ASSESSMENT OF AUDITORY PROCESSING IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER AND LANGUAGE-BASED LEARNING IMPAIRMENTS[*]

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Introduction and background

Temporal processing disorders

The 1995 report on Central Auditory Processing: Current Status of Research and Implications for Clinical Practice (ASHA, 1996) published definitions of

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major issues relative to central auditory processing. In that consensus statement, **Central Auditory Processes** include the auditory system mechanisms and processes responsible for the following behavioral phenomena:

Sound localization and lateralization
Auditory discrimination
Auditory pattern recognition
Temporal aspects of audition*, including –
temporal resolution
temporal masking
temporal integration
Temporal ordering
Auditory performance decrements with competing acoustic signals
Auditory performance decrements with degraded acoustic signals
* (Emphasis added here)

According to the ASHA statement, these mechanisms and processes are presumed to apply to nonverbal as well as to verbal signals, and to affect many areas of function, including speech and language. They have neurophysiological as well as behavioral correlates.

Further, a Central Auditory Processing Disorder (CAPD) is defined as an observed deficiency in one or more of the behaviors listed above. The diagnosis of a CAPD is accomplished using a variety of indices, including behavioral auditory measures that encompass . . . . . "tests of temporal processes – ordering, discrimination, resolution (e.g., gap detection), and integration."

In research conducted over many years, Tallal and her associates (Tallal, Miller and Fitch, 1993; Merzenich et al., 1996, Tallal et al., 1996) contend that dysfunction of higher level speech processing, necessary for normal language and reading development, may result from difficulties in the processing of basic sensory information. One component of basic sensory information is the role that temporal processing plays in relation to identification of brief phonetic elements presented in speech contexts (Tallal et al., 1996). Tallal states that " . . . rather than deriving from a primarily linguistic or cognitive impairment, the phonological and language difficulties of language-learning impaired children may result from a basic deficit in processing rapidly changing sensory inputs"

(Page 81). She proposes that temporal deficits disrupt normal development of an efficient phonological system, and that these phonological processing deficits result in subsequent failure to speak and read normally (Tallal et al., 1993). A brief summary of the work of Tallal and her associates is that processing of rapidly occurring acoustic information is critically involved in the development and maintenance of language. In fact, language-impaired children differ considerably from normally developing children in the rate at which they access sensory information.

In summary, results of research conducted over the years have established that sensory analysis of the temporal aspects of auditory signals is critical to the understanding of speech and language. Disorders in the discrimination of temporal (timing) or spectral cues of speech can lead to a breakdown in phonemic discrimination, and consequent disorders in receptive and expressive language and reading.

Auditory fusion test-revised

The Auditory Fusion Test-Revised (AFT-R) is a procedure for measuring temporal processing ability by determining the duration in milliseconds (msec) at which listeners can detect a brief silent interval between two pure tone pulses, and report whether tonal presentations are heard as one or two. The inter-pulse interval (IPI) of the tones is varied between zero and 300 msec. The auditory fusion threshold (AFT) is computed by averaging the ascending (the interval at which the tone pairs are perceived as two) and descending (when the interval at which the tone pairs are perceived as one) fusion points for each of five frequencies (250, 500, 1000, 2000, and 4000Hz). These two points are averaged to arrive at the AFT for that frequency. After determining the AFT for each frequency tested, the average AFT across all frequencies is computed.

Competing sentence tests

The Competing Sentence Test (CST) is a dichotic listening test in which sentences of equal length and duration but different semantic content are presented to the two ears simultaneously. Stimulus intensity is equal, at the subject's most comfortable listening level. Subjects are asked to listen to and repeat verbatim the sentence presented in one ear while ignoring the sentence presented to the opposite ear. The competing sentence score indicates an individual's auditory maturation (developmental level) or damage to the auditory reception areas of the cortex. A depressed score may suggest that the adolescent's auditory system is functioning similar to that of a younger person.

