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The effect of auditory processing abilities on acceptable noise levels

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THE EFFECT OF AUDITORY PROCESSING ABILITIES ON ACCEPTABLE NOISE LEVELS

by

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Abstract

The purpose of the present study was to determine typical acceptable noise levels (ANLs) in children diagnosed with auditory processing disorder (APD) and compare those to ANLs in children without APD. Sixteen participants, eight children with APD and eight children without APD, were administered a complete audiological evaluation and a series of APD tests [Filtered Words, Competing Sentences, and Auditory Figure Ground (0) subtests of the *SCAN – 3C*; Staggered Spondaic Word test; and Pitch Pattern test] to determine normal or abnormal auditory processing ability. Conventional ANLs were measured on each participant to determine acceptance of background noise. The results revealed no significant difference for ANLs in participants with and without APD; however, a trend for lower ANLs in those without APD seemed to be presented. Furthermore, the results showed no significant correlation between ANL and any administered APD test. Possible clinical implications/applications were discussed.

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Chapter I

Introduction

A serious problem impacting children today is auditory processing disorder (APD). The prevalence of children in the United States with APD is estimated to be 3-5% with a 2 to 1 ratio of boys to girls (Geffner & Ross-Swain, 2013). According to the American Speech-Language-Hearing Association (ASHA, 2005) APD is defined as:

> A deficit in neural processing of auditory stimuli that is not due to higher order language, cognitive, or related factors. Children with APD will show poor performance in one or more of the following abilities or skills: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination, temporal ordering, and temporal masking; auditory performance in competing acoustic signals; and auditory performance with degraded acoustic signals. (p.2)

In other words, APD refers to the difficulties in the perceptual processing of auditory information at the level of the central nervous system. Furthermore, the underlying cause is vague due to the complexity of the disorder.

Children with APD have normal hearing sensitivity, but behave similar to children who have a hearing loss (Geffner & Ross-Swain, 2013). Specifically, children with APD produce inconsistent responses to auditory stimuli and/or exhibit difficulties in a number of listening environments such as understanding speech in the presence of noise and/or understanding rapid speech (Smoski, Brunt, & Tannahill, 1992). Other characteristics children with APD may exhibit include difficulty localizing sound, poor auditory memory, frequently needing information repeated, and difficulty discriminating, remembering, and manipulating phonemes (Anthony, Kleinow, & Bobiak, 2009). Furthermore, some children with APD have academic difficulties such as reading, spelling, and/or learning problems (Sharma, Purdy, & Kelly, 2009). All of these difficulties hinder the child's listening and processing abilities in typical everyday environments, especially in the classroom (Geffner & Ross-Swain, 2013).

Furthermore, the diagnosis of APD can be difficult to make because children can present with many symptoms of APD. According to Jerger and Musiek (2000), the diagnosis of APD is complicated due to three factors. First, other childhood disorders, like Attention Deficit Disorder (ADD)/Attention Deficit Hyperactivity Disorder (ADHD) produce similar behaviors as children with APD (Jerger & Musiek, 2000). Second, children with APD and children with other problems are not accurately distinguished through the audiological procedures and APD test battery (Jerger & Musiek, 2000). Third, behaviors such as lack of motivation or attention in children with APD can confound the interpretation of the results (Jerger & Musiek, 2000). Furthermore, there is no standard APD test battery (Museik, et al., 2010). Some APD test batteries consist of behavioral testing (e.g., pure tone audiometry, word recognition testing, dichotic task, duration pattern sequence test, and temporal gap detection), electrophysiologic and/or electroacoustic testing (e.g., immitance audiometry, otoacoustic emissions, and auditory brainstem response), and neuroimaging studies (Jerger & Musiek, 2000). Other test battery approaches are completed through screenings using systematic observation of listening behavior, performance on auditory function tests, and through questionnaires related to academic achievement, listening skills, and communication (Jerger & Musiek, 2000). Two test battery approaches that are commonly used are the Buffalo Model (Katz 1992) and the Bellis/Ferre Model (Bellis & Ferre, 1999). According to Katz (1992), the Buffalo Model test battery consists of administration of the Staggered Spondaic Words (SSW), the Phonemic Synthesis (PS) Test, and the Speech-in-Noise (SIN) Test. The results of these tests are interpreted and related to a specific category of APD including Decoding, Tolerance-Fading Memory (TFM), Integration, and Organization. According to Bellis and Ferre (1999), they refined the four categories of the Buffalo Model into three primary categories (Auditory Decoding Deficits, Integration Deficits, and Prosodic Deficits) and two secondary categories (Associative Deficits and Output Organization Deficits). Furthermore, Bellis and Ferre (1999) recommend an APD test battery which evaluates dichotic listening, monaural low-redundancy speech tasks, temporal patterning, and binaural interaction. Other test batteries developed by Musiek and Chermak (1994), ASHA (2005), and American Academy of Audiology (2010) are also used in the diagnosis of APD.

Mentioned above are the listening characteristics of children with APD, and multiple test batteries used in the diagnosis of APD. Specifically, one area that children with auditory processing difficulties exhibit difficulty in is problems understanding speech in the presence of background noise. In 1991, Nabelek, Tucker, and Letowski introduced a procedure to measure the amount of background noise an individual is willing to listen to while following the words of a story. This procedure is known as acceptable noise level (ANL). According to Nabelek, Tampas, and Burchfield (2004), ANLs are reliable when compared to other speech in noise test such as the Speech

Perception in Noise (SPIN) test. In addition, in 2006, Freyaldenhoven and Smiley demonstrated that ANLs can be reliably obtained in children aged 8 and 12 years, and mean ANLs are similar to ANLs in the adult population. In 2011, Moore, Gordon-Hickey, and Jones continued this work by comparing ANLs in children (aged 8 to 10 years) and young adults (aged 19 to 29 years) and found no difference in mean ANLs between children and young adults. Furthermore, Gordon-Hickey, Adams, Moore, Gaal, Berry, and Brock (2012) found that ANLs can be measured reliably and accurately in adults and children across multiple testers in laboratories and clinics by testing the same 25 young adults among three different testers.

In summary, one problem that children with APD exhibit is the processing of auditory stimuli in the presence of background noise (Smoski, Brunt, & Tannahill, 1992). To this end, specific APD tests [i.e., Selective Auditory Attention Test (SAAT), Auditory Figure Ground (AFG) subtest of the SCAN-3 for Children (SCAN- 3C), and the Masking Level Difference (MLD) test] measure an individual's performance in background noise can be administered as part of the APD test battery. As ANL assess auditory preference for background noise, ANL testing may be added to the APD test battery to aid in the diagnosis of APD. Therefore, the following research is aimed in determining typical ANLs in children with APD and comparing those to ANLs in children without APD. The following research questions will be addressed:

1. Do children with APD have similar ANLs when compared to children without APD?
2. Do ANL results correlate with the administered APD tests results for any particular APD test administered?

Chapter II

Review of Literature

Auditory Processing Disorder (APD)

According to ASHA (2005) APD is defined as:

> A deficit in neural processing of auditory stimuli that is not due to higher order language, cognitive, or related factors. Children with APD will show poor performance in one or more of the following abilities or skills: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination, temporal ordering, and temporal masking; auditory performance in competing acoustic signals; and auditory performance with degraded acoustic signals. (p.2)

In other words, APD refers to the difficulties in the perceptual processing of auditory information at the level of the central auditory nervous system. According to Geffner and Ross-Swain (2013), the prevalence of school-age children in the United States diagnosed with APD is estimated to be 3-5% with a 2 to 1 ratio of boys to girls. Common complaints parents of children with APD report are their child has normal hearing sensitivity but behaves similar to children who have a hearing loss (Geffner & Ross-Swain, 2013). Specifically, the child produces inconsistent responses to auditory stimuli; exhibit difficulties in a number of listening environments such as understanding speech in the presence of noise, understanding rapid speech, and/or difficulty localizing sound; and difficulty remembering and repeating information (Geffner & Ross-Swain, 2013).

Furthermore, common complaints teachers of children with APD report are the child is easily distractible and inattentive (Geffner & Ross-Swain, 2013). Also, these children exhibit poor listening skills, poor auditory memory, and frequently need information repeated (Geffner & Ross-Swain, 2013). Additionally, teachers report some children with APD have academic difficulties such as reading, spelling, math, and/or learning problems (Geffner & Ross-Swain, 2013). Other complaints teachers of children with APD express are the children do not participate in class discussions, misunderstand homework assignments, and have trouble understanding stories read aloud (Geffner & Ross-Swain, 2013). These difficulties can hinder the child's listening, learning, and processing abilities in most everyday environments, especially the classroom (Geffner & Ross-Swain, 2013).

Diagnosis of APD. APD in children can be difficult to identify. Specifically, Musiek et al. (2010) reported there is no gold standard or agreed upon test battery used to identify APD; therefore, clinicians use different criterion to identify those children with APD. Two models, the Buffalo Model and the Bellis/Ferre Model, which are based on auditory test results, academic difficulties, and language difficulties were developed to help better guide in the testing and intervention of children with APD. According to Katz (2007), the Buffalo Model audiological test battery consists of pure tone threshold testing, tympanometry, and acoustic reflexes. The APD test battery consist of the SSW (Katz, 1961), the PS Test (Katz & Harmon, 1981), and the SIN test (Mueller & Bright, 1994). Once all test battery requirements are reviewed, the individual is categorized into one of four categories: Decoding, TFM, Integration, or Organization. As described by Stecker (1998), Decoding is characterized by difficulty processing rapid auditory information and responding slowly to stimuli, TFM is characterized by difficulty understanding speech in a variety of listening situations and decreased short-term memory, Integration is characterized by difficulty integrating auditory information with other information such as visual stimuli, and Organization is characterized by having difficulty sequencing events (Stecker, 1998).

