconsistent attention to oral stories and directions, and distractibility in most listening environments, especially in background noise. D.K.'s primary deficit was in auditory memory and sequencing. D.K. also had difficulty processing and decoding predictable and unpredictable spelling words. His errors were comprised of omissions and substitutions, characteristic of a child with auditory processing deficit. Specific deficits in D.K.'s morphological and syntactic rules negatively affected oral and written expression. D.K. was unable to process, remember, or answer comprehension questions pertaining to vocabulary meaning, or recall factual information. Management for D.K. included acoustic signal enhancement, environmental adaptations, skills development, and improvement of language capacities. Emphasis for DK's intervention was placed on improvement of morpheme and syntax rules that affected his oral and written expression, meta-linguistic techniques to process auditory information more efficiently, and management strategies to aid his ability to process and recall multistep information.

Case Study III was on C.C., an eleven-year-old male who was referred to the school system because of difficulty remembering oral directions at home and in school, written language difficulties in spelling and organization of material, and processing and expressing information in the classroom. Results from the CHAPPS, as well as observation from C.C.'s parents and teachers, indicated that C.C. had difficulty with short attention and trouble staying focused. Although C.C. was able to pay attention and respond to questions and simple instructions very well, C.C. had difficulty staying focused when given multiple, complicated instructions. Psycho-educational evaluation indicated that C.C. fell in the lower normal range in intelligence functioning. Furthermore, the Lindamood Auditory Conceptualization Test indicated that C.C. demonstrated a basic knowledge of sound-symbol correspondence of isolated sounds and letters, but an inadequate conceptual basis for application to spelling. Intervention management recommendations for C.C. included environmental modifications, strengthening auditory decoding, and refining processing abilities of auditory memory in various environments.

Although all recommended interventions in these sixteen studies are reflective and consistent with both the top-down and bottom-up interventions as described in the theoretical framework of this paper, they are a prime example of how not all children with listening and auditory language learning problems demonstrate the same academic difficulties, nor show the same deficit pattern on diagnostic psycho-educational, language, and auditory screenings. Hutchinson et al (1998) appeared to be particularly applicable to the foundational interventional framework for this study, because of its emphasis on the need for an interdisciplinary intervention and management approach for children with CAPD and associated language difficulties.

## Pathway Model and Bottom-up Intervention

The Sharma et al. (2012), Kuk, Jackson, Keenan, & Lau (2008), and Ross-Swain (2007) studies focused on the effectiveness of including environmental modifications, such the use of assistive listening devices, in CAPD intervention treatment. These studies are each described below.

Sharma et al. (2012) conducted a study comparing two intervention approaches for children with Auditory Processing Disorder (APD). These two intervention approaches were split between bottom-up and top-down training based activities, including the use of personal assistive listening devices. Both treatments followed a six week intervention schedule. This included weekly one-hour sessions with a therapist in the clinic and assigned homework. Participants in the Sharma et al. (2012) study included fifty-five children between seven and thirteen years of age with diagnosed APD. Results indicated positive outcomes for bottom-up discrimination training and use of personal assistive listening devices and discrimination training only. In both treatments, there were positive results on participants' language measure. This includes concepts and following directions, word structure, recalling structures, and formulated sentences. However, there were differences in the audiology assessment, which may have attributed to the differences in the baseline. For participants that went through the language top-down and personal assistive listening device treatment, their sentence recall and non-word spelling only improved with the listening device. The participant group who had language and top-down training with the personal listening device and the participant group that had no language treatment, improved on auditory processing, language measures, and reading measure. Pre-intervention nonverbal IQ, age, and severity of APD did not influence the study results.

Personal listening device systems systems in addition to the two different types of training yielded slightly higher positive results.  (CELF, Pearson, 2008).

Kuk et al. (2008) performed a single, blind longitudinal study that focused on the environmental modifications and appropriate signal to-noise ratio difficulty for children with auditory processing disorders.  This study was designed to determine whether personal amplification would result in improvement in attentiveness, speech recognition, and daily functioning.  Participants included fourteen normal hearing children between the ages of  seven to eleven who had a previous Auditory Processing Disorder diagnosis. All participants wore a hearing aid fitted in an open-ear mode.  Hearing aids were adjusted to provide 10 decibels of insertion gain for conversational input.  The directional microphone and noise reduction were used on the hearing aids.  Participants in this study were required to wear the hearings aids daily at home, school, and in the community. Participants were seen for a total of four times including hearing aid fitting.  They were evaluated on the Northwestern University Word-List and the Auditory Continuous Performance Test in noise at most visits. Parents and teachers of each participant were asked to complete the Children's Auditory Processing Performance Scale questionnaire before and at the end of each study.  Results of the study indicated that the use of the hearing aids with the noise reduction mode and directional microphone improved speech understanding in noise.

Stephenson (2008), Phillips, Comeau, and Andrus (2010), Swain (2007), and Crosbie and Dodd (2001) all focused on the effectiveness of auditory discrimination as a type of bottom-up treatment for CAPD students.

Stephenson (2008) identified the need for further research in the remediation therapies for individuals diagnosed with CAPD. He proposed a study on a new therapy program called Dichotic Auditory Training. In the context of this study, dichotic training can be classified as "testing that involves the presentation of the same stimulus to both ears simultaneously. The reason behind this selection of training is due to the reported difficulty with dichotic testing due to the demand for the breakdown of processing in both ears" (Stephenson, 2008). Study participants included eight children between the ages of seven and twelve years old. The Dichotic Auditory Training intervention duration was four weeks. The Staggered Spondaic Word test, SCAN-C/A, and a test designed after the Dichotic Auditory Training were given prior to and immediately following intervention treatment to measure participant response. All conditions that were associated with the dichotic presentation of words were statistically significant.

Phillips, et al (2010) conducted a study to measure the auditory gap in children. According to the study, auditory gap detection comes in two forms: the within or between channel. In the within channel, the listener is provided with two streams of the same sound. However, one sound signal contains a silent period (gap) at its temporal midpoint, and the other sound signal does not. In the between channel, the sounds bounding the gap are spectrally different from each other. Between channel gap detection is correlated with phonological reading in normal developing children. Participants in the Phillips, Comeau, and Andrus study (2010) included 16 control children and 20 children referred for the Auditory Processing Disorder assessment. Children in all three groups were between the ages of 10 to 11 years old. Out of the 20 children referred for APD assessment, nine were diagnostically positive for APD and eleven were negative. Two computerized libraries of gap detection were prepared for auditory gap testing. All stimuli were presented at a frequency of 44.1 kilohertz (kHz). Results indicated that the within channel best gap durations were very similar across the three participant groups. The between channel best gap durations varied between listener groups. The greatest difference in auditory gap durations were between the control participants and the positively diagnosed Auditory Processing Disorder participants. As a result of the best auditory gaps varying significantly between listener groups, the article concluded that the perceptual timing processing required by the between channel is more affected by the perceptual and processing deficits found in children diagnosed with CAPD.