When competing sentence tests are administered to children below the age of 10 years, performance from the right ear approaches 100%. Results from the left ear are highly variable in young children, with improvement in mean scores from 0% to 100% between the ages of 5 and 9 years. The increased performance in the left ear reflects maturation of the auditory system. When overall performance in adolescents and adults is poor, or when scores in either the right or left ear are depressed, the result is abnormal, indicating the presence of an auditory processing disorder. Adolescents with developmental disabilities may experience decreased performance in the left ear due to delays in the maturation of the central nervous system. With maturation, improvement in left ear performance will occur. Persons with learning disabilities or central nervous system disease may experience reduction of test performance in both ears. Persons with specific hemispheric damage from trauma, infarct or tumor will experience decreased performance in the ear opposite the damage. Finally, persons with degenerative disease of the central nervous system may experience reduction of test performance in one or both ears.

Attention Deficit Hyperactivity Disorder-ADHD

"Attention deficit hyperactivity disorder (ADHD) is a persistent pattern of inattention and/or hyperactivity-impulsivity. To be diagnosed with ADHD a child must have symptoms that are more frequent and severe than is typically observed in individuals at a comparable level of development. The symptoms must be manifested in at least two settings, interfere with developmentally appropriate social, academic or occupational functions; and have been present before the age of 7 years" (Chermak & Musiek, 1997). ADHD is also a major cause of school failure among children today (Barkley, 1990).

Numerous terms such as "defect in motor control", postencephialitic disorder, hyperkinesis, hyperkinetic reaction to childhood, minimal brain dysfunction, hyperkinetic syndrome, and attention deficit disorder (ADD) with and without hyperactivity have been used to describe this disorder during the past several decades. The present terminology, attention deficit hyperactivity disorder, as reflected in The Diagnostic and Statistical Manual of Mental Disorders, 1994 (DSM-IV) lists nine symptoms of inattention; six of hyperactivity, and three of impulsivity. The DSM-IV and its definition of ADHD is widely used for making a diagnosis. Histories of children with possible central auditory processing disorders (CAPD) describe similarities between the behaviors of these two disorders.

In recent years there has been growing interest in the relationship between CAPD and ADHD. There seems to be general agreement that a complex relationship between these disorders exist. However, the nature of this association remains unclear. Studies by Gascon, Johnson, and Burd, (1986) and Cook, Mausback, Burd, and Gascon, (1993) have suggested that tasks used in the assessment of auditory processing may, in fact, be more sensitive to the presence of attention deficits (assessing attention). Keith et al. (1989) conducted research to compare results of SCAN with other central auditory and language tests and found that children with histories of Attention Deficit Disorder have poorer SCAN scores than children without ADD.

Language-based Learning Impairment (LLI)

The term language-based learning impairment (LLI) is used to describe those children with learning disabilities specifically related to language and its effect on verbal expression, listening, writing, and reading.

Tallal and Piercy (1973) found that the phonological and language deficits of children with LLI might stem from an inability to process the rapidly changing acoustic cues of fluent, ongoing speech. It is also suggested a LLI may be attributed to difficulty in phonological discrimination, which is a function of the processing system (Rissman et al., 1990).

In addition to having difficulty comprehending auditory information, children with LLI frequently display poor reading, writing, and spelling abilities. Failure to learn to read is the most common academic problem associated with a language-based learning impairment. For instance, such children find it difficult to learn phonics and may read slowly. Also, when reading orally, words are often omitted or substituted. These problems are suspected to arise from poor perceptual processing of acoustic information (Taub et al., 1994). Similarly, Merzenich et al. (1996) hypothesized that the abnormal language learning of this population of children with LLI can be attributed to deficits in phonetic reception of language which may be the result of abnormal perceptual learning early in life.