Next, the Bellis/Ferre Model can also be used to categorize APD (Bellis & Ferre, 1999). The test battery consists of dichotic speech tasks, monaural low-redundancy speech tasks, tests of temporal patterning, and binaural interaction tasks. With this model, APD is categorized into one of five subtypes. The three primary APD subtypes include Auditory Decoding Deficit, Prosodic Deficit, and Integration Deficit; the two secondary APD subtypes include Associative Deficit and Output-Organization Deficit. According to Bellis (2003), the Auditory Decoding Deficit subtype is characterized by difficulties listening to degraded speech and/or in noisy situations and is the most auditory-modality-specific of the categories. The Prosodic Deficit subtype is characterized by difficulty understanding the intent of verbal messages. The Integration Deficit subtype is characterized by experiencing difficulty with tasks requiring both the left and right hemispheres of the brain to work together (i.e., present one word to the left ear and a different word to the right ear and get the participant to repeat both words). The Associative Deficit subtype is mainly a receptive language disorder and the Output-Organization Deficit subtype is mainly an attention and/or executive function disorder (Bellis, 2003).

Previous studies have been conducted on the clinical applicability of the two models. One study conducted by Katz, Kurpita, Smith, and Brandner (1992) examined the relationship between the categories within the Buffalo Model. Specifically, the researchers investigated their bases and how they relate to scholastic and language abilities. The categories investigated were Decoding, TFM, Integration (Type 1 and 2), Organization, and other (i.e., children who exhibited problems but could not be placed in a specific category). The participants were 100 children ages 6-15 years, 61% male and 39% female, who were referred to four participating centers in the United States and Canada for APD evaluations. All children had data on pure tone thresholds, word discrimination, SSW, PS test, and SIN tests. Furthermore, the parents and teachers completed a questionnaire. The authors reported that the questionnaires were not as helpful as expected due to inconsistencies in the responses and confusion by the parents and teachers. The children's results from the SSW, PS, and SIN were reviewed; each child's scores were compared to the indicators of each test to determine which Buffalo Model category was their primary, secondary, and tertiary category. The results indicated that when looking at each child's primary level, 47% were classified as Decoding, 22% were classified as TFM, 19% were classified as Integration, 3% were classified as Organization, and 8% were categorized as other. When evaluating each category (i.e., primary, secondary, tertiary category), regardless of the level of diagnosis, the results indicated that 66% of children were classified as Decoding, 47% were classified as TFM, 18% were classified as Organization, and 17% were classified as Integration (13% as Integration-1 and 4% as Integration-2; Katz, Kurpita, Smith, & Brandner, 1992).

A second study completed by Stecker (1998) examined 300 children diagnosed with APD from the Speech-Language and Hearing Clinic at the University of Buffalo. Each child was administered the recommended test battery using the Buffalo Model. The results showed that 49%, 16%, and 43% of children were classified in Decoding as their primary, secondary, and tertiary category, respectively; 43% of children were classified in TFM as their primary category, 23% were classified in TFM as their secondary category, and 9% were classified in TFM as their tertiary category; 8% of children were classified in Integration as their primary category with 0% being classified in Integration as their secondary and tertiary category; and 0% of children were classified in Organization as their primary category, 53% were classified in Organization as their secondary category, and 2% were classified in Organization as their tertiary category. The results showed overall 69% of children were identified as having difficulties in Decoding, 73% had difficulties in TFM, 8% were grouped into Integration, and 18% were grouped into Organization (Stecker, 1998).

Furthermore, Schow and Chermak (1999) completed a factor analysis of the SSW (Katz, 1968) and SCAN Screening Test for APD (Keith, 1986) to determine what factors were responsible for performance on the SSW and SCAN Screening Test for APD. The data reviewed had already been gathered and analyzed in a study completed by Schow, Newman, and Vause (1992; as cited in Schow & Chermak, 1999). The data that was reanalyzed consisted of 331 children, 230 males and 101 females, ages 6 to 17 years. The children who participated in the study were referred for APD testing due to factors such as underachievement, poor classroom performance, and/or attention deficits; none of the participants had confirmed APD. All children had normal hearing (i.e., equal to or better than 20 dB HL from 500 to 4000 Hz), normal speech thresholds, and normal word recognition scores in quiet. All children were administered the SSW and the Filtered Words, Competing Words, and AFG subtests of the SCAN Screening Test for APD in the conventional manner. The right competing and left competing variables were evaluated on the SSW.

A factor analysis was completed; the results showed a two-factor solution. Factor one was identified as binaural separation/competition factor evaluated by performance on left competing variables, right competing variables, and Competing Words subtest. Binaural separation involves separating stimuli when two different stimuli are presented to each ear. Factor two was identified as a monaural low-redundancy degradation involving auditory closure and was evaluated by performance on the AFG and Filtered Words subtests of the SCAN Screening Test for APD. Monaural low-redundancy tests examine one ear at a time by presenting a stimulus where the frequency, timing, or amplitude has been altered. The individual relies on auditory closure, which is the ability to fill in information that is missing. The authors indicated that factor analysis of the data on auditory performance provided an important method of grouping underlying deficits that involve APD. Furthermore, the authors suggested that factor analysis can aid in determining a gold standard for APD. However, they recommended future studies where other modality-specific tests and tests distinguishing between auditory-specific and more generalized processing deficits be administered.

To further investigate the applicability of APD test batteries, Jutras et al. (2007) completed a study to evaluate the clinical applicability of the Bellis/Ferre Model. In addition, they sought to determine the repeatability of the results obtained from previous studies using the Buffalo Model. To complete this study, the researches reviewed clinical records from audiology clinics where 178 French-speaking children diagnosed with APD were receiving intervention services for hearing difficulties. Of the 178 children, there were 48 children diagnosed with APD alone; other children were diagnosed with APD along with additional problems such as attention, dyslexia, and hearing loss. The majority of the children were educated in the regular school system where there main academic difficulties were in reading and writing.

The data in the children's records included auditory processing tests results on the French versions of the SSW (Rudmin & Normandin, 1983), the French version of the Synthetic Sentence-Identification-Ipsilateral Competing Message test (SSI-ICM; Lynch & Normandin, 1983), the monosyllabic identification under noise condition test, and the Pitch Pattern Sequence Test (PPST). All data was placed in a database and children were classified into the Buffalo Model and Bellis/Ferre Model categories. When searching the database using the Buffalo Model criteria, the inclusion criteria for the Decoding category was abnormal performance on the SSW for the right competing or left noncompeting condition or exhibiting a high/low ear effect or low/high order effect; children were categorized as TFM if performance was abnormal for the left competing condition or exhibiting a low/high ear effect or high/low order effect on the SSW; children were categorized as Organization if the number of reversals was abnormal compared to the norm. The inclusion criterion was not established for the Integration category because no data on the eight cardinal numbers was available; therefore, this category was not analyzed.When searching the database using the Bellis/Ferre Model, the inclusion criteria for an Auditory Decoding Deficit was abnormal performance on the right and left competing SSW conditions, the SSI-ICM, and the monosyllabic identification under noise condition, but normal performance on the PPST verbal and humming conditions; the inclusion criteria for a Prosodic Deficit was abnormal performance for the left ear competing SSW condition and PPST verbal and humming conditions, but normal performance on the SSI-ICM and monosyllabic identification under noise condition; the inclusion criteria for an Integration Deficit was the same as a Prosodic Deficit, except the performance on the PPST was abnormal for the verbal condition only; the inclusion criteria for an Associative Deficit was abnormal performance on all SSW conditions; and the inclusion criteria for an Output-Organization deficit was abnormal performance on all tests composed of more than two elements, such as the SSW and PPST.

The results showed that more children were categorized in at least one category of the Buffalo Model (60% in the Decoding category, 21% in the TFM category, and 6% in the Organization category) compared to the minimal amount of children categorized in the Bellis/Ferre Model (0% in the Auditory Decoding and Prosodic Deficit categories, 2% in the Integration and Associative Deficit categories, and 4% in the Output-Organization Deficit category), suggesting that the Buffalo Model is more clinically applicable compared to the Bellis/Ferre Model. This is because the Buffalo Model is based on the SSW tests results to determine deficits, whereas the Bellis/Ferre Model uses a combination of normal and abnormal results to determine deficits. The Decoding category of the Buffalo Model is where the majority of the children were placed, which is consistent with findings from a previous study by Katz et al. (1992) mentioned previously. Furthermore, based on the APD diagnosis criteria suggested by ASHA where the child is classified as having APD if the child scores are two standard deviations below the mean on at least two APD tests, 60% of the children in the current study would have been diagnosed with APD. Overall, this study showed that the two models provide a conceptual framework for APD; however, they are not perfect and questions about appropriate diagnosis and treatment still remain. Both of the models provide guidelines for intervention, but from the current study, the models are inadequate for clinical use. Therefore, further studies should be completed to assess the clinical applicability of these models in different clinical settings.

Furthermore, Singer, Hurley, and Preece (1998) investigated a number of APD tests to determine which tests were most efficient and effective in differentiating normal learning children from children with suspected APD. The researchers looked at the cost compared to the effectiveness of APD testing. The participants were 238 children ranging in age from 7 to 13 years. There were two groups of listeners, normal learning (NL) and classroom learning disabled (CLD) or suspected APD. There were 91 participants in the NL group, 71 males and 20 females, and 147 participants in the suspected APD group, 101 males and 46 females. All participants had normal hearing (i.e., pure tone thresholds of 15 dB HL or better at 250, 500, 1000, 2000, 4000, and 8000 Hz), normal word recognition ability, and normal speech and language development. The participants in the NL group were classified as average to above-average students with reading ability at or above grade level and able to follow directions. The participants in the suspected APD group had difficulty following directions, reading, and paying attention in class.