Swain (2007) studied the use of the Tomatis Method as an effective auditory stimulation intervention strategy for children with Auditory Processing Disorder. According to Swain (2007), "The Tomatis Method of auditory stimulation is a therapeutic intervention used to improve characteristics and behaviors in children and adults with disorders of communication, learning and autism, and autism spectrum disorders" (p. 141). The Tomatis Method produces improvements in skills of auditory perception and discrimination, immediate auditory memory, interpretation and following directions, auditory sequential memory, auditory cohesion, and auditory latency.

Participants in this study included a total of 41 subjects, 18 females and 21 males, all diagnosed with Central Auditory Processing Disorder. The age ranges of participants were between 4.3 to 19.8 years. During the duration of this study, all participants were not receiving other therapies and studied for a pre- and post- retrospective case review. Each participant received a total of ninety hours of auditory stimulation involving active and passive listening. According to Swain (2007), “The progression of the Tomatis Method parallels processing, language development, acquisition, and mastery with regard to sound perception, discrimination, and perception” (p.143).

According to Swain (2007), The Tomatis Method is organized into four blocks: The Passive Phase, Active Phase, Stabilization Phase, and Maintenance Phase. In the experimental design, the frequency level of modulated voices and music increased in hertz during each phase. During the Passive phase, the child listened to Mozart music and Gregorian Chants for two hours a day for a total of fifteen passive days. While the protocol of listening progresses, the child was introduced to the Active phase of listening where he or she first listened to recorded discourse and audio-vocal exercises. In the active phase, the child participated in ten days of active listening for two hours a day, where he or she began to tone, sing, read, or repeat the modulated words and phrases into a microphone. The phase ended with reading aloud. During the Stabilization phase, there were ten days of mixed active and passive listening for two hours daily. The Maintenance phase included ten days of mixed active, passive, and various levels of listening for two hours daily. During all listening phases, the children through headphones with an attached bone conduction oscillator, allowing the sounds to be heard through bone conduction and usual air conduction. It is important to note that each participant was able to take a three week break between each block. The participants received the same battery of assessments for pre and post tests. This included the Wide Range Achievement Test, Lindamood Auditory Conceptualization Test, Phonemic Awareness Test, Token Test for Children, and Test of Auditory Perception Skills.

Crosbie and Dodd (2001) conducted a single-case study, examining the effects on auditory discrimination therapy on a seven-year-old female named Amy with severe language disorder. In this study, the participant's performances on experimental tasks were compared to age matched controls. Although the participant's diagnosis was not CAPD or APD, the design and implementation of treatment in the Crosbie and Dodd (2001) study is nearly identical to the type of intervention treatment design that has been shown to be effective for individuals diagnosed with CAPD. In this single-case study, the participant was referred to speech services because of difficulty in understanding spoken language and constructing sentences. Hearing and speech assessments found the participant to be normal in all areas including normal hearing and age-appropriate non-verbal skills. The auditory discrimination therapy included eight sessions, provided on an individual basis with the clinician, twice weekly at school. Auditory training involved two strands, monitoring skills and auditory discrimination. A criterion of 90 % accuracy was used to measure the effects of therapy. Reading was chosen as an unrelated skill not targeted towards therapy. Reading was measured before and after the period of therapy so that any change in Amy's ability to discriminate between words could be correlated with the therapy and not other factors. A series of linguistic and non-linguistic auditory processing tasks were presented to the participant. Non-linguistic tasks were based off of the Learning Development Aids (1985) and included asking the participant "What was that sound?" In these non-linguistic tasks, the participant had to analyze the sound accurately, access word knowledge, and match it to a representative picture. In the linguistic auditory processing tasks, the participant's processing skills were assessed with a word and non-word discrimination task. The participant's performance was compared to a group of age-matched peers. In the discrimination of real world minimal pairs, twenty four word pairs were spoken by the researcher. Half of the items differed in one phoneme. The participant had to judge if the words were the same or different (Yes/No response). Results in this discrimination task indicated that the participant's eight errors were the result of judging two different words as being the same. Syllable length did not affect the number of errors, but the position of the sound change did. In the discrimination of non-word minimal pairs, the participant listened to twenty-four pairs of non-words and had to decide whether or not they were the same. The items followed the same variations as the word task and the same auditory processing skills as the word minimal pair task. In this task, the participant's errors were the result of misjudging the two non-words as the same. The number of errors increased with syllable length but was not affected by the position of the sound change in the non-word. The participant's patterns of performances indicated a specific linguistic auditory discrimination problem, which has been found to later lead into difficulty with phonological discrimination, word recognition, and lexical access.

An additional task that was measured was phonological awareness. During this phase, the participant had to engage in a variety of tasks including clapping segmented syllables after hearing the words aurally, segmenting words into syllables, and isolating syllables. The participant performed at an age developmental level on all phonological discrimination tasks.

On the lexical decision task where the participant had to identify a string of speech sounds as a word or reject an unfamiliar string, her scores compared to a normal age control score. On the two picture-name verification tasks, there was no control data available for comparison. In the semantic knowledge task where the participant had to use within-category semantic knowledge and integrate word knowledge to make a decision, the participant demonstrated the ability to work out complex relationships between items; however, the participant performed better on object test items rather than verb items. In the categorization tasks, pictures from three categorization tasks (food, clothing, and animals) were chosen and given to the participant to sort into groups. The task was non-verbal and the participant completed the task quickly and accurately. The participant was reassessed twice, at four and twelve months after the block of therapy. A psycholinguistic framework was used to pose questions about the participant's underlying processing deficits. Auditory tasks revealed a specific auditory linguistic impairment that affected word recognition and lexical access. Intervention was successful in the Crosbie and Dodd (2001) study, and the participant's post-therapy auditory discrimination abilities were within normal limits. Although the participant's discrimination skills were changed, it did not impact their overall and receptive and expressive language skills measured commonly by clinical assessments.