Although the links among CAPD, language disorder, and learning disability are complex, CAPD is frequently reported in association with learning disabilities (Jerger et al., 1987, Willeford 1980,1985), and language impairment (Keith, et al., 1989, Tallal et al., 1993). Tallal & Piercy (1973) discovered that many children with LLI have temporal processing deficits. Specific therapeutic strategies involving extensive daily training with computer games with acoustically modified speech were implemented to obtain improvements in temporal processing thresholds (Tallal et al., 1996; Merzenich et al., 1996). Results revealed significant improvements in the speech discrimination and language comprehension abilities of children with LLI.

Several tests are available to diagnose CAPD. Two examples include the competing sentence test (CST) and the auditory fusion test-revised (AFT-R). The competing sentence test, as described previously, is a dichotic test (ASHA, 1996) consisting of paired sentences of equal duration. The listener is instructed to direct attention to the sentence presented in one ear while ignoring the sentence presented to the other ear. The AFT-R, a gap detection test, is an example of a temporal processing test (ASHA, 1996). Performance on the Auditory Fusion Test indicates the temporal integrity of the auditory system (McCroskey and Kidder, 1980). Results of the AFT-R help detect auditory temporal deficiencies that may be a contributing factor to problems of comprehension in children and adults (McCroskey and Keith, 1996).

In order to demonstrate how the competing sentence test and the Auditory Fusion Test-Revised are used, results of two experiments using these measures are reported here. Experiment 1 was conducted on children with ADHD using an expanded central auditory test battery. Experiment 2 was conducted to verify published data on two different tests of central auditory function in both children with ADHD and children with LLI. The tests used included the competing sentence test (CST) and the auditory fusion test-revised (AFT-R). Both of these tests have been available for several years, however, were recently recorded on compact disk. It was necessary to verify that previously published normative values remained unchanged by this new format. Original norms were obtained on children with no evidence of attention deficit disorder. In addition, the CST was developed on adults and norms that currently exist only for subjects aged 12-50 years. There is a need to develop norms on younger children to (a) see how they compare to CST norms published by Willeford (1985), and (b) to see if they can help to diagnose auditory processing problems in children with ADHD and LLI.

Methods

Subjects

The subjects were 35 children, ranging in age from 6 to 10 years. Subjects were patients from the University Affiliated Cincinnati Center for Development Disorders. Eighteen children (10 boys and 8 girls) between the ages of 6 and 9 years with a mean of 8.3 years had a primary diagnosis of attention deficit hyperactivity disorder (ADHD). Thirteen were on medication for the control of hyperactivity. Seventeen children (11 boys and 6 girls) between the ages of 6 and 10 years with a mean of 8.2 years had a language-based learning impairment (LLI).

Only those children demonstrating normal intelligence with I.Q.[s] above 80 as measured by the Wechsler Intelligence Scale for Children-Revised (WISC-R) were included in this study. All children had normal hearing sensitivity bilaterally at octave frequencies 500 to 4000Hz, and tympanograms showing normal middle ear function. Care was taken to exclude from the study children with histories of seizures, head trauma, or other neurologic disorder, and non-native speakers of English.

Procedure

All children were tested at the University Affiliated Cincinnati Center for Developmental Disorders, in Cincinnati Ohio. The "experimental" tests included the auditory fusion test-revised (AFT-R), (McCroskey & Keith, 1996) and the competing sentence test (CST) from SCAN-A (Keith, 1994).

The AFT-R and the CST were administered to each child individually under headphones in a double-room soundproof booth. Each child first received verbal instructions. Only after the child understood the tasks were the test stimuli presented using a two-channel clinical audiometer (GSI-10 Audiometer and OB 822 Clinical Audiometer) and a D-151 C Discman CD player at 50dBSL re their spondee threshold.

The CD used was recorded by Auditec of St. Louis and contains a selection of speech materials on 23 tracks: calibration tone (track #1), SCAN (tracks 2-5), SCAN-A (tracks 6-11), AFT-R (tracks 12-21), and ACPT (tracks 22-23).

Experiment 1

Subjects

Eighteen children (10 boys and 8 girls) from the group of 35 children between the ages of 6 and 9 years with a mean of 8.3 years with a primary diagnosis of attention deficit hyperactivity disorder (ADHD) served as subjects.