The following tests were included in the test battery: Binaural Fusion (Willeford, 1977), speech recognition MLD (Cullen & Thompson, 1974), Filtered Speech (Willeford, 1977), 60% Time Compressed Speech (Beasley & Maki, 1976), Dichotic Digits (Musiek, 1983), the SSW (Katz & Immer, 1972), and Pitch Pattern (Pinheiro, 1977). The results showed that the Binaural Fusion test separated the NL from the suspected APD group most effectively, the Filtered Speech test separated the two groups next most effectively, and the SSW was the least effective test. When hit rate, false positive rate, and cost factors were considered, a test battery approach should contain either the Binaural Fusion and Filtered Speech tests or the Binaural Fusion and MLD tests to be the most effective. The results further indicated a three-test battery approach including the Binaural Fusion, Filtered Speech, and MLD would be more effective in differentiating between these two groups; however, a two-test battery approach including the Binaural Fusion and MLD is the best battery approach when considering be effectiveness and cost efficiency.

In summary, there are a number of recommended test batteries for testing and diagnosing APD. All test batteries need to be individualized based on the individual's complaints and include a detailed case history. Musiek and Chermak (1994) recommended an APD test battery including first-order tests and second-order tests, which are used along with first-order tests or to replace first-order tests. The first-order tests include:

- Dichotic Digits-a test of dichotic processing where the individual integrates acoustic stimuli, such as numbers, presented to both ears simultaneously;
- Competing Sentences- a test of dichotic processing of heavy linguistic information where the child separates acoustic stimuli presented to both ears simultaneously;
- Frequency Patterns- a test of evaluating interhemispeheric transfer of auditory information where the individual analyzes acoustic stimuli over time; and
- Pediatric Speech Intelligibility- a test of receptive language ability for preschool children.

The second-order tests include:

- Middle Latency Response (MLR)- an electrophysiological measure to assess synchronous neural firing generated by the central nervous system;
- SSW- a test of dichotic listening where the individual integrates the different stimuli presented to both ear simultaneously;
- Compressed Speech- a test of monaural low-redundancy speech perception or a test of processing speech stimuli with spectral information removed in some way to evaluate the individual's ability to achieve closure when the auditory signal is manipulated.

Bellis and Ferre (1999) recommended a minimum APD test battery consisting of the following:

- Dichotic Speech Task- a test of dichotic processing where the individual integrates acoustic stimuli presented to both ears simultaneously;
- Monaural Low-Redundancy Speech Task- a test of processing speech stimuli with spectral information removed in some way to evaluate the individual's ability to achieve closure when the auditory signal is manipulated;
- Temporal Patterning- a test of evaluating interhemispeheric transfer of auditory information where the individual analyzes acoustic stimuli over time; and
- Binaural Interaction- a test of the ability to integrate separate stimuli presented to both ears simultaneously.

In 2003, Bellis further recommended a minimum APD test battery consisting of:

- Binaural Separation - Dichotic listening that involves directed attention - a test of dichotic processing where the individual separates acoustic stimuli presented to both ears simultaneously;
- Binaural Integration - Dichotic listening that involves report of both ears - a test of dichotic processing where the individual integrates acoustic stimuli presented to both ears simultaneously;
- Temporal Patterning Test- a test evaluating interhemispeheric transfer of auditory information where the individual analyzes acoustic stimuli over time;
- Monaural Low Redundancy Speech Test- a test of processing speech stimuli with spectral information removed in some way to evaluate the individual's ability to achieve closure when the auditory signal is manipulated;
- Temporal Detection Task- a test which assesses interhemispeheric transfer of tonal information where the individual analyzes tonal stimuli over time;
- Auditory Discrimination- a test of repeating words at a comfortable listening level; and
- Auditory Brainstem Response (ABR) and MLR to assess the status of the brainstem.

Jerger and Musiek (2000) recommended a minimum APD test battery consisting of:

- Behavioral tests including:
    - Pure-tone Audiometry to asses presence of peripheral hearing;
    - Performance-Intensity Functions for Word Recognition to asses word recognition ability over a variety of speech levels;

  - A Dichotic Task to asses dichotic processing where the individual integrates acoustic stimuli presented to both ears simultaneously;
  - Duration Pattern Sequence Test to asses interhemispeheric transfer of auditory information where the individual analyzes acoustic stimuli over time; and
  - Temporal Gap Detection to assess interhemispeheric transfer of tonal information where the individual analyzes tonal stimuli over time.
- Electrophysiologic and electroacoustic tests including
  - Immitance Audiometry to assess the middle ear function;
  - Otoacoustic Emissions (OAEs) to assess the inner ear function; and
  - ABR and MLR to asses the status of the brainstem.
- Neuroimaging test to assess the ability to process auditory information.

ASHA (2005) recommended a minimum APD test battery consisting of:

- Auditory Discrimination Test- a test of the ability to differentiate similar acoustic stimuli that differ in frequency, intensity, and/or temporal features;
- Auditory Temporal Processing and Patterning Test- a test of evaluating interhemispeheric transfer of auditory information where the individual analyzes acoustic stimuli over time;
- Dichotic Speech Test- a test of dichotic processing where the individual integrates acoustic stimuli presented to both ears simultaneously;
- Monaural Low-Redundancy Speech Test- a test of processing speech stimuli with spectral information removed in some way to evaluate the individual's ability to achieve closure when the auditory signal is manipulated;

- Binaural Interaction Test- a test of the ability to integrate separate stimuli presented to both ears simultaneously;
- Electroacoustic Measures- to assess the status of the middle and inner ear; and
- Electrophysiologic Measures- to assess the status of the brainstem.

According to Katz (1992) the Buffalo Model recommended a minimum APD test battery consisting of:

- The SSW- a test of dichotic listening where the individual integrates the different stimuli presented to both ear simultaneously;
- The PS Test- a test of individual speech sounds; and
- The SIN Test- a test of a person's ability to repeat speech with competing background noise.

AAA (2010) recommended a minimum APD test battery consisting of:

- Behavioral central auditory tests including:
    - Temporal Processing Test- a test of evaluating interhemispeheric transfer of auditory information where the individual analyzes acoustic stimuli over time;
    - Dichotic Speech Test- a test of dichotic processing where the individual integrates acoustic stimuli presented to both ears simultaneously;
    - Monaural Low-Redundancy Speech Test- a test of processing speech stimuli with spectral information removed in some way to evaluate the individual's ability to achieve closure when the auditory signal is manipulated;

- Localization, Lateralization, and Other Binaural Interaction Test- a test of the ability to integrate separate stimuli presented to both ears simultaneously; and
- Auditory Discrimination Test- a test of the ability to differentiate similar acoustic stimuli that differ in frequency, intensity, and/or temporal features.

- Behavioral peripheral auditory function tests including:
  - Distortion Product OAEs- to assess the inner ear function;
  - Immitance Measures- to assess the middle ear;
  - Pure Tone audiometry- to assess the status of peripheral hearing; and
  - Word Recognition- to assess the ability of word recognition at a comfortable speech level.
- Auditory Electrophysiological tests including:
  - ABR and/or MLR- to assess the auditory structures along the brainstem.

To determine if audiologist who tested children for APD use the recommended APD test battery, Emanuel, Ficca, and Korczak (2011) completed a survey to determine the diagnostic and intervention protocols used by audiologist when evaluating children with APD. Specifically, the researchers explored how audiologist determined specific tests to administer and if the audiologists used a test battery approach. The survey was developed based on two previous surveys (Emanuel 2002; Chermak et al. 2007) and included six sections: pretesting, screening, test battery, specific tests, management, and demographics. The survey was mailed to 515 audiologists who had an interest in APD and were members of ASHA. It consisted of 27 closed set questions and 10 additional comments sections. In addition, the survey was emailed to approximately 200 audiologists who were members of the Educational Audiology Association (EAA). The emailed copy consisted of 37 questions. Therefore, a total of 717 audiologists received the survey.

A total of 195 surveys were completed making the response rate 27%, the largest survey of current APD diagnosis and management practices to date. The data from both the mailed and emailed surveys were analyzed together. When reviewing the pretesting results, the results showed that 98.4% of audiologists reported they require a basic audiometric evaluation. Within the audiometric evaluation, 100% reported they performed pure tone audiometry, 97% reported they performed tympanometry, 92% reported they performed speech recognition thresholds, 90% performed word recognition, 69% performed acoustic reflexes, 58% performed OAEs, 54% performed word recognition in noise, 14% performed acoustic reflex decay, and 2% performed performance intensity functions. When asked if they distributed a questionnaire, 75% responded they distributed a questionnaire to the parent and 65% distributed one to the teacher. The three most popular questionnaires were Fisher's Auditory Problems Checklist (63%; Fisher, 1976), Children's Auditory Performance Scale (CHAPS) (51%; Smoski, Brunt, & Tannahil, 1998), and Screening Instrument for Targeting Educational Risk (Anderson, 1989; 39%). In addition, 20% chose other specifically listed questionnaires, and 31% specified they used site-generated questionnaires. About half (52%) of the audiologist reported they screen for APD. Out of these 52%, 69% used the Screening Test for Auditory Processing Disorders in Adolescents and Adults (SCAN-A;

Keith, 1994) or the Screening Test for Auditory Processing Disorders in Children-Revised (SCAN-C; Keith, 2000). Some audiologists (33%) used classroom observation to screen for APD, and 25% used other screening tests including speech-in-noise testing (9%), Dichotic Digits (11%), Random Gap Detection (5%), and a speech and language evaluation (3 respondents).

The majority of audiologist (97%) did use an APD test battery. Additionally, they were asked what factors determined the test battery. The largest number of responses (155 audiologist; 80%) reported they have a set minimum test battery for all patients with additions based on individual case history and age. Others (110 audiologists) reported they have a set minimum test battery for all patients with additions based on individual case history alone. Furthermore, they were asked how their test battery was selected. The majority (57%) indicated based on clinical experience; some (45%) indicated based on a review of literature; some (40%) indicated based on ASHA technical reports; and a few indicated their battery was based on seminars/workshops on APD (36%), clinical site training (31%), and/or the Bruton Conference (26%). Very few audiologists wrote in their protocol was based on the Buffalo Model (5%). Additionally, 58% reported they administer 4-5 tests in their battery; 28% reported they administer 6-9 tests in their battery; 15% administer 1-3 tests; and 5% administer 10 or more. Lastly, they were asked about the frequency of use of 27 specific APD tests in the categories of dichotic listening, monaural low-redundancy speech, temporal processing, binaural interaction, and electrophysiology. The SSW, Dichotic Digits, SCAN-A/SCAN-C, and Competing Sentences Test were ranked as always administered in the dichotic listening category. The SCAN-A/SCAN-C and the SIN test were ranked as always administered in the monaural low-redundancy category. A pitch pattern test was ranked as always administered in the temporal processing category. For the binaural interaction and electrophysiology categories, the most common answer was never administered.