Earobics is a commercialized reading program that has been reported as being 'effective' by research studies conducted by *What Works Clearinghouse* (2005). The audience for this program is struggling readers, children with learning disabilities, and language/auditory deficits. Earobics provides students in Pre-K through third grade with individual instruction in early literacy skills. Similar to the intended goal of LIPS and Fast ForWord language training computer programs, Earobics is designed to improve participants' cognitive and language skills necessary for reading comprehension. However, instead of a top-down language approach that is evident in LIPS and FFW, Earobics directs cognitive and language skills in a bottom-up training approach focusing on the development of children's auditory skills in phonemic awareness, auditory processing, and phonics, with emphasis on breaking, sorting, and pushing sound back together. In this program, children practice recognizing and blending sounds, rhyming, and discriminating phonemes. The skills and question complexity adjusts based on the students' ability level. Earobics is commonly utilized by speech language pathologists in language therapy, or by educators, in conjunction with the language arts curriculum. According to the *What Works Clearinghouse* (2005) intervention effectiveness standards, this program was found to have positive effects on alphabetics and potentially positive effects on reading fluency.

Moncrieff and Wertz (2008), Miller, Uhring, and Brown (2001), and Bellis and Anzalone (2008), tested dichotic listening intervention as a possible effective bottom-up treatment intervention for individuals diagnosed with CAPD. For years, dichotic listening intervention has been used in research related to language, reading disorders, and in the clinical diagnosis of auditory processing disorders. Dichotic listening is when two different auditory stimuli are presented simultaneously to the listener. In the Moncrieff and Wertz (2008) study, children with dichotic left ear deficits received intensive training in two-phased clinical trials, that were designed to establish the efficacy of directly training dichotic listening. According to Moncrieff & Wertz (2008):

> Deficits in dichotic listening have been associated with language, learning, and reading difficulties in children. There is growing evidence that interaural symmetry during dichotic listening (primarily a left ear deficit), is a common finding among children suspected of language and auditory processing difficulties. (p. 84).

Moncrieff and Wertz (2008) further state that since dichotic listening presents more information than can be easily identified, it can also be sensitive to non-auditory factors including intelligence, attention, working memory, language, and motivation.

In Phase I of the Moncrieff and Wertz (2008) study trial, there were 8 total participants, including 2 females and 6 males ranging from 7 to 13 years of age. Out of the total, seven children were patients in the multidisciplinary diagnostic training program at Shands Hospital at the University of Florida, where they had been diagnosed with speech and language disorders. The other child was recruited to participate in research studies of CAPD at the Auditory Processing Laboratory of the University of Florida, and did not have a prior diagnosis of a speech or language disorder. All participating children in this study had achieved a normal level of performance on a standardized test of intelligence. However, two children had underlying diagnosed neurological disorders. One child had Attention Deficit Disorder and was receiving associated medication, and the other child had been diagnosed with Arnold Chiari malformation, which is a malformation in the brain resulting in headaches, fatigue, muscle weakness in the head and face, difficulty swallowing, dizziness, nausea, impaired coordination, and sometimes paralysis. These two children were still included in the Phase I treatment, as the researcher wanted to see if these co-morbid disorders would have an impact on the dichotic training. In both phases, each child was fitted with TDH-49 supra-aural earphones, and all measures of hearing and auditory processing were performed in a double-walled sound suite. Since the dichotic skills test was recommended as a screening test for auditory processing disorders in children, it was used to pre-assess each child's dichotic listening performance.

Throughout the test, two digits were presented to each ear and the child was instructed to repeat both pairs of digits following each presentation. The test consisted of twenty pairs of double digits for a total number within each ear of 40 digits. Each child was also assessed with low pass filtered speech and the frequency pattern test. Core phonological processing skills were assessed in each child with the comprehensive test of phonological processing. The subtests used were rapid naming, phonological awareness, and phonemic memory. Each test was administered in a quiet room. Participants were selected based on the results from their dichotic digits test, and if the test indicated a significant interaural symmetry due to poor performance in the left ear relative to performance in the right ear. For the purpose of this study, a significant asymmetry was defined as a difference of greater than 20% for children younger than 8 years, 15% for children ages 8 to 9 years, and greater than 10% percent for children ages 10 years and older. Training consisted of 30 minute sessions, three times a week, for a period of four weeks. Training was delivered in the sound suite via speakers.

The purpose of phase I was to suppress performance in the right ear and to enhance performance in the left ear so that the child could correctly identify seventy to one hundred percent of the material presented to the left side, since researchers hypothesized that performance on digits would be higher than performance on words. During the study, each child was instructed to listen to the presented material and to repeat everything that was heard in cases involving single-syllable digits or words. With sentence material, the children were instructed to repeat only the sentence that was heard in the left ear. Following training, each child returned for a post-training evaluation where he or she was again tested with the same auditory processing and language assessments that had been used for pre-training assessment. Phase I results indicated that seven out of the eight participants demonstrated training-induced benefits in left ear performance. Five children demonstrated benefits in right ear performance. Only two children demonstrated normal levels in both ears on dichotic listening tests. The children's ability to establish normal levels in both ears on dichotic listening tests may have been attributed to receiving supplemental outside services, in addition to the dichotic therapy.

In Phase II of the Moncrieff and Wertz study (2008), eight males and five females were recruited from the Multidisciplinary Diagnostic Training Program at Shands Hospital at the University of Florida. All participants showed normal intelligence on psychoeducational testing, but were at risk for language disorder. These participants were pre-assessed with language skills from the subtests in the Brigance Comprehensive inventory of basic skills such as listening comprehension, word recognition, and oral reading. Pre-training measures of dichotic listening were also obtained with the dichotic digits test and the competing words sub-test of the SCAN-C. All training and pre-and post assessments were administered and conducted the same way in Phase II, as in Phase I; however, the amount of trainings in Phase II were increased to up to four sessions per week. In Phase II, participants benefitted from the training experience with significant improvements in dichotic listening.

Miller et al., (2005) studied children between the ages of seven to nine with auditory processing difficulties. Participants received intensive treatments designed to improve auditory processing skills for twenty days. Three children participated in either Fast ForWord Language or Earobics computer-based intervention and two children participated in a "traditional" intervention using games, worksheets, and hands-on activities. The purpose of the Miller et al

(2005) study was to increase the amount of data for informal and formal auditory training intervention for children with auditory processing deficits, including the commercialized language and auditory programs, Earobics and Fast ForWord. Change following intervention was assessed through measures of auditory processing, phonological processing, and reading skills. The Scan-C measures performance under several conditions: filtered words, speech in the presence of background noise, and input to both ears simultaneously. The Staggered Spondaic Word Test compares performances on competing and non-competing verbal stimuli. In relation to CAPD, both of these instruments measure binaural integration, separation, and processing of non-redundant speech signal in individuals diagnosed with CAPD. In this study, both the SCAN-C and the Staggered Spondaic Word Test were used to pre-assess auditory functions of participants. Additionally, a non-word repetition task was used as a measure of phonological processing and The Gray Oral Reading Tests were used as a comprehensive measure of reading ability (rate, fluency, accuracy, and comprehension). A parent questionnaire was also administered to gauge parents' perceptions of changes in their child over the treatment period.