Procedures

The experimental test battery to assess auditory processing abilities included the Competing Sentence Test, The Auditory Fusion Test-Revised, the subtests from SCAN-Screening Test for Auditory Processing Disorders, including Filtered Words (FW), Auditory Figure Ground (AFG), and Competing Words (CW) (Keith, 1986). The Auditory Continuous Performance Test (ACPT) (Keith, 1993) was used to assess auditory attention by evaluating a child's ability to listen to speech stimuli over a prolonged period of time and to respond only to a specific stimulus. The SCAN and ACPT test were administered in the same manner as the AFT-R and the CST using the same clinical audiometer and CD.

A diagnosis of central auditory processing disorder was made when the child failed at least two CAP tests (SCAN, AFT-R, and competing sentence test).

Experiment 2

Subjects

The seventeen children with LLI served as subjects for experiment 2. These children included 11 boys and 6 girls, between 6 and 10 years with a mean of 8.2 years.

Procedure

Only the auditory fusion test (AFT-R) and the competing sentence test (CST) described above were administered to subjects in this experiment.

Results and discussion

Experiment 1

Central auditory Test Battery Results

Of the eighteen children with ADHD included in this study, 38.8% (n=7) were diagnosed with a central auditory processing disorder based on the results from the central auditory tests battery (three SCAN subtests, CST-R and CST-L, AFT-R). Of these seven children, 16.6% (n=3) demonstrated impairment on two of the central measures; 16.6% (n=3) demonstrated difficulty on three of the measures; and 5.5% (n=1) demonstrated impairment on four measures. Children encountered less difficulty on the AFG test and the FW test of SCAN, with 5.5% (n=1) and 11% (n=2) failing these tests, respectively. The AFG test assesses word discrimination abilities in the presence of a competing background noise. Some children with ADD have difficulty processing speech in noise (Keith, 1986). Geffner et al. (1996) reported poor speech discrimination in noise in their study with children having ADD. Poor performance on the FW test suggests a need to decrease the acoustic distortions that interfere with speech communication, provide preferential seating in the classroom, and increase the speech intensity to ensure a clear signal of adequate loudness (Keith, 1986). On the CW test, 33% of the children (n=6) had great difficulty. According to Keith (1986), the Competing Words test is a dichotic speech task that reflects the development of the auditory system, auditory maturation, and hemispheric specialization. The poor results on this test suggest that children with ADHD have developmental delays of the auditory nervous system, or that they are unable to attend to the complex listening instructions that are required.

The analysis of the AFT-R thresholds for children with ADHD revealed that 27.5% of the children (n=5) had great difficulty with the task. The range of scores varied from a low of 1.8msec to a high score of 25msec,with a mean of 12.4msec (SD=6.4). Analysis of individual performance on the AFT-R test revealed that in twelve of the eighteen children with ADHD it was not possible to compute the AFT at both 250Hz and 4000Hz. Analysis of the CST results showed means of 84.4 (SD=17.5) and 45.5 (SD=35.5) for the competing sentence test-right ear (CST-R) and the competing sentence test-left ear (CST-L), respectively. There were two children who failed the CST-R, two children who failed the CST-L, and two children who failed both the CST-R and CST-L. Of the six who failed on the CST there was only one child who was not diagnosed with a central auditory processing disorder.

Correlations among administered tests

Table 1 includes correlation among tests administered in this study to ADHD children. The results of this study indicate that the SCAN Composite Standard Score showed statistically significant correlation with the AFT-R (p=.045). On the other hand, no significant correlation was found between individual SCAN subtests and the AFT-R. This non-significant correlation might be expected due to the different auditory processing abilities that are examined by these tests and the AFT-R. These findings support the need to do a battery of central auditory tests, and to include tests of temporal processing as suggested by ASHA, 1996.

There were no significant correlations between the tests examining auditory processing abilities by low redundancy speech (Filtered Word and the Auditory Figure Ground) and any other test administered in this study. This finding confirms that additional information is obtained by combining different test approaches to a central auditory test battery (Keith et al., 1989).