In conclusion, the researchers indicated the two questionnaires that are fairly common are the Fisher's Auditory Problems Checklist and CHAPS. Furthermore, most audiologists used a test battery approach when testing for APD in children that consisted of 4-6 tests based on clinical experience and/or a review of the literature. The APD test battery is usually a set minimum battery for all patients but additions are made based on individual case history and age. According to the current survey, two thirds of the audiologists who completed the survey are not using one specific recommended test battery approach; instead they are selecting their test battery using multiple sources. The three most common tests categories administered are dichotic tests, monaural low-redundancy tests, and temporal processing tests, and the most common tests administered were the SSW, Pitch Pattern, the SIN test, Dichotic Digits, SCAN-A/SCAN-C, Competing Sentences, Low Pass Filtered tests, and Random Gap Detection (Emanuel, Ficca, & Korczak, 2011).

Furthermore, Wilson and Arnott (2013) looked at diagnostic criteria for APD testing. Specifically, the researchers attempted to quantify the rates of possible APD diagnosis using nine criteria based on the minimum APD test batteries of three groups including AAA (2010), ASHA (2005), and the British Society of Audiology (BSA; 2011) and the recommendations of three selected researchers: Bellis (2003), Dawes and Bishop (2009), and McArthur (2009). Additionally, the researchers discussed the implications for diagnosing APD.

This study was a retrospective, single-observation design where the participants were 150 children (mean age = 9.3 years), 94 boys and 56 girls. These 150 participants were retrospectively sampled from 750 children recruited from the audiology clinic in a large university in Queensland, Australia. Each participant was referred to the clinic for an APD evaluation by a wide range of professionals; these APD evaluations were completed between March 2003 and June 2009. The children exhibited no diagnosis of intellectual, cognitive, attention, emotional, or articulation impairments; attended a regular public or private school; had normal hearing sensitivity (i.e. pure-tone thresholds better than or equal to 15 dBHL at 250, 500, 1000, 2000, 4000, and 8000 Hz), normal speech performance intensity functions, normal tympanograms; and completed at least four behavioral APD tests.

All participants were given a basic audiometric evaluation including a detailed case history, otoscopy, pure-tone threshold testing, speech audiometry, tympanometry, and ipsilateral and contralateral acoustic reflexes. Then, all participants were given an APD assessment including up to seven tests based on recommendations by ASHA (2005) and Bellis (2003). Results of the Low-Pass Filtered Speech, Competing Sentences, two-pair Dichotic Digits, Frequency Patterns with Linguistic Report (FP-LR), and Frequency Patterns with Non-Linguistic Report (FP-nonlin) were reported. The FP-nonlin was administered when the participant failed the FP-LR. The results were obtained by taking the percentage scores for the right and left ears for each of the APD tests. Then, the scores were compared to the normative data by Bellis (2003) using two standard deviations below age-appropriate mean scores as the cut-off for failing the test. Once the pass/fail results were calculated, they were analyzed using nine sets of diagnostic criteria for APD [(1) failed two or more tests binaurally based on ASHA (2005) and AAA (2010) test battery; (2) failed two or more tests at least monaurally based on ASHA (2005) and AAA (2010); (3) failed one or more tests binaurally within one or more APD domains from the breakdown of APD test types in ASHA (2005) and AAA (2010); (4) failed one or more tests monaurally within one or more APD domains from the breakdown of APD test types in ASHA (2005) and AAA (2010); (5) failed two or more tests binaurally, with one or more involving nonspeech sounds and one or more involving speech sounds based on BSA (2011); (6) failed two or more tests at least monaurally, with one or more involving nonspeech sounds and one or more involving speech sounds based on BSA (2011); (7) failed one or more tests using nonspeech sounds binaurally based on Dawes and Bishop (2009) and McArthur (2009); (8) failed one or more tests using nonspeech sounds monaurally based on Dawes and Bishop (2009) and McArthur (2009); and (9) failed any tests in a pattern consistent with the primary APD subprofiles by Bellis (2009)] based on three professional groups including AAA (2010), ASHA (2005), and BSA (2011); researchers who based APD diagnosis on nonspeech stimuli (Dawes & Bishop, 2009; McArthur, 2009); and one researcher who found APD subprofiles that are applied to APD test battery (Bellis, 2003).

The results showed that the ranking of most failed test to least failed test was the Competing Sentences, Low-Pass Filtered Speech, FP-lin, Dichotic Digits, and FP-nonlin. Furthermore, using each of the nine criteria the lowest APD diagnosis rate was 7.3% and the highest APD diagnosis was 96%. This means that when using nine different diagnostic criteria, the diagnosis of APD ranges from 7.3% to 96%. Therefore, these results indicate that in a clinical report, both a diagnosis of APD and a statement regarding the criteria, model, or approach used should be stated.

Comorbid conditions and APD. One prominent difficulty in children with APD is listening in background noise (Smoski, Brunt, & Tannahill, 1992). Therefore, children with APD can be expected to have difficulty with performance in the classroom. Along with difficulty listening in noise, children with APD also have problems with language, learning, and reading.

First, Bailey and Snowling (2002) reported APD can affect a child's language development because the perception of speech requires an ability to determine spectral shape, to detect amplitude modulation, and to detect fundamental and spectral frequency modulation. To have the ability to make these determinations, temporal resolution is needed. Temporal resolution includes being able to identify the slow changes that occur during an utterance and the fast changes that occur as a result of the production of consonants. Furthermore, speech is rarely presented in a quiet environment in a classroom setting. Therefore, the child must segregate the speech signal from the background noise to appropriately process the auditory pattern of the speech signal of interest.

Sharma, Purdy, and Kelly (2009) assessed the comorbidity of auditory processing disorders, language disorders, and reading disorders to further evaluate the relationship between auditory processing, language, and reading. The participants consisted of 68 children, 44 boys and 24 girls, 7-12 years of age who were either diagnosed with APD or had suspected APD. All participants had normal (Type A) tympanograms, normal hearing sensitivity (i.e., pure tone thresholds of at least 15 dBHL at octave frequencies from 250 to 8000Hz), present ipsialteral acoustic reflexes at 1000Hz, present transient evoked otoacoustic emissions, nonverbal intelligence score of 80 or higher, and left and right ear consonant-vowel-consonant (CVC) phoneme scores of 90% or better for speech in quiet. The participants did not have a formal diagnosis of a speech or language impairment.

Once all the participants were diagnosed with normal peripheral hearing, they proceeded to the psycho-educational, language, hearing, and auditory processing test battery. The research was completed in four sessions. The parents completed a detailed case history and the CHAPS questionnaire. The participants were administered five behavioral APD tests including Dichotic Digit Test Version 2 (DDT-2), Frequency Pattern Test, Random Gap Detection Test, compressed (45%) and reverberant (0.3 sec.) CVC words, and 500 Hz tone MLD. Next, the participants were administered the Test of Nonverbal Intelligence-3 (TONI-3; Brown, Sherbenou, & Johnsen 1997)) to assess their reasoning ability with minimum language influence. They were also administered the Clinical Evaluation of Language Fundamentals, 4th edition (CELF-4; Semel, Wiig, & Secord, 2003) to assess their receptive and expressive language. Furthermore, the participants reading fluency and accuracy were measured by administering the Wheldall Assessment of Reading Passages (WARP; Madelaine & Wheldall, 2002), and the Castle's Word/Nonword Test was used to assess their reading accuracy for regular/irregular words and nonwords. Also, their phonological awareness was measured by administering the Queensland University Inventory of Literacy; the CELF-4 forward digit task assessed their auditory memory, and the Integrated Visual and Auditory

Continuous Performance Test assessed their performance on combined visual and auditory task.

The results showed that 49 children (72%) were diagnosed with APD based on the CHAPS questionnaire and performance on the APD test battery. According to the participants performance on the CELF-4, most participants showed difficulty with following directions, recalling sentences, formulating sentences, and the forward number repetition. In addition, 52 participants (76%) were diagnosed with a language impairment. There were also 44 participants (65%) who were diagnosed with a reading disorder due to problems with reading accuracy, reading fluency, and phonological awareness. From these diagnoses of APD, language, and reading disorders, more children had a combination of difficulties rather than a single diagnosis. Additionally, the results showed that APD and attention problems do not necessarily present together due to the fact that out of the 68 participants, 26 children were diagnosed with APD but did not have attention difficulties, and 9 children were not diagnosed with APD but did have attention difficulties.

In summary, the main purpose of the current study was to determine how often children with possible APD get diagnosed with APD alone or APD with a reading disorder and/or language impairment. The authors concluded that nearly half of the children (47%) presented with problems in all three areas with only 4% with APD alone. This was probably because current APD assessments were not able to accurately distinguish between auditory processing, language, or reading deficits.

Listening in noise. Listening in noise involves the auditory processing of the signal and the language based the processing of that information. When speech becomes masked by extraneous noise, compensatory strategies must be used to understand the speech signal. With this concept in mind, Smoski, Brunt, and Tannahill (1992) evaluated the listening performance of children with APD. The participants included 64 children, 48 males and 16 females, ranging from age 7 to 11 years. All participants had normal hearing from 250 to 8000 Hz, normal middle ear function, and normal speech reception thresholds of 15 dB HL or better. All participants failed two or more of the four APD tests administered including the Competing Sentences, Dichotic Digits, Pitch Pattern, and the SSW. Furthermore, all participants had normal intelligence and scholastic aptitude.