In the Miller et al., (2005) study, The Fast ForWord Intervention Program consisted of seven exercises, integrating and testing the following skills: working memory, sound sequencing ability, processing speed, phoneme discrimination, sustained and focused attention, auditory word recognition, listening comprehension, and syntax. The Earobics training program consisted of five computerized exercises that included auditory processing, phonology, word closure, following directions, and rhyming. Both the FFW and Earobics programs adapted to the child's performance with each exercise. The "traditional" intervention reflected what a speech language pathologist generally administers and incorporates in therapy session for individuals with

Auditory Processing Disorder. For the purpose of this study, the “traditional” intervention focused on auditory memory, auditory discrimination, auditory closure, auditory synthesis, auditory figure-ground, and auditory multisensory integration. All of these skills were presented in a game and worksheet format. During this “traditional” intervention therapy, background noise was sometimes introduced. Within each skill area, specific objectives were formulated. In this case study investigation, the SCAN-C (Test for Auditory Processing Disorders in Children, Gray Oral Reading Test-Fourth Edition, and Woodcock Johnson III permitted computation of confidence intervals. Ninety percent confidence intervals were computed for pretest and posttest scores. When the confidence intervals did not overlap, the change was considered significant. Changes >1 standard deviation and >2 standard deviation were noted. Post treatment results indicated that all of the participants that received the FFW intervention increased in their reading confidence and their ability to listen with background noise; however, all of the participants receiving FFW had had to be encouraged and redirected consistently. Additionally, the parents of the participants receiving FFW treatment reported that improvement in reading and spelling skills, as well as oral expression were not observed. The participants that received the Earobics intervention were reported as being able to use better oral expression after treatment, including improvement of grammaticality in spoken language. Increased persistence, determination, and confidence was also noted as being observed with these participants. The participants that received “traditional” therapy reported improvement in listening skills, on-task behavior, and effort in reading and writing. It was also reported that these students were trying harder, and showed increased interest in reading to self as opposed to being read to. Furthermore, regardless of the type of intervention that the participant received, all post-treatment results demonstrated language and auditory abilities within normal limits at the conclusion of intervention.

Earobics and Fast ForWord had a schedule for intervention delivery set forth by the company, Scientific Learning Corporation. For the first three days, children participated in the games for 60 minutes each day. On days four and five, children participated for 80 minutes each day. After the first week of computerized intervention treatment, children participated in five exercises for a total of 100 minutes per day, five days a week, for a total of four to six weeks. Similar to Earobics and FastForWord, there were also a repetition of trials for the traditional treatment, which gradually increased in difficulty according to the participants' response. All of the children participated in a total of four weeks of intervention (twenty days). Post intervention data were collected from the same set of pre and post assessments one to two weeks after the intervention concluded. Improved scores were found for the two children in Fast ForWord, one child in Earobics, and one child in traditional therapy. According to the article, the third child in the Fast ForWord intervention had also improved significantly by the time the post assessments were administered. The letter-word identification, spelling sounds subtests, and non-word repetition task did not show a consistent pattern of improvement. Clinically significant changes were small, with six instances of significant increases and three instances of significant decreases. All of the increases were on either Spelling of Sounds or non-word repetition.

In the Intervention Approaches For Individuals With (Central) Auditory Processing Disorder, Bellis and Anzalone (2008) presented a case study on an eight-year-old male diagnosed with CAPD. This participant was referred for therapy because of reading and spelling difficulties in the area of word attack and phonological decoding, and presented complaints of hearing difficulty in “noisy” environments. Despite these symptoms, the participant’s speech, language, and hearing abilities were within the normal range. While seen in the audiology clinic for CAPD screening, the participant was receiving special education services in the area of specific reading learning disability and was working on improving his reading fluency, reading rate, and reading comprehension.

During CAPD screening, the participant’s results were compared to age-specific normative values. The participant’s pre-treatment test results revealed a right-ear deficit on both the Dichotic Digits Test and the Competing Sentences Test, as well as a bilateral deficit on Low-Pass Filtered Speech, with the right ear worse than the left ear. The results of the central auditory evaluation correlated with a deficit in the left-hemisphere of the central auditory nervous system, including primary auditory cortex. According to Bellis and Anzalone (2008), since the primary auditory cortex region of the brain is linked with discrimination of speech sounds involving rapid acoustic changes, it may have resulted in the participant’s auditory discrimination difficulties including poor speech-sound representation. Poor-speech sound representation negatively affects reading, spelling, and phonological awareness abilities (Bellis, 2002). Additionally, tests results indicated that this participant showed difficulty with the ability to fill in missing elements of a speech signal, which impacts speech-in-noise abilities, especially when trying to hear in a noisy environment. Based on results from evaluation and screening, the following recommendations were made to this participant: 1) Modifying the classroom environment to include preferential seating in a place away from extraneous noise and with a direct line of vision to the teacher, 2) Re-teaching new vocabulary to assist with auditory closure abilities, 3) Employing sensory and visual cues, especially during written instruction, and 4) Trying to use a hearing assistive device (personal FM system). Parents and teachers of this participant were also instructed by the audiologist and speech language pathologist to use clear speech by speaking at a slower rate, enunciate key words, and introduce frequent but natural pauses during lengthy communications (Bellis & Anzalone 2008). Top-down interventions for this participant included 1) Using stimuli where words, syllables, or phonemes were exercised, and 2) Using context-based vocabulary building. Bottom-up interventions included 1) Speech-sound discrimination using consonant-vowel syllables and words with minimal pair contrasts, and 2) Basic phonological awareness training and speech-to-print skills training for transfer and application to orthographic skills. Once fundamental interventions were employed, training was repeated, except in various backgrounds of noise. Post-training results indicated an improvement in auditory abilities, with performance in the normal range for age for the left ear and in the borderline normal range for the right ear. The child's parents and teachers reported a significant improvement in the child's ability to understand speech in the classroom under noisy conditions. Although there was some improvement in phonological awareness, contextual derivation, and speech-to-print skills, intervention goals were made for the participant to continue working on improving reading speed, fluency, and reading comprehension.