The mean and Standard Deviations (SD) obtained for each test administered to the ADHD group is shown in Table2. Results of the three SCAN subtests were reported in standard scores, and the ACPT is reported as an absolute score.

Experiment 2

Language-based learning impairment

The analysis of the AFT-R thresholds for children with LLI revealed that the range of scores on AFT-R varied from a low of 4.5msec to a high score of 13msec. The mean of 8.3msec (SD=2.1) found in this group was within what has been considered normal limits. Analysis of the CST results showed means of 87.0 (SD=14.0) and 47.6 (SD=23.3) for the CST-R and the CST-L, respectively. There were two children who failed the CST-R and five children who failed the CST-L. It should be noted that all but one child performed better on the CST right-ear task versus the left-ear task, indicating left-hemisphere dominance for language for most of the group. The scores of subject #10, however, suggest that brain dominance may not be well established in this child, thus implying a neurophysiologic component to this child's learning problem.

Comparison of the Auditory Fusion Test-revised (AFT-R) and the competing sentence test (CST) in children with Attention Deficit Hyperactivity Disorder (ADHD) and children with Language-based Learning Impairment (LLI).

Statistical analysis was accomplished using the SPSS for Windows Advanced Statistics, release 6.0, 1993. Means and standard deviations (SD) were calculated for the auditory fusion thresholds (Table 3), for the auditory fusion thresholds according to the frequency of the stimulus, and the competing sentence test results (Table 4) for both groups, the ADHD children and LLI children. We compared these data to results of previously published normative data from the AFT-R (McCroskey and Keith, 1996) and the competing sentence test (Willeford, 1985). The data were computer-analyzed statistically with multivariate analysis of variance for repeated measures. The criterion for significance was the .05 level of confidence. The AFT-R was reported in milliseconds, and the CST was reported in percent of correct responses from each ear.

The Auditory Fusion Test-Revised (AFT-R)

The difference between the ADHD children and LLI children was statistically significant (F=11.729, df=18.11, p=.002) with the children with ADHD showing longer (poorer) fusion thresholds. The mean and standard deviation of auditory fusion thresholds for the children with LLI were within normal limits.

Competing Sentence Test (CST)

Performance on the CST primarily indicates the level of maturation of the subject's auditory system. The mean and standard deviation of CST findings for ADHD and LLI children are shown in Table 4. In addition, normative data from the CST of the Willeford central auditory test battery are included for comparison. A t-test for independent samples revealed no significant difference between the two groups (ADHD and LLI) on both the right competing (F=.951, df=32.15, p=.336) and left competing (F=7.988,df=29.53, p=.008) conditions. A significant difference was found between the normative data and the children with ADHD and the normative data and the children with LLI on both the competing sentence test-right ear (t=-3.61, p<.05; t=-4.98, p<.05) and competing sentence test-left ear (t=-3.61, p<.05; t=-4.98, p<.05).

Based on norms established by Willeford & Burleigh (1985, 1994) normal performance from the right ear is 100%, and results for the left ear are lower and variable (0 to 100%) from age five to ten years old, at which time performance in the right and left ears are equal. Poor performance from the right ear is unusual at any age, and suggests a disordered or damaged auditory nervous system. Poor left ear performance on dichotic sentence tasks in children may reflect the decreased ability of a smaller corpus callosum in children with ADHD (Hynd et al., 1991) to transfer complex stimuli from the right hemisphere (Musiek, Gollegly, & Baran, 1984).