Two questionnaires, the CHAPS and an Educator's Case History, were given to each participant's teacher one to two weeks before APD testing. The CHAPS is a questionnaire which evaluates listening behavior in a variety of listening environments such as quiet, ideal, multiple inputs, noise, auditory memory, and auditory attention. The Educator's Case History asked questions about classroom placement, academic success in basic subjects, social and behavioral performance, reaction towards disciple, and feelings towards school. The teacher was asked to use these questionnaires to compare listening behaviors of the participant to other children of the same age and background from less to significantly more listening difficulty or cannot function at all.

The results showed that listening performance was dependent on the listening environment (i.e. listening in noise, listening in quiet, listening in an ideal condition, listening with multiple inputs). Specifically, children with APD had trouble in more than one listening situation, but not necessarily all of the listening environments. The results further showed that all the children with APD ranged from at grade level in all academic areas to failing in all academic areas; reading was the only area where majority of the participants showed problems. These results indicated that listening characteristics and performance varied between participants. Specifically, the listening performance of children with APD was dependent on the listening condition and/or function. Furthermore, children with APD may show difficulty in one or two listening conditions but not in all listening conditions.

Likewise, Elliott, Bhagat, and Lynn (2007) sought to determine if children with APD could ignore irrelevant sounds while assessing their recall performance of visually presented stimuli. Because some children with APD demonstrate problems with understanding speech in background noise and have difficulty filtering out unrelated auditory information, previous studies have shown that the irrelevant sound effect (i.e., the phenomenon that irrelevant sounds reduce one's ability to recall visual information) has a negative effect on children based on their age. Specifically, as the child's age increased, the magnitude of the irrelevant sound distraction decreases. In the current study, the researchers sought to determine if children with APD were affected differently by speech and non-speech stimuli and compared to children without APD. Participants were matched for age and memory span performance.

The researchers examined 11 participants who had normal peripheral hearing sensitivity, normal speech reception thresholds, and were referred for APD testing and diagnosis. Additionally, there were 22 participants with no know academic, hearing, or visual deficits recruited from the East Baton Rouge Parish School system. This group was referred to as the control group. Out of the 22 participants, 11 were age matched and 11 were memory span matched to the group of children who were referred for APD testing.

The participants with APD were tested in a sound proof booth for the immediate visual span assessment and the irrelevant sound task, and the participants in the control group were tested in a quiet room. For the visual span assessment and irrelevant sound task, a list of digits from one to nine were presented individually and in a random order in the center of a computer screen for immediate recall. The participants' responses to serial recall were typed using the keyboard.

First, the immediate span task was performed where the participants completed one practice trial, three trials with a three digit length, and four trials at each list length, which was from three to nine items. The list length increased until the length when the participant failed to answer at least two of the four trials correctly. At the beginning of the immediate span task, instructions to remember the numbers in order and not speak the numbers aloud or to themselves, but to think about the numbers in their head were given. After each trial, the computer cued the participant to type in their answer by recalling the digits that just appeared on the screen. Since the list were different lengths, there was a recall message at the top of the computer screen that indicated how many numbers the participant was to recall for each trial. The participants answer remained on the screen and the computer cued if there needed to be changes made. If they needed to change their response, the participant indicated yes by pressing the "y" key and no by pressing the "n" key. To continue to the next trial, the participant pressed the spacebar.

Next, the participants completed the serial recall with the irrelevant sounds task. At the beginning, each participant's span number was entered into the computer and used to determine the list length for this task. The list length remained constant, and the span number was calculated from the highest list length where at least two trials were answered correctly. The participants were given instructions to ignore any sound and focus on remembering the digits in order and not to say anything aloud. They were instructed to follow the above-mentioned instructions for the immediate span task for entering their response. This task consisted of three auditory conditions, a quiet baseline, words (i.e., red, blue, green, yellow, white, tall, big, short, and long), and tones (i.e., 500 ms in duration at frequencies of 87, 174, 266, 348, 529, 696, 788, 800, and 972 Hz). The words and tones were presented randomly and were not repeated in a single trial. Initially, the participants completed a practice trial for each auditory condition. Then, each participant completed 33 trials total, including 10 trials for each of the three auditory conditions.

Elliott et al. (2007) found that all three groups of participants demonstrated a decrease in recall when irrelevant sounds were present, indicating that none of the participants were able to completely block out irrelevant sounds. The participants with APD had similar recall performance with both irrelevant tones and speech, indicating their responses did not differentiate with a speech and non-speech stimuli. However, the participants in the two control groups showed significant differences in their recall performance when irrelevant speech was presented compared to tones (i.e., performing worse with speech compared to tones). This suggested that participants with APD do not process auditory stimuli differences of tones and speech in the same manner as participants without APD. Specifically, children with APD experience additional difficulties when the background noise is speech compared to children without APD. The results of the current study possibly give an explanation to why children with APD have difficulty in the classroom - because they are unable to process speech in the presence of noise.

Lastly, Anthony, Kleinow, and Bobiak (2009) completed a study evaluating the relationship between auditory processing and higher level language abilities; how typical classroom noise levels affect the scores of typically developing school-aged children on higher level language performance; and the vulnerability of typically developing school-aged children, especially the children with lower auditory processing skills, to noise on higher level language performance. The participants included 49 children (ages 6 years to 8 years and 11 months) with normal hearing and vision who had not received prior speech and language services. Children with a previous diagnosis of ADD/ADHD or a learning disability were excluded from the study.

First, each participant was given the SCAN-C Revised as a screening tool to help identify children with possible APD. The four subtests administered were Filtered Words, AFG, Competing Words, and Competing Sentences. Next, the modified version of the Test of Narrative Language (TNL) was administered in quiet and in background noise; the TNL is a test which plays a sound clip of a classroom at the same intensity as the background noise in a typical classroom during activities and is used to assess the ability to repeat and understand information in stories that is presented orally and to make inferences about the information (i.e., narrative comprehension). The four subtests used were Story Comprehension without picture cues, Story Retell without picture cues, Story Comprehension with sequenced picture cues, and Story Comprehension with one picture cue. Also administered was a pTNL, which consisted of stories that paralleled the TNL subtests in length, number of elements, story sequence, number of conflicts, number of resolutions, and the stories names matched in syllable length.

Anthony et al. (2009) found that participants performed better in a quiet environment on both the TNL and pTNL narrative comprehension tests, indicating background noise has a negative effect on one's ability to comprehend, retain, and retell a short story. Furthermore, the participants with lower processing abilities scored disproportionately lower on the narrative language subtests in the presence of background noise, suggesting that those with slower auditory processing are more negatively affected by background noise. These findings indicated the presence of background noise has an effect on language performance in typical children and a heighten effect on children with slower auditory processing abilities.

Acceptable Noise Levels

Nabelek, Tucker, and Letowski (1991; as cited in Freyaldenhoven, 2007), established a procedure known as acceptable noise level (ANL). ANL is a way to quantify a listener's willingness to listen to speech in the presence of background noise. Freyaldenhoven (2007) reported that the premise of ANL is that some listeners do not accept hearing aids because of their inability to accept background noise. In other words, some listeners cannot benefit from hearing aids because they are unable to tolerate the background noise present when hearing aids are used. To measure ANL conventionally, the listener listens to a story and adjusts the level of the story to their most comfortable listening level (MCL). Next, background noise, 12-talker speech babble, is added and the listener adjusts the level of the noise to the highest level they are willing to accept while following the speech stimuli for a long period of time without becoming tense or tired.

This level is defined as the listener's background noise level (BNL). To determine the listener's ANL, the BNL is subtracted from the MCL (MCL – BNL = ANL). Lastly, there are eight factors that are not related to ANL measurements: age, hearing sensitivity, gender, type of background noise distraction, preference for background sounds, primary language of the listener, acoustic reflex thresholds or contralateral suppression of otoacoustic emissions, and speech understanding in noise scores.

ANL reliability. The following section described research related to ANL reliability in those with normal and impaired hearing. First, Nabalek, Tampas, and Burchfield (2004) conducted a study to establish the reliability of individuals' aided and unaided ANL and SPIN scores. Furthermore, the authors compared ANL and SPIN scores over a 3-month period of wearing hearing aids. The participants were 41 full-time hearing aid users (mean age = 71 years) and nine part-time hearing aid users (mean age = 69 years). Audiologists independent of the study fit the participants with hearing aids ranging from basic analog technology to high-performance digital technology to fit their individual needs.

For this study, Nabalek et al. (2004) obtained each participant's aided and unaided ANL and SPIN scores in three different sessions, when the participants were fit with hearing aids, one month post-fitting, and three months post-fitting. ANLs were measured in the conventional manner. The SPIN was administered at each participant's MCL in the conventional manner. During the second testing session, the participants completed a questionnaire regarding their hearing aid use. Based on this questionnaire, the participants were categorized into one of three groups (i.e., full-time, part-time, or non-users of hearing aids). Full-time hearing aid users were defined as those who wore hearing aids when needed; part-time hearing aid users were defined as those who wore hearing aids only occasionally; and non-users of hearing aids had rejected hearing aids.

The results showed that ANL and SPIN measurements had good and comparable reliability. The results further showed that mean ANLs remained constant for the unaided and aided conditions while SPIN scores increased in the aided condition compared to the unaided condition. These results indicated that hearing aids provided benefit for speech perception in noise performance; however, ANLs remained unchanged with the introduction of amplification. Furthermore, ANLs were not related to speech perception in noise performance. Collectively, the results showed mean ANL and SPIN scores did not change over the three month test period, indicating a listener's acceptance of background noise does not change over a three-month period and adapting to hearing aids does not indicate a change in either acceptance of background noise or speech perception in noise performance.

To continue this work, in 2006, Freyaldenhoven, Smiley, Muenchen, and Konrad completed a study to determine the reliability of ANL in a large group of adults with normal hearing. The authors also considered that ANL might be related to listening preference (i.e., how people perceive background noise); therefore, the relationship between ANL and personal preference for background sound was also examined. They hypothesized that persons who enjoyed background noise in their everyday life would have lower ANLs. Freyaldenhoven et al. (2006) tested 30 adults, half male and half female, with normal hearing sensitivity (i.e., pure-tone hearing thresholds less than or equal to 20 dB HL at 500, 1000, 2000, and 4000 Hz in each ear). All participants were 18 to 25 years (mean = 23 years). Furthermore, all participants were native English speakers with no known neurological, cognitive, or learning deficits.