A complete list of all interventions included in this literature review can be found in Appendix C.

# CHAPTER SEVEN: DISCUSSION

The purpose of this study was to provide understanding and evidence-based interventions to better prepare and inform educators on CAPD. Chermak and Musiek (1997) argue that CAPD is more common than hearing loss, and affects approximately two to five percent of the school aged population ( as cited in Bellis and Anzalone, 2008). This literature review was designed to answer the proposed clinical questions: 1) What top-up and bottom-down interventions across the psychology, audiology, educational, and speech language pathology domains are most effective for children and adolescents with Central Auditory Processing Disorder? 2) What considerations for planning research and intervention might be offered to a classroom teacher to further support students diagnosed with CAPD? In order to best examine and answer these questions, an interdisciplinary, multi-phase literature review was conducted across educational, psychology, speech language pathology, and audiology databases in terms of CAPD language, auditory, and processing components. During this multi-phase literature review the following was examined 1) Central Auditory Processing Disorder, 2) relation of bottom-up and top-down intervention to CAPD, and 3) CAPD language and auditory deficit in relation to the SOI Information Processing Model.

After reviewing and analyzing case studies, articles, books, and databases on Central Auditory Processing Disorder, there is a consistent pattern in the research and proposed APD and CAPD interventions across the educational, audiology, speech language, and psychology disciplines. All studies indicated a significant difference in post treatment intervention sessions when a combination of employed bottom-up and top-down treatment approaches were employed. Based on the eight bottom-up intervention treatments, the treatment approaches that appeared to consistently yield positive significant results were the following: 1) Auditory discrimination including following directions, listening and speaking, classroom modifications designed to reduce the effects of noise, increasing visual cues and specific remedial and compensatory strategies, 2) Improving ability to process, recall, and execute multistep directions, 3) Personal assistive listening devices such as FM or hearing aid, 4) Dichotic auditory training (testing that involved the presentation of the same stimulus to both ears simultaneously), 5) Speech-sound discrimination and 6) Earobics, a program that integrates cognitive and language skills in the development of children's auditory skills in phonemic awareness, auditory processing, and phonics. Based on seven top-down intervention treatments, the interventions that appeared to consistently yield positive significant results were the following: 1) Fast ForWord computer assisted training, 2) Lindamood Phonemic Sequencing, 3) Distinguishing phonemic sound changes, 4) Identifying, detecting, producing, or deleting specific phonemes, reinforcing memory, and reasoning skills within nonsense syllables that differ by a single phoneme, 5) Teaching listening comprehension, and 6) Teaching higher language skills.

After reviewing the description of each bottom-up and top-down treatment intervention study, it appears that there is a large emphasis on incorporating phonological awareness training in interventions to increase fluency and comprehension for individuals diagnosed with CAPD. Phonological awareness training was the primary reading educational construct found among the researched interventions. It can also be noted that most CAPD studies employed a combination of both bottom-up and top-down treatments in interventions. This finding suggests that in order for a CAPD intervention to be even more beneficial to the student, both bottom-up and top-down treatments should be considered and incorporated in relation to the student's individualized needs.

## Limitations

Although there was a large variety and number of findings based on the impact of CAPD interventions amongst multi-disciplinary academic resources, there also appeared to be many limitations. The associated CAPD disciplines do not cite each other. Furthermore, results and discussions among all referenced articles including the ASHA Technical Report (2005), state that effective intervention for the CAPD population is limited and warrants the need for increased multi-disciplinary collaboration and clinical decision making for CAPD. Results also confirmed that there are few research and intervention implications for CAPD students within the educational discipline, including Special Education. Search results in this discipline primarily included methods to improve listening in the classroom environment, but did not specifically mention CAPD or children with learning disabilities. One example includes search results from the *What Works Clearinghouse* Special Education database. Under the key word search terms of "Central Auditory Processing Disorder," "Auditory Processing Disorder," "Central Auditory Processing Disorder and intervention," and "Auditory Processing Disorder and intervention," the publications and reviews were limited, producing only nine related results, two of which offered no significant results. Additionally, there were no single study reviews or reference resources for either CAPD or APD (or unrelated specifically to CAPD or APD), and only three results for "Practice Guides For Educators" under the search terms "CAPD or APD." Similar limited findings were found for ERIC-Ebscohost and the Professional Education Development Education.

Age limitations were also found amongst some of the reviewed literature. Although the skills and intervention treatment in the CAPD studies were effective for older populations, the skills and intervention may not be applicable to the developmental level and needs of younger students diagnosed with CAPD.

Furthermore, after extensive research and review across the multi-disciplinary databases, it was difficult to find a large number of articles under the inclusion criteria for this study and with a CAPD diagnosis, even with different and specific search terms such as "Auditory Processing Disorder AND interventions or CAPD." Results were even more limited across the databases with either the search terms "Central Auditory Processing Disorder" and "Central Auditory Processing Disorder AND interventions OR Case Study." Although these search terms provided a slight limitation, effective and statistically significant results were still found for the bottom-up and top-down treatment approaches described, as well as consistent intervention pattern among all articles. It is important to also note that not all studies included in this literature review had participants with an APD or CAPD diagnosis. This includes the Crosbie and Dodd (2001), Veale (1999), and Moncrieff and Wertz (2008) studies. For these particular studies, the participant diagnosis was either Speech and Language Disorder and Severe Language Disorder. These studies were only included in the literature review because of the similarities of the academic and psychological assessment patterns and treatment between CAPD and Language Disorder. This can be seen in the Crosbie and Dodd (2001), where a single case study was conducted with a seven-year-old girl with Severe Language Disorder. Her test pattern results and therapy were very similar to the pre-assessment and therapy for individuals diagnosed with CAPD. This includes auditory discrimination therapy and phonological awareness training.

A further limitation that was found within most of the research conducted within the different disciplines and databases on CAPD, were the publication dates of the articles. Although there are some articles that were published recently and provided current and updated information on CAPD intervention and management, most of the largest and most significant findings on CAPD were found within the articles that were published between 1999 and 2005. One of the leading disciplines in the field for CAPD, the American-Speech-Language-Hearing Association, also has its most "recent" CAPD technical and management report reflective of a 2005 publication date.