Summary

In summary, this report provides information on one category of central auditory processing disorder, the temporal processing disorder. The Auditory Fusion Test-Revised was used to identify that disorder, and results of a brief study that utilized this measure are described. Results showed a significant difference between the ADHD and LLI children on the AFT-R test with longer (poorer) auditory fusion thresholds obtained from children with ADHD. The children with ADHD showed abnormal performance, while those with language learning impairments were in the normal range. In the case of the competing sentence test, children in both the ADHD and LLI groups performed significantly poorer than children who were normal. These results indicate that children with attention deficit disorders in this study had problems of temporal processing, or were unable to attend to the complex instructions required by the test. The children with LLI had normal temporal processing abilities, contrary to expected results. It is highly possible that these children did not exhibit the extent of language impairment consistent with having problems of temporal processing. In this study, temporal processing disorders were not detected in children with LLI using the AFT-R, contrary to our expectations. This may also be due to the definition of LLI used in this study or possibly the small number of subjects.

The authors hope that this brief communication provides information on central auditory processing assessment that may be of use to readers of *Distúrbios da Comunicação* While there is need to develop a Portuguese language competing sentence test, the Auditory Fusion Test-Revised is a non-linguistic tonal test, and can be used with children from any linguistic background. Normative data would have to be confirmed if the test were to be used in Brazil.

Abstract

The purposes of this report are to provide information about two tests of central auditory processing disorders; competing sentence tests, and a test of temporal processing disorders called the Auditory Fusion Test-Revised (AFT-R) and to show results of these tests on two patient populations. Auditory fusion thresholds and competing sentence test scores of 18 children with Attention Deficit Hyperactivity Disorder (ADHD) and 17 children with Language-based Learning Impairment (LLI) were investigated using the AFT-R and competing sentence test (CST). Findings were compared to previously published normative values. There was a significantly different auditory fusion threshold between groups, with ADHD children scoring poorer than children with LLI and normal children. Children with ADHD had a higher mean (poorer results) and larger standard deviation of auditory fusion thresholds than found in children who were normal and those with LLI. No significant difference was found between the two groups (ADHD and LLI) on both the right competing (CST-R) and left competing sentences (CST-L). There was a significant difference of performance between the normal children and the ADHD children and LLI children on both the CST-R and CST-L. The clinical implications of these findings are discussed.

Key-words: *Central auditory processing disorders, attention deficit hyperactivity disorder, language learning impairment, temporal processing.*

Resumo

Este artigo tem dois objetivos principais. O primeiro é fornecer informação sobre dois testes de desordens do processamento auditivo central, do teste de sentenças com competição e de um teste para desordens do processamento temporal denominado Teste de Fusão Auditiva-Revisado (AFT-R). O segundo objetivo é mostrar resultados desses testes quando aplicados em duas populações. Limiares de fusão auditiva e escores do teste de sentenças com competição de 18 crianças com Déficit de Atenção e Hiperatividade (ADHD) e 17 crianças com problemas de linguagem (LLI) foram investigados usando o AFT-R e o teste de sentenças com competição (CST). Os resultados foram comparados aos valores

normativos publicados previamente. Observou-se diferença significativa entre os grupos com relação aos limiares de fusão auditiva: as crianças com ADHD apresentaram limiares mais pobres (piores) do que as crianças com LLI e as crianças normais. As crianças com ADHD tiveram uma média mais alta (resultados piores) e um desvio padrão maior de limiares de fusão auditiva do que os encontrados em crianças normais e naquelas com LLI. Nenhuma diferença significativa foi encontrada entre os dois grupos (ADHD e LLI) no teste de sentenças com competição à direita (CST-R) e com competição à esquerda (CST-L). Observou-se diferença significativa de performance entre as crianças normais, as crianças com ADHD e as crianças com LLI nos testes CST-R e CST-L. As implicações clínicas desses resultados são discutidas.

Palavras-chave: *desordens do processamento auditivo central, déficit de atenção e hiperatividade, problemas de linguagem, processamento temporal.*

Bibliography

AMERICAN PSYCHIATRIC ASSOCIATION (1994). *Diagnosis and statistical manual of mental disorders: DSM-IV.* 4th ed., Washington, DC, American Psychiatric Association.

AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION TASK FORCE ON CENTRAL AUDITORY PROCESSING CONSENSUS DEVELOPMENT (1996). Central auditory processing: Current status of research and implications for clinical practice. *American Journal of Audiology*, 5(2), 41-54.