A self-developed questionnaire was used to determine preference for background sounds where participants made judgments on the following scale: never (# 1), seldom (# 2), sometimes (# 3), frequently (# 4), and always (# 5). Specifically, the participants were asked to make judgments about how often they would add background noise in their everyday life when completing tasks such as reading, sleeping, driving, studying, or doing chores if they had control over the environment. Then, ANLs were examined for each adult participant in the conventional manner. The questionnaire was answered and ANLs were measured during three different sessions, each one week apart. During each session, three ANLs were measured using two types of background noise stimuli, which included speech spectrum and speech babble noises. Therefore, each participant completed six experimental trials during each test session, totaling 18 measured ANLs for each participant.

The results showed that ANLs could be reliably obtained in adults with normal hearing, at least over a three week time period. Furthermore, the results indicated consistent responses on the questionnaire for each participant at all three test sessions, meaning the participants were able to report their preference for background noise reliably. The results further showed that measured ANLs were not related to the participant's response on the questionnaire, possibly indicating that participants are not good reporters for how much background noise they are willing to accept. Based on these results, the authors concluded that ANLs are reliable over a three week time period. However, preference for background noise was not related to the patients' measured

ANL, meaning ANL has to be measured and not determined by asking a person their preference for background noise.

In addition, in 2012, Gordon-Hickey et al. conducted a study to determine the intertester reliability of ANL, MCL, and BNL. The researchers hypothesized that if the tester follows the instructions correctly, ANL measurements should be obtained reliably between different testers. Three testers were given specific ANL instructions and told to practice ANL measurements until they were comfortable with the testing. None of the testers had previously made ANL measurements prior to this study. Two testers had two years of clinical experience, and the other tester had one year of clinical experience. The participants were 25 young adults, ages 21-36 years, who had never previously participated in ANL testing. Furthermore, the participants had normal hearing sensitivity (i.e., pure tone thresholds less than 25 dB HL at 500, 1000, 2000, and 4000 Hz) and no reported otologic or neurological disorders. ANL measurements were randomly completed by three testers in the conventional manner.

The results showed ANL, MCL, and BNL were reliably obtained, independent of the tester. Based on these results, the authors concluded that when the instructions for measuring MCL, BNL, and ANL are given to the participant accurately and the participant follows the instructions correctly, there is high intertester reliability. Therefore, the comparison of ANL scores across testers is accurate.

Predictive value of ANL. One main complaint of people wearing hearing aids is listening in background noise. Therefore, Nabalek, Freyaldenhoven, Tampas, Burchfield, and Muenchen (2006) completed a study to determine if ANL could be used to predict hearing aid use. Furthermore, Nabalek et al. (2006) compared ANL data to predictive (i.e.

unaided) and outcome (i.e. aided) data; examined the reliability of the pattern of hearing aid use questionnaire; evaluated the relationship of ANL, SPIN scores, and hours of daily hearing aid use; and determined the effect of hearing aids on SPIN scores and ANLs.

The participants were 191 adults who wore bilateral hearing aids obtained within the last three years and had no known neurological or cognitive deficits. The patient's analog or digital hearing aids were used based on the participant's needs and preference. The 191 adult participants were categorized into three groups: full-time hearing aid users, part-time hearing aid users, and nonusers of hearing aids based on responses from a questionnaire that asked questions about patterns of hearing aid use and hours of hearing aid use daily.

Unaided testing was completed on all participants while aided testing was completed on 164 participants (i.e., full-time and part-time users) because the nonusers of hearing aids did not retain hearing aids. The first 58 participants were tested in three sessions, and all testing was conducted in one session for the remaining 133 participants. Unaided and aided ANLs were completed in the conventional manner. Then, the SPIN test was conducted twice at the participant's MCL in both the unaided and aided conditions.

The results showed the pattern of hearing aid use questionnaire was reliable over the three-month time period. The results further showed the mean unaided and aided ANLs were not different for any of the three groups; however, the mean unaided and aided SPIN scores were different for all of the three groups. Specifically, whereas ANL scores did not change when amplification was utilized, SPIN scores improved when tested in the aided condition. This means that, speech perception in background noise and acceptance of background noise are two different measurements and assess different areas of hearing aid performance. Lastly, when comparing the numbers of observed successful and unsuccessful hearing aid users, obtained from questionnaire responses, and predicted successful and unsuccessful hearing aid users, obtained from the regression analysis, the results showed that measured ANLs accurately predicted successful hearing aid use with 87.0% accuracy, unsuccessful hearing aid use with 83.6% accuracy, and overall accuracy for all users with 84.8% accuracy.

ANLs in children. ANLs in children and the reliability of these measured ANLs have been compared to ANLs in young adults. First, Freyaldenhoven and Smiley (2006) completed a study to determine typical ANLs in children and determine if ANLs could be reliably obtained in children. A number of variables were evaluated to determine if ANLs were influenced by factors such as age, gender, or type of noise distraction. Furthermore, the distribution of ANLs was evaluated to determine if ANLs were normally distributed in children with normal hearing.

Freyaldenhoven and Smiley (2006) tested 32 children with normal hearing sensitivity (i.e., passed a hearing screening at 20 dB HL at 500, 1000, 2000, and 4000 Hz in each ear). Sixteen children were 8 years old, half male and half female, and 16 children were 12 years old, half male and half female. All children were selected from mainstreamed schools and placed in a regular class the entire school day. Three conventional ANLs were measured using speech spectrum as the background noise stimuli, and three conventional ANLs were measured using speech babble as the background noise stimuli. Therefore, each child completed six experimental trials.

The results showed that ANLs could be measured in children ages 8 and 12 years in about 2-4 minutes with high test-retest reliability. Also, the study found that gender, age, and type of noise did not influence ANLs in children. Furthermore, ANLs are normally distributed in children with normal hearing ages 8 and 12 years and mean ANLs are similar to those of adults with normal hearing. Based on these results, the authors concluded that ANLs obtained from children and adults are similar; therefore, it was suggested that measured ANLs in children might be able to predict hearing aid success for children. This notion should be further investigated in children with hearing impairment.

Furthermore, Moore, Gordon-Hickey, and Jones (2011) investigated the difference between ANLs of children with normal hearing and ANLs of young adults with normal hearing. MCLs and BNLs were evaluated to see if there was a difference between these two measurements in the children and young adult populations. Moore and colleagues (2011) tested 34 children (ages 8 – 10 years) and 34 young adults (age 19- 29 years) with normal hearing sensitivity (i.e., passed a hearing screening at 25 dB HL or better at 500, 1000, and 2000 Hz). None of the participants had ever participated in previous ANL studies. MCL measurements were made one time, and BNL measurements were measured three times for each participant. ANL were measured using the conventional method.

The results showed that ANLs in children and young adults did not differ significantly; however, the MCLs and BNLs in young adults were greater than MCLs and BNLs measured in children. The study implied the possibility of a developmental change in MCLs and BNLs between young adults and children. The authors further indicated a possible maturation process in the auditory system due to greater MCLs in young adults. Even though the MCLs and BNLs differed, the measured ANLs in children and young adults did not differ.

Chapter III

Methods

Participants

Sixteen children (ages 7-12 years old) with normal hearing sensitivity participated in this study. The participants were divided into two groups: a control group, which consisted of 8 children with normal auditory processing abilities and an experimental group, which consisted of 8 children with APD. The participants with suspected APD were recruited from the Louisiana Tech University Speech and Hearing Center based on a referral for decreased auditory function or parental concerns with auditory related complaints. The participants without APD were recruited through telephone calls to friends and family in both Ruston and Lafayette, Louisiana. Furthermore, participants from the control group were age matched with the participants in the experimental group. None of the participants had identifiable neurological disorders or speech and language delays as reported by their parents, and all participants were right handed. Furthermore, participants were excluded based on the diagnosis of attention deficit (hyperactivity) disorder.

Please note that after reviewing charts of children who were previously diagnosed with APD by an audiologist at the Louisiana Tech University Speech and Hearing Center, there were 28 potential participants. Of the 28 potential participants, a total of 17 were excluded from the study for a variety of reasons. Specifically, two potential participants had ADD/ADHD, three were left handed, one was outside of the age range, and three exhibited multiple factors (e.g. diagnosed with ADD/ADHD and left handed or ADD/ADHD with a speech and language delay). Furthermore, three potential participants' parent/guardian rejected participation in the study and five potential participants did not return telephone calls to schedule an appointment. This left 11 potential participants of children with APD who were tested for the current study. After testing, three could not be included due to inconsistent performance on the Random Gap Detection (RGD) Test.

Qualification Procedures

Audiometric measures. All participants had normal peripheral hearing sensitivity defined as pure tone thresholds of 15 dB HL or better at 500, 1000, 2000, and 4000 Hz bilaterally. In addition, visibility of a normal tympanic membrane was present, and normal middle ear function was present as determined by peak middle ear pressure of no less than -150 daPa and no greater than +150 daPa with static compliance measures between 0.30 to 1.60 ml using a 226 Hz probe tone (Duffey, 2007). Furthermore, all participants had present ipsilateral and contralateral acoustic reflexes at 500, 1000, and 2000 Hz. Additionally, speech recognition thresholds (SRTs) were in good agreement with pure tone average and word recognition scores (WRS) were 88-100% for all participants. If any above mentioned tests were abnormal, the participant was referred for further evaluation by an audiologist or physician and excluded from the study or deferred until normal audiological results were obtained.