## Considerations for Future Research

CAPD research is warranted in the educational field due to a lack of: 1) Educator awareness of CAPD and how it may affect the diagnosed student's academic and cognitive behavior in the classroom, 2) Readily available reference guides on empirical-based Tier II and III interventions for educators to employ in the classroom environment for CAPD students, 3) A clinical based framework to determine an appropriate duration and management goal for intervention, 4) Available research on effective CAPD interventions that best highlight constructs commonly found in education (fluency, comprehension, vocabulary, phonics) and 5) lack of instructional whole-group classroom support for teaching students with CAPD.

### Participants & Measures

In order to propose a possible study for CAPD students that educators and school psychologists may employ, an intervention compatible with the Multi-Tiered System of Supports framework and current emphasis in schools is necessary. First and foremost, children who are manifesting at least one of the many characteristics associated with CAPD should be screened with a CAPD testing tool, such as the SCAN-C. A language and auditory test should also be administered, such as the Test of Language Development, Letter-Word Identification and Spelling of Sounds subtests of the Woodcock Johnson Tests of Achievement, and Gray Oral Reading tests. Working memory may also be assessed with the Digits Forward and Digits Backward of the Test of Memory and Learning, and intelligence testing may be assessed with the WISC-IV. In order to rule out other cognitive deficits that may have affected the student's language or auditory ability, psycho-educational testing and parent-teacher rating scales should be administered, especially to help exclude ADHD and Autism Spectrum Disorders.

Many of the studies included in this literature review mention pre-assessing students with CAPD with a Children's Auditory Processing Performance Scale (CHAPPS). According to Kuk et al. (2008), the CHAPPS is designed to quantify the observed listening behaviors of children ages seven years and older. It is used as a screening test to identify children who are at risk for auditory processing disorders. It has thirty-six questions that are grouped into six listening categories – Noise, Quiet, Ideal Situation, Multiple Inputs, Auditory Memory Sequencing, and Auditory Attention Span. The response to each question may range from -5 (cannot function at all) to +1 (less difficulty) (Kuk et al, 2008, pg. 472). Due to the design and nature of this test (including observed behaviors), it could be readily administered by either a school psychologist or educator.

Once all assessment takes place and all auditory and language deficits are noted, the intervention may begin. Abnormal performance on at least two tests of central auditory function may yield a diagnosis of CAPD for a student. After testing, observation, and clinical diagnosis, students with CAPD may be either placed in Tier II or Tier III of the MTSS system, based on the severity level of their diagnosis.

**Intervention**

Depending on the students' placement, students with CAPD may receive small group intervention in Tier II or more intensive one-on-one intervention in Tier III of MTSS. In regards to the interventions studied, a combination of both bottom-up treatment and top-down treatment should be employed for students with CAPD. Additionally, environmental modifications (such as sound-proof or carpeted ground with tennis balls on bottom of chair to muffle noise) should be employed to ensure that treatments take place in a quiet room. Once a student is successful with a treatment given environmental modifications, these treatments should then be incorporated in a room with background competing noise, where CAPD students have been found to have particular difficulty with processing the sensory and instructional input. According to the interventions found, students with CAPD are more successful with deficit-specific, or individualized intervention plans depending upon the severity of their diagnosis. According to the ASHA technical report (2005), the key terms and components for an effective intervention are treatment goal, management, and approach implication (baseline performance, measureable outcomes, and schedule of treatment). Since it is difficult for educators to implement an empirical-based study within the fast-paced classroom environment, the following are more practical for a treatment study: baseline performance, measureable outcome, and schedule of treatment. This type of criteria is also consistent with what most educators and related professionals are expected to implement within the MTSS framework. Depending upon the specific needs of the CAPD student and found deficits from observation and assessment, the student may benefit more from either top-up, bottom-down, or a combination of treatments. Two critical factors that should be taken into account before the intervention is started are the management goal and schedule of treatment. All of the successful academic interventions noted in this study produced significant results with an intervention duration of between four to sixteen weeks, with the child being engaged in the intervention for five days and between 15 to 30 minutes per day. Similar to how educators set learning goals and measure of academic success on a unit, the same protocol should be set forth for a CAPD intervention. Although not all of the case studies used the same pre and post assessment measures and management goals, the studies that yielded significant results utilized a 90% confidence interval for pretest and posttest scores, and regarded the intervention as significant when the confidence intervals did not overlap. A potential proposed CAPD study may consider using a 90% percent confidence interval and academic, behavior, and observation reports from parents and teachers to manage and successfully conclude the effectiveness of a CAPD intervention.

## Conclusions

Although research suggests that students diagnosed with CAPD should receive intervention, there is very little research on intervention and instructional support for CAPD students within the educational discipline, including special education. A pattern was found within the CAPD intervention research, indicating that most of the investigated CAPD case studies employed a combination of both bottom-up and top-down treatments in intervention. This finding may possibly indicate that in order for a CAPD intervention to be beneficial to the student, both bottom-up and top-down treatment, schedule, and management goal should be considered and incorporated. This intervention may be implemented by an educator in the classroom environment, within the Multi-Tiered System of Supports Tier II and Tier III framework to best meet the student's individualized needs. For instance, the educator may choose to include a combination of environmental modifications (preferential seating, visual aids, reverberation time, personal assistive listening devices) while also designing a combination of phonological awareness training activities with auditory activities (ie, dichotic listening and speech-sound discrimination). Students participating in this treatment should be progress-monitored, while receiving intervention 15 to 30 minutes a day for approximately four to sixteen weeks. The same pre and post tests should be administered before and after intervention in order to accurately assess the students' progress.

Results concluded that CAPD intervention and qualifying factors that make a CAPD intervention effective are limited. Results of the literature review, the limited research on CAPD within each related academic discipline, and the language, audiology, and cognitive nature of the disorder confirmed that a multi-disciplinary effort is needed and that these disciplines should be encouraged to refer to and cite each other in order to provide clinical decision and effective intervention for the CAPD population.

# APPENDIX A: GLOSSARY OF RELATED TERMS

## Appendix A: Glossary of Related Terms

Auditory Cohesion-The ability to interpret, organize, and synthesize auditory information on a higher-order level of functioning. These skills are necessary for listening comprehension, organization, understanding ambiguous information, abstract reasoning, and problem solving.

Auditory Discrimination- The process used to discriminate among sounds of different frequency, duration, or intensity (high/low, long/short, loud/soft).

Auditory Latency- Refers to processing delays either in a lapse, hesitation, or delay in response time when presented with auditory stimuli requiring a response.

Auditory Memory- Refers to the recall of the acoustic signal after it has been labeled, stored, and recalled. This skill also requires that one be able to remember and recall various acoustic stimuli of different length and/or number

Auditory Processing Disorder- Disorders involving deficits in the processing of information in the auditory domain that are not due to higher order language, cognitive, or other related factors.