BARKLEY, R. A. (1990). *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment.* New York, Guilford Press.

CHERMAK, G. D., & MUSIEK, F. E. (1997). *Central auditory processing disorders: New perspectives.* San Diego, Singular Publishing Group.

COOK, J. R., MAUSBACH, T., BURD, L., & GASCON, G. G. (1993). A preliminary study of the relationship between central auditory processing disorder and attention deficit disorder. *Journal of Psychiatry and Neuroscience*, 18 (3), 130-137.

GASCON, G. G., JOHNSON, R., & BURD, L. (1986). Central auditory processing and attention deficit disorders. *Journal of Child Neurology*, 1, 27-33.

GEFFNER, D., LUCKER, J. R., & KOCH, W. (1996). Evaluation of auditory discrimination in children with ADD and without ADD. *Child Psychiatry & Human Development*, 26(3): 169-179.

HYND, G. W., SEMRUD-CLIKEMAN, M., LORYS, A. R., NOVEY, E. S., ELLIOPULOS, D., AND LYYTINEN, H. (1991). Corpus callosum morphology in attention deficit-hyperactivity disorder: morphometric analysis of MRI. *Journal of Learning Disabilities*, 24(3): 141-146.

JERGER, S., MARTIN, R., JERGER, J. (1987). Specific auditory perceptual dysfunction in a learning disabled child. *Ear and Hearing*, 8:78-86.

KEITH, R. W. (1986). SCAN: *A screening test for auditory processing disorders.* San Antonio, TX, Psychological Corporation.

_____(1993). ACPT: *Auditory continuous performance test.* San Antonio, TX, Psychological Corporation.

_____(1994). SCAN-A: *A test for auditory processing disorders in adolescence and adults.* San Antonio, TX, Psychological Corporation.

_____ Rudy, J., Donahue, P. A., & Katbamna, B. (1989). Comparison of SCAN results with other auditory and language measures in a clinical population. *Ear and Hearing*, 10 (6), 382-386.

McCROSKEY, R., & KEITH, R. W. (1996). *AFT-R: Auditory fusion test-revised.* San Antonio, TX, Psychological Corporation.

_____. & KIDDER, H. C. (1980). Auditory fusion among learning disabled, reading disabled, and normal children. *Journal of Learning Disabilities*, 13(2):18-25.

MERZENICH, M. M., JENKINS, W. M., JOHNSTON, P., SCHREINER, C., MILLER, S. L., AND TALLAL, P. (1996). Temporal processing deficits of language-learning impairment children ameliorated by training. *Science*, 271: 77-83.

MUSIEK, F. E., GOLLEGLY, K. M., & BARAN, J. A. (1984). Myelination of the corpus callosum and auditory processing problems in children: Theoretical and clinical correlates. *Seminars in Hearing*, 5, 231-241.

RISSMAN, M., CURTISS, S., TALLAL, P. (1990). School placement outcomes of young language impaired children. *Journal of Speech-Language Pathology and Audiology*, 14, n. 2, pp. 49-58.

TALLAL, P., MILLER, S., BEDI, G., BYMA, G., WANG, X., NAGARAJAN, S., SCHREINER, C., JENKINS, W., AND MERZENICH, M. (1996). Language comprehension in language-learning impairment children improved with acoustically modified speech. *Science*, 271: 81-83.

_____MILLER, S. & FITCH, R. (1993). Neurobiological basis of speech: a case for the preeminence of temporal processing. In: TALLAL, P., GALABURDA, A., LLINAS, R. & von EULER, C. (eds.), *Temporal information processing in the nervous system*. New York, New York Academy of Sciences, pp. 27-47.

_____AND PIERCY, M. (1973). Defects of nonverbal auditory perception in children with developmental aphasia. *Nature*. 241: 468-471.

TAUB, C. F., FINE, E., AND CHERRY, R. S. (1994). Finding a link between selective auditory attention and reading problems in young children: a preliminary investigation. *Perceptual and motor skills*, 78: 1153-1154.