Central processing tests. All participants received an initial APD test battery to determine whether or not they were classified as having normal or abnormal processing abilities. The battery of testing for APD included the following; a detailed description of each test is provided in the Material Section below:

- 750 Hz Filtered Words (FW) subtest of the SCAN-3C– test of monaural low redundancy speech perception;
- Competing Sentences (CS) subtest of the SCAN-3C– test of binaural separation;
- AFG (+0) subtest of the SCAN-3C– test of monaural low redundancy speech perception;
- Staggered Spondaic Words (SSW) – test of binaural integration;
- Pitch Pattern using a hum response- test of temporal patterning; and
- Random Gap Detection (RGD) – test of temporal processing.

Materials

Otoscopy was performed using a Welch Allyn otoscope. Middle ear function and brainstem function were assessed using a Grason-Sadler Tympstar Version 2 Middle Ear Analyzer. Pure-tones and speech recognition testing were performed using a Grason-Sadler GSI-61 audiometer. Spondee words were used as the stimuli to measure SRTs. The Northwestern University Auditory Test No. 6 (NU-6) recorded word list was used as the stimuli to measure word recognition ability. The NU-6 word list, auditory processing test battery, and MCL and BNL of the ANL procedure were delivered through the GSI-61 audiometer coupled to a Tascam CD-160 CD player. EARTone 3A insert earphones were also used for presentation of all audiometric testing (i.e., pure tones, SRT, WRS, and APD tests). The front loudspeaker in the testing booth was used for completion of ANL testing. All equipment received annual electroacoustical calibration and daily biological checks to ensure consistency of performance. All qualification and experimental testing were conducted in a sound-treated examination room (IAC, Model #404A; 2.7 x 2.5 meters) with ambient noise levels appropriate for testing unoccluded ears (ANSI S3.1-1999, R2008) and at the calibration point in the booth specifically, in the center of the booth.

The SCAN-3C was one test used to determine if the child had normal or abnormal auditory processing abilities. The SCAN-3C has normative data for ages 5-12 years. The SCAN-3C is presented at 55 dB HL. The SCAN-3C has three screening tests (Gap Detection, AFG [+8], and Competing Words-Free Recall), three diagnostics tests (FW, Competing Words-Directed Ear, and CS), and three supplementary tests (AFG [+0] or [+12] and TCS). For this study, CS, FW, and AFG (+0) were used. CS measures the ability to process competing speech signals by presenting pairs of unrelated sentences to the right and left ears. The participant is to repeat the sentence heard in one ear with 10 presentations to the right and left ears. The participant was directed on which ear to listen to and repeat. FW measures the ability to process distorted speech. This test consists of 20 presentations to the left and right ears that are monosyllabic low pass filtered at 750 Hz words. AFG measures the ability to detect speech in the presence of background noise. This is completed with a zero signal-to-noise ratio (SNR). There are 20 presentations in the right ear followed by 20 presentations in the left ear. According to Keith (2009), the reliability of the SCAN-3C was estimated using test-retest stability, internal consistency, and interscorer reliability. The validity of the SCAN-3C includes evaluation of previous versions of the test, evaluation of the updated version, and research evaluating the utility of the new measure in a variety of clinical contexts.

The SSW has normative data for ages 5-69 years. The SSW presents two spondaic words dichotically (i.e., one word presented to one ear and a different word presented to the other ear at the same time) that are staggered in time. For example, the first syllable of the first word is presented to the right ear by itself; the second syllable of the first word is presented to the right ear and the first syllable of the second word is presented to the left ear and both words overlap; and the second syllable of the second word is presented to the left ear by itself. This order is alternated from right to left as the test is completed. The participant is required to repeat all four words beginning with the presentation in the first ear; the presentation level is at 55 dB HL. Four conditions (Right Non-Competing, Right Competing, Left Competing, and Left Non-Competing) provide the eight cardinal numbers used to score the SSW. According to Katz (1998), the reliability of the SSW was estimated using split-half and test-retest reliability. The validity of the SSW includes evaluation of previous versions of the test, evaluation of the updated version, and research evaluating the utility of the new measure in a variety of clinical contexts.

Pitch Pattern consists of two test versions; the child version and the adult version. The child version has normative data for ages 6-9 years, and the adult version has normative data for ages 9-65 years. Pitch Pattern presents a series of three tone burst patterns that are variable in frequency (i.e. high-1430 Hz and low- 880 Hz). The child version consists of 10 practice three tone patterns followed by 50 three tone patterns for each ear; the test is completed one ear at a time. The adult version consists of 10 practice three tone patterns followed by 60 three tone patterns for each ear. The participant is required to respond verbally or by humming the pattern; the presentation level is 50 dB HL. The responses are recorded as percent correct. The normative data for age 6 years is

45-100%, age 7 years is 60-100%, age 8 years is 70-100%, ages 9-10 years are 85-100%, and ages 11-65 years are 88-100%. Reversals are also scored on Pitch Pattern. The pattern is scored as a reversal if the participant responds "high, low, high" to a pattern of "low, high, low." Reversals are scored as percent correct; they are scored separately but still counted as correct. Reversals are indicative of a short term memory problem (Willeford & Burleigh, 1985).

RGD has normative data for ages 5-12 years. RGD presents tone and click pairs with inter-stimulus intervals of 0-40 milliseconds (msec) with specific intervals of: 0, 2, 5, 10, 15, 20, 25, 30, and 40 msec. The inter-stimulus intervals are recorded with gaps randomly assigned using a table of random numbers. The test frequencies are 500, 1000, 2000, and 4000 Hz. RGD measures the smallest time interval between two closely approximated stimuli that can be detected. The participant is required to respond verbally whether they heard one or two tones; the presentation level is at 55 dB HL. The normal gap detection threshold is between 2 and 20 msec. According to Keith (2000), the validity of RGD includes preliminary studies of two experimental standardization versions of the RGD that indicated no statistical difference in RGT thresholds of the two standardization versions.

Procedure

Prior to initiation of this study, the Institutional Review Board (IRB) at Louisiana Tech University approved this project (see Appendix A). Then, guardians of each participant signed a consent form (see Appendix B) and were allowed to ask questions before initiation of data collection. All participants also signed an assent form (see Appendix B) and were allowed to ask questions before data collection. All participants received a complete audiological evaluation including otoscopy, tympanometry, ipsilateral and contralateral acoustic reflexes, pure tone thresholds, speech testing, and an APD test battery consisting of RGD, Pitch Pattern, SSW, and the CS, FW, AFG (+0) subtests of the SCAN-3C.

For the purposes of this study and due to limitations with the number of participants, a binaural abnormality on the SSW was used to determine placement in the experimental group. Specifically, participants placed in the experimental group presented with an abnormal score on the RC and LC conditions of the SSW or an abnormal score on RNC and LNC conditions of the SSW. All other participants (i.e., those that presented with no abnormalities on the RC, LC, RNC, or LNC conditions of the SSW) were placed in the control group; please note as previously stated that those from the control group were age matched with the participants in the experimental group.

All participants also were administered ANL testing through the loudspeaker located at 0° azimuth (see Appendix C for instructions). Each participant was given two buttons, one labeled louder and one labeled softer. The button labeled louder indicated the participant wanted the examiner to increase the stimulus, and the button labeled softer indicated the participant wanted the examiner to decrease the stimulus. First, the participant's MCL was determined using the following procedure. The story was presented at 30 dB HL and increased in 5 dB steps until the story was too loud. Next, the story was decreased in 5 dB steps until it was too soft. Then, the story was increased or decreased in 2 dB steps until the participant indicated it was at their MCL. Then, with the MCL held constant, speech babble noise was added. The speech babble noise was presented at 30 dB HL and increased in 5 dB steps until the participant indicated they could not hear the story. Next, the speech babble noise was decreased in 5 dB steps until the participant indicated the story was very clear. Finally, the noise was increased or decreased in 2 dB steps to a level the participant could "put up with" while still following the story without becoming tense or tired. This test was completed twice on every participant. If the results from the first two attempts were not within 4 dB, the ANL test was completed a third time. ANL was then calculated by subtracting BNL from MCL.

For the purpose of this study, all participants completed an audiological evaluation initially. Then, the APD test battery and ANL testing were administered in a completely random order for all participants, regardless of placement in the control or experimental group. In order to reduce fatigue throughout testing, each participant was given frequent breaks throughout the 2 hour session as needed.

Chapter IV

Results

The purposes of this study were (1) to determine if children with APD had similar ANLs when compared to children without APD and (2) to determine if ANL results correlated with the administered APD tests results for any particular APD test administered. The present study included a total of 16 participants, 8 participants who were identified as having normal processing abilities (i.e., control group) and 8 participants who were identified as having APD (i.e., experimental group). Furthermore, each participant from the experimental group was age matched with a participant in the control group. The data collected was obtained from a series of APD tests including the FW, CS, and AFG (0) subtests of the SCAN-3C, the SSW, Pitch Pattern – hum response, and the RGD tests. Furthermore, ANL was completed at least twice on every participant. If the results from the first two attempts were not within 4 dB, the ANL test was completed a third time, and the median score was used for analysis purposes. The ANL test was completed three times on two participants. For each participant, the mean results were obtained by taking the average of the two ANLs, or if three ANLs were obtained, the median of the three ANLs was used. Then, the mean for all of the participants in the control group was calculated, and the mean of all the participants in the experimental group was calculated. The results are shown in Figure 1.

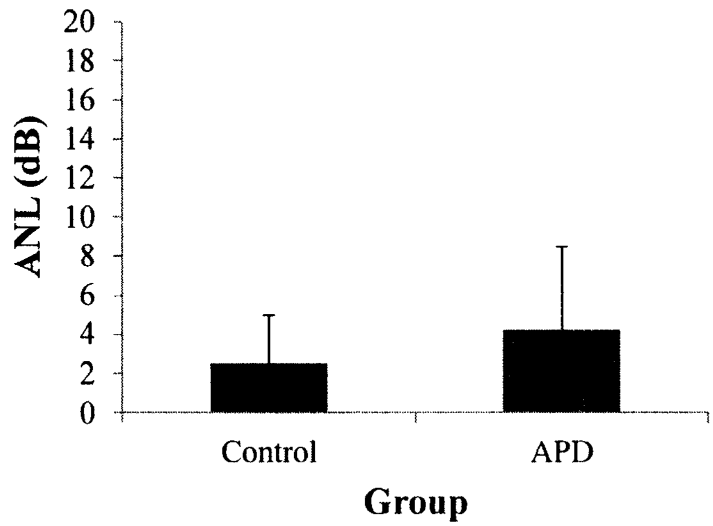

Figure 1. Mean ANLs and standard deviations for the experimental and control groups.