Bottom-Up-Focuses on auditory and environmental modification strategies in CAPD intervention

Central Auditory Processing Disorder and Auditory Processing Disorder are interchangeably used in literature.

Language-Learning Impairment- Difficulty with age-appropriate reading, spelling, and/or writing

Personal FM (Personal Frequency Modulation Systems)- Consists of a transmitter microphone used by the speaker (such as the teacher in the classroom, or the speaker at a lecture) and a receiver used by the listener. The receiver transmits the sounds to the listener's ears.

Temporal Processing- The rate at which auditory information is processed.

Top-Down- Focuses on cognitive and language strategies in CAPD intervention.

# APPENDIX B: MULTI-DISCIPLINARY CRESWELL LITERATURE MAP OF CAPD INTERVENTIONS

**Table 2: Multi-disciplinary Creswell Literature Map of CAPD Interventions**

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| Psychology Journal of Neurotherapy:<br>Search Terms: "Auditory Processing Disorder and Intervention"<br>1. Beyond DSM: The role of auditory processing in attention and its disorders (Bailey, 2012) | Medline: EbscoHost<br>Search Terms: "Auditory Processing Disorder"<br>*Very little to no results for search terms: central auditory processing disorder AND interventions or case studies"<br>1. A randomized control trial of interventions in school-aged children with auditory processing disorders (Sharma, Purdy, and Kelly, 2012)<br>2. Auditory temporal gap in children with and without auditory processing disorder (Phillips, Comeau, & Andrus, 2010) | Exceptional Education:<br>What Works Clearinghouse<br>Search Terms: "Central Auditory Processing Disorder"<br>"Auditory Processing Disorder"<br>*LIPS (Patricia & Phillis 2008)<br>*Fast ForWord (Tallal, 2008)<br>*Earobics (Houghton Mifflin Harcourt Learning Technology, 2005)<br>*Phonological Awareness Training (US DEPT OF ED, 2006)<br>*Note Limitations: In the Publications and Review section, there were only nine related results, two of which interventions had no effective results.<br>*No single study reviews, quick reviews, or reference |

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| | 3. Targeting academic success: An interdisciplinary assessment program for children with central auditory processing deficits (Hutchinson & Daria, 1998) | resources for either CAPD or APD or unrelated specifically to CAPD or APD, only three results for practice guides for educators under “CAPD” or “APD”; unrelatable as well |
| ProQuest<br>Search Terms: “Auditory Processing Disorder AND case studies OR interventions”<br>1. Training auditory | International Journal of Audiology<br>“Search Terms: CAPD and interventions”<br>1. Auditory rehabilitation for interaural asymmetry: Preliminary evidence of improved dichotic listening performance | Psychology: PsychInfo<br>Search Terms: “Auditory Processing AND case studies OR interventions”<br>1. Backward and simultaneous masking measured in children with language-learning impairments who |

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| discrimination: A single case study (Crosbie & Dodd, 2001) | following intensive training (Moncrieff & Wertz, 2008) | received intervention for Fast ForWord or laureate learning system software (Marler et al., 2001)<br>2. Short term memory and auditory processing disorders: Concurrent validity and clinical diagnostic markers. (Maerlender, 2010) |
| Speech and Language<br>Search Terms: "Auditory Processing Disorders AND case studies OR interventions<br>1. Targeting Temporal Processing Deficits through fast ForWord: Language Therapy with A new twist (Veale, 1999) | Audiology<br>Search Terms: "Auditory Processing Disorders AND case studies OR interventions"<br>1. Personal Amplification for School-Age Children with Auditory Processing Disorder (Kuk et al 2008).<br>2. Effects of Dichotic Auditory Training on Children with Central Auditory Processing | Education: Professional Development Collection<br>1. Search terms: "Central auditory processing disorder"<br>2. Targeting academic success: An Interdisciplinary Assessment Program for Children with Central Auditory Processing Deficits (Hutchinson, Daria 1998). |

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| 2. ASHA: Intervention Approaches for Individuals With (Central Auditory Processing Disorder (Bellis, Anzalone 2008)<br>3. ASHA:Clinical Forum: Treatment for Central Auditory Processing Disorders, clinical deicison-making in the assessment and intervention of central auditory processing disorders (Friel-Patt, 199).<br>4. ASHA CAPD Technical Report | Disorder (Stephenson, 2008).<br>3. Case studies of auditory training for children with auditory processing difficulties: A preliminary analysis. (Miller et al 2005)<br>4. Auditory rehabilitation for interaural asymmetry: Preliminary evidence of improved dichotic listening performance following intensive training( Moncrieff & Wertz, 2008)<br>5. Earobics Auditory Training: What Works Clearinghouse Report<br>6. The effects of auditory stimulation on auditory processing disorder: A summary of | |

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| | the findings (Swain, 2007).<br>7. Auditory temporal gap detection in children with and without auditory processing disorder (Phillips, Comeau, and Andrus 2010) | |

# APPENDIX C: INTERVENTION TABLE

Table 3: Intervention Table

| Study | Sample Size | | | | Study Design | Training Type | Training Period | Results |
|---|---|---|---|---|---|---|---|---|
| | Exp *N* | Control *N* | Diagnosis | Ages | | | | |
| Marler, 2001 | 7 | Empirical Study | Language Learning Impairments compared with Typically Developed | 6 years 10 mo-9 years 3 mo | Empirical Study | FastForWord Training Computer Assisted language intervention programs (Laureate Language Systems) | Five days a week for four weeks, minimum of fifteen minutes and maximum of 20 minutes | *No support for one type of specific program that helps to improve temporal processing. Auditory memory and maintaining attention is needed for successful temporal-auditory improvement in training |
| Lindamood Phonemic Sequencing (Lindamood, Patricia & | | | Students with language related learning | 5-9 or struggling readers | Commercialized Language Program | Language: Decoding, identify individual sounds and blends in words | Developer recommends that program last four to six months for one | *Potentially positive effects on alphabetic, reading fluency, and math |

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| Phillis 2008) | disabilitie s | | | hour a day or four to six weeks for four hours a day | |
| Veale, 1999 | Students with Speech and Language Deficit | Overview, analysis, and efficacy of the Fast ForWord Language Intervention Program | Language and Auditory: Processing and temporal sequencing skills, distinguishing phonemic sound changes, identifying specific phonemes, reinforcing memory, and reasoning skills within nonsense syllables that differ by a single phoneme, teaching listening comprehension, and | 100 minutes of the game per day | *90% of all children with language impairment improved in auditory discrimination abilities, following directions, listening and speaking, overall language development *Significant results were also in overall language abilities, auditory processing speed, working memory, phonological |