WILLLEFORD, J. A. (1980). Central auditory behaviors in learning disabled children. *Seminars in Speech, Language and Hearing*, 1: 127-140.

_____(1985). "Assessment of central auditory disorders in children". In: PINHEIRO, M. L. & MUSIEK, F. E. (eds.). *Assessment of central auditory dysfunction*. Baltimore, MD, Williams & Wilkins, pp. 239-257.

_____ & BURLEIGH, J. M. (1985). *Handbook of central auditory processing disorders in children*. Orlando, Fl, Grune and Stratton.

_____(1994). "Sentences procedures in central testing". In: Katz, J. (ed.). *Handbook of clinical audiology*. 4. ed., Baltimore, Williams & Wilkins, pp. 256-268.

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Table 1. Significant correlation coefficient among tests administered for ADHD children.

	CSS	FW	AFG	CW	CSTRE	CSTLE	AFT-R	ACPT	CONNERS	CHAPPS	FISHER
CSS	*	.000	.000	.000	a	.049	.045	a	a	a	a
FW	.000	*	.032	.000	a	a	a	a	a	a	a
AFG	.000	.032	*	.001	a	a	a	a	a	a	a
CW	.000	.000	.001	*	.046	.050	a	a	a	a	.050
CSTRE	a	a	a	.046	*	a	a	a	a	a	a
CSTLE	.049	a	a	.050	a	*	a	a	a	a	.029
AFT-R	.045	a	a	a	a	a	*	a	a	a	a
ACPT	a	a	a	a	a	a	a	*	a	a	a
CONNERS	a	a	a	a	a	a	a	a	*	a	a
CHAPPS	a	a	a	a	a	a	a	a	a	*	a
FISHER	a	a	a	a	a	.029	a	a	a	a	*

a correlation is not significant
* is printed if a coefficient cannot be computed

P<.05
*CSS, Composite Standard Score; FW, Filtered Word Test; AFG, Auditory Figure Ground Test; CW, Competing Word Test; CST-RE, Competing Sentence Test-Right ear; CST-LE, Competing Sentence Test-Left ear. AFT-R, Auditory Fusion Test-Revised,. ACPT, Auditory Continuous Performance Test.

Table 2. Mean and Standard Deviation of results obtained for each test for ADHD group. SCAN is reported in standard score with Competing Sentence Test reported as percent correct scores. AFT-R is reported in msec. ACPT is reported as score.

TESTS*															
CSS		FW		AFG		CW		CST-RE		CST-LE		AFT-R		ACPT	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
98.4	20.8	9.8	3.5	10.3	2.6	9.5	4.1	84.4	17.5	45.5	35.5	12.4	6.4	18.3	11.1

*CSS, Composite Standard Score; FW, Filtered Word Test; AFG, Auditory Figure Ground Test; CW, Competing Word Test; CST-RE, Competing Sentence Test-Right ear; CST-LE, Competing Sentence Test-Left ear. AFT-R, Auditory Fusion Test-Revised,. ACPT, Auditory Continuous Performance Test.

Table 3. Mean and Standard Deviations (SD) for Auditory Fusion Test-Revised (AFT-R) for all subjects. The AFT-R is reported in msec.

Subjects		AFT-R	
	N	Mean	SD
ADHD	18	12.4	6.4
LLI	17	8.3	2.1
Norm*	358	9.6	3,6

* test results from McCroskey and Keith, 1996.

Table 4. Mean and Standard Deviations (SD) for Competing Sentence Test-Right ear (CST-RE) and Competing Sentence Test-Left ear (CST-LE) for all children. The CST is reported in percent correct responses.

Subjects		CST-RE		CST-LE	
	N	Mean	SD	Mean	SD
ADHD	18	84.4	17.5	45.5	35.5
LLI	17	87.0	14.0	47.6	23.3
Norm*	160	97.7	3.3	75.8	24.1

* test results from Willeford, 1985.