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| | | | higher language skills | | awareness, listening and comprehension skills, and syntax usage |
| Fast ForWord (Tallal, 2008) | 5-9 or struggling readers | Commercialized Language and Cognitive Reading Program | Develop and strengthen the cognitive skills necessary for successful reading and learning | Designed to be used between 30 and 100 minutes a day, five days a week. Duration is between four to sixteen weeks | *Significant positive results in fluency and comprehension |
| Phonological Awareness Training (2006, What Works Clearinghouse Intervention | Preschool 2-5, struggling readers, or students with learning | Commercialized Language Program | Identifying, deleting, detecting, or producing rhyme or alliteration | Can be used by teachers with individual children, in pairs, or in small group settings. This | *Potentially positive effects on communication/language competencies for children with learning disabilities |

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| Report) | | | | disabilities or developmental delays | | | program is generally used as a supplement to the regular classroom curriculum. |
| Hutchinson & Mauer, 1998 | 3 | 3 | APD | 7-11 years | Case Study | Recommendations include classroom modifications designed to reduce the effects of noise, increase visual cues and specific remedial and compensatory | |

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| | | | | | | strategies, improving ability to process, recall, and execute multistep and instructions, and how to process information in a “noisy” environment. | |
| Sharma et al, 2012 | 55 | 55 | APD | 7-13 years | Empirical based study | Bottom-Up and Top-Down Training Systems, including personal FM systems | *Results indicated positive outcomes for both bottom-up and top-down training systems, as well as personal FM systems |

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| | | | | | | | Six week intervention with weekly one hour sessions with a therapist in the clinic | *Personal FM systems in addition to the two different types of training yielded slightly higher positive results |
| Kuk et al., 2008 | 14 | 14 | APD | 7-11 years | | Single, blind longitudinal study | Bottom-Up treatment: Personal Amplification (hearing aid fitted in an open-ear mode) | *Results indicated that the use of the hearing aids with the noise reduction mode and directional microphone improved speech understanding in noise |
| Stephenson, 2008 | 8 | 8 | CAPD | 7-12 years | | Experimental study | Dichotic Auditory Training | Duration of the study was four weeks *All conditions that were associated with the dichotic |

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| | | | | | | | presentation of words were statistically significant |
| Phillips, et al., (2010) | 16 | 20 | APD | 10-11 years | Experimental Study | Measuring the auditory gap in children (between and within channel) | *The between channel best gap durations varied significantly between the control and APD between listener groups. *The perceptual timing processing required by the between channel is more affected by the perceptual and processing deficits found in children with APD |
| Swain, 2007 | 41 | 41 | APD | 4.3-19.8 | Case Study | Tomatis Method | 90 hours of auditory stimulation involving |

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| | | | | | | | active and passive listening<br>*Results indicate positive effect on the improvement of auditory processing skills. |
| Earobics (Houghton Mifflin Harcourt Learning Technology, 2005) | | | Students with learning disabilities, struggling readers, and language/auditory deficits | 2-8 years | Commercialized Speech-Language-Pathology Program | Cognitive and Language skills necessary for reading comprehension; directs these cognitive and language skills in a bottom-up training approach | *Program has been found to have positive effects on alphabetic and potentially positive effects on reading fluency<br>*To be used in conjunction with existing language arts program in the school |
| Crosbie | 1 | 1 | Severe | 7 years | Single Case Study | Auditory | *Results indicated that |

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| and Dodd, 2001 | | language disorder | | | discrimination therapy (eight sessions, provided on an individual basis with the clinician, twice weekly at school), Linguistic and non-linguistic auditory processing tasks, phonological awareness | the intervention was successful and the participant's post-therapy auditory discrimination abilities were within normal limits. However, although the participant's discrimination skills were changed, it did not impact her overall and receptive and expressive language skills measured commonly by clinical assessments. |
| Moncrieff and | Phase I: 8 Phase II: | Phase I: Speech and | Phase I: 7-13 years Phase II: 7-13 years | Clinical Trial Experimental Study | Phase I: Dichotic | *Phase I: 30 minute sessions, three times a |

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| Wertz, 2008 | 13 | Language Disorders Phase II: At risk for language disorder | Listening Intervention Phase II: Same Type of training, increase in # of days (3-4) | week, for a period of four weeks *Phase II: 30 minute sessions, four times a week, for a period of four weeks *Phase I: Results indicate that seven out of the eight participants demonstrated training-induced benefits in left ear performance. Five children also demonstrated benefits in right ear performance. Only two children demonstrated normal levels in both ears on dichotic |

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| | | | | | | | listening tests. *Phase II: Children benefitted from the training experience with significant improvements in dichotic listening |
| Miller, Uhring, & Brown (2005) | 5 | 5 | APD | 7-9 years | Case Study | Three children participated in Fast ForWord Language computer-based intervention and two children participated in "traditional" intervention using games, worksheets, and hands-on activities | *For the first three days, children participated in the games on Earobics and FastForWord for 60 minutes each day. On days four and five, children participated for 80 minutes each day. After, children participate in five exercises for a total of |

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| | 100 min per day, five days a week, for a total of four to six weeks. The traditional therapy followed the same schedule. All of the children participated in intervention for 4 weeks (twenty days)<br>*Results indicated improved scores found for the two children in FastForWord, one child in Earobics, and one child in traditional therapy.<br>*All of the increases were on either Spelling of Sounds or non-word |

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| | | | | | | repetition |
| Bellis and Anzalone, 2008 | 1 1 CAPD | 8 years old | Case Study | *Preferential seating *Reteach new vocabulary *Employ sensory cues via visual vues:written instructions, using a hearing assistive device (personal FM system). *Instructions should be given in: clear speech by speaking at a slower rate, enunciating key words, and introducing frequent but natural pauses | Auditory training activities (speech-sound discrimination using consonant-vowel syllables and words with minimal pair contrasts, and basic phonological awareness training (Earobics) &Earobics was employed 30 | *Child's parents and teachers reported a significant improvement in the child's ability to understand speech in the classroom under noisy conditions. Further goals would continue to focus on improving reading speed and fluency as well as reading comprehension, although these skills also were reported to demonstrate some improvement following |

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| | | during lengthy communications. | min per day, 5 days a week, for 6 weeks using a computer and a quiet therapy room | therapy. |

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