ANL Comparison for Children with and without APD

The first purpose of the present study was to determine if children with APD had similar ANLs when compared to children without APD. An independent sample t-test was performed to determine the effect of auditory processing ability on ANL. The independent/grouping variable was group with two levels (i.e., control and experimental/APD). The dependent variable was ANL. The results showed no significant main effect for group ($t = -0.51$, $p = 0.62$). Statistically, these results indicated participants with APD ($M = 4.25$ dB) had similar ANLs when compared to participants without APD ($M = 2.5$ dB). In other words, the participants without APD could not accept more background noise that participants with APD.

Correlation of ANL and APD Tests

The second purpose of the present study was to determine if the ANLs correlated with the administered APD tests results for any particular APD test. Each participant was administered a series of APD tests including, the FW, CS, and AFG (0) subtests of the SCAN-3C, the SSW, Pitch Pattern – hum response, and RGD tests. After reviewing the obtained tests results, the RGD test results were not included in the data analysis due to inconsistent responses from three of the eight participants.

First, Pearson correlation coefficients were performed to determine the correlation between ANL and selected administered APD tests [FW Scaled Score, CS Scaled Score, AFG (+0) Scaled Score, SSW RNC, SSW RC, SSW LNC, SSW LC, Pitch Pattern right ear (RE)-hum, and Pitch Pattern left ear (LE)-hum] (see Table 1 and Figures 2 – 11). The results showed no significant correlation between the ANL results and the administered APD tests results for any administered APD test. These results seem to indicate that ANL results are not correlated with the results for any of the administered APD tests. In other words, ANL scores do not seem to indicate or predict poor, fair, or good performance on any particular administered APD test.

Table 1. Pearson Correlation between ANL and Administered APD Tests.

APD Tests	Pearson Correlation	Significance
FW Scaled Score	.242	.366
CS Scaled Score	.133	.623
AFG (0) Scaled Score	.278	.297
SSW RNC	.367	.162
SSW RC	.326	.217
SSW LNC	.214	.426
SSW LC	.251	.575
SSW Total	.286	.282
Pitch Pattern RE – hum	.306	.249
Pitch Pattern LE - hum	.346	.189

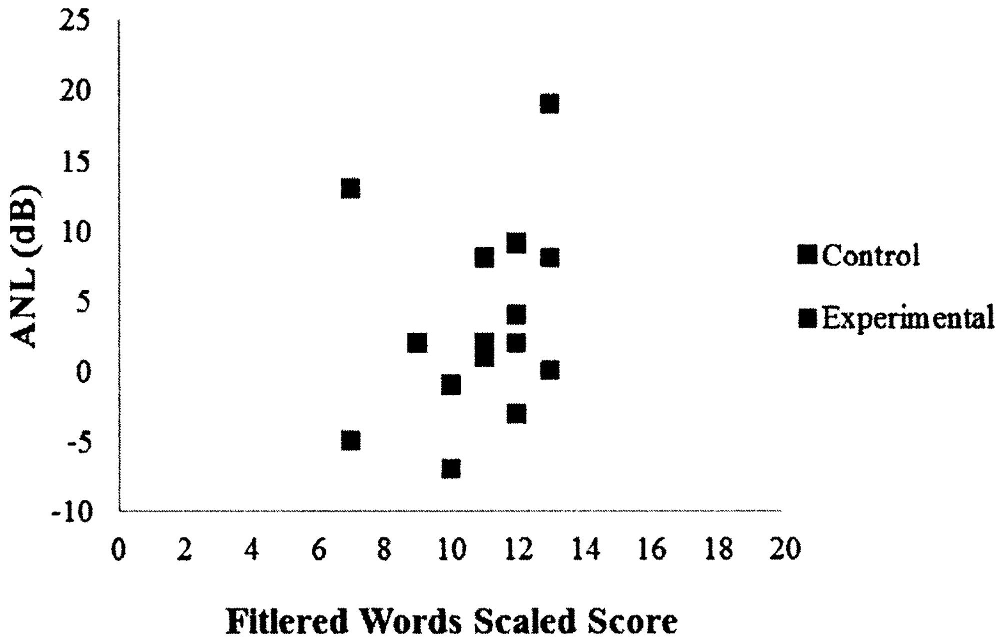

Figure 2. Correlation between the FW subtest of the SCAN - 3C and ANL for each participant.

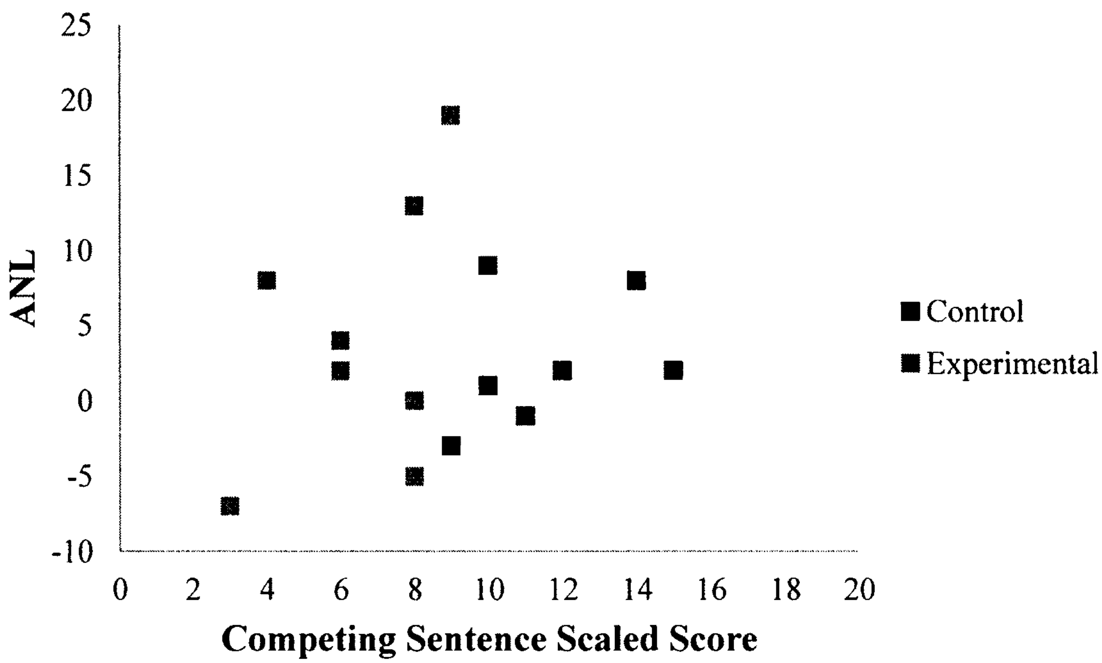

Figure 3. Correlation between the CS subtest of the SCAN - 3C and ANL for each participant.

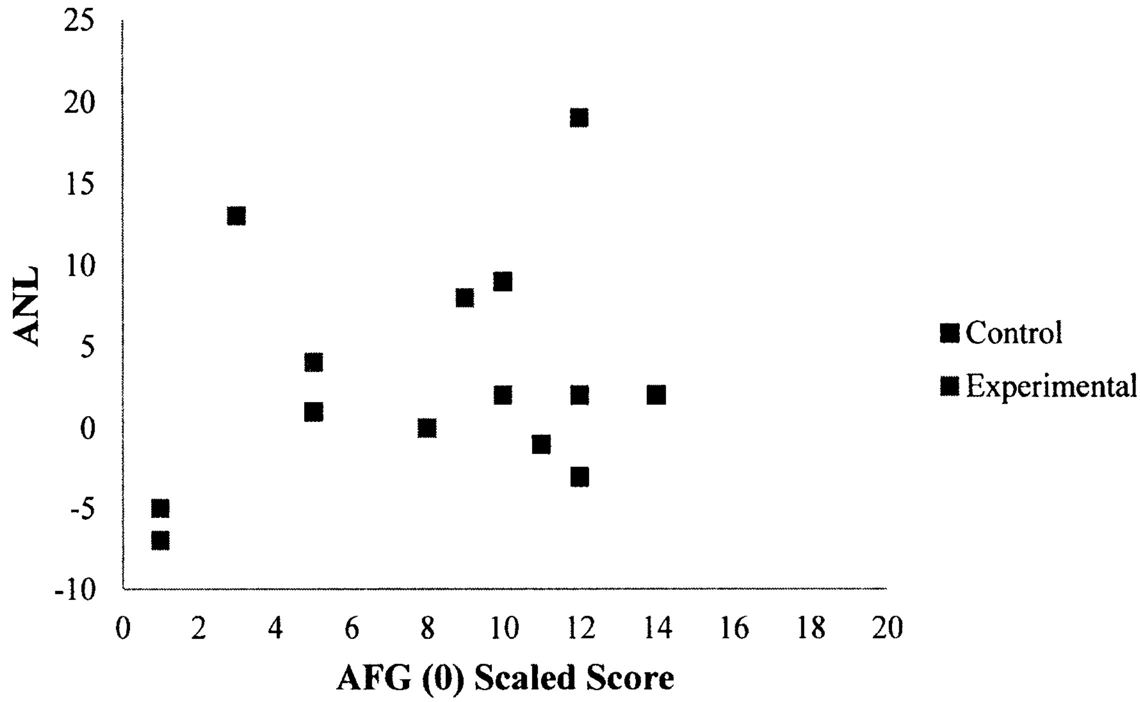

Figure 4. Correlation between the AFG (0) subtest of the SCAN -3C and ANL for each participant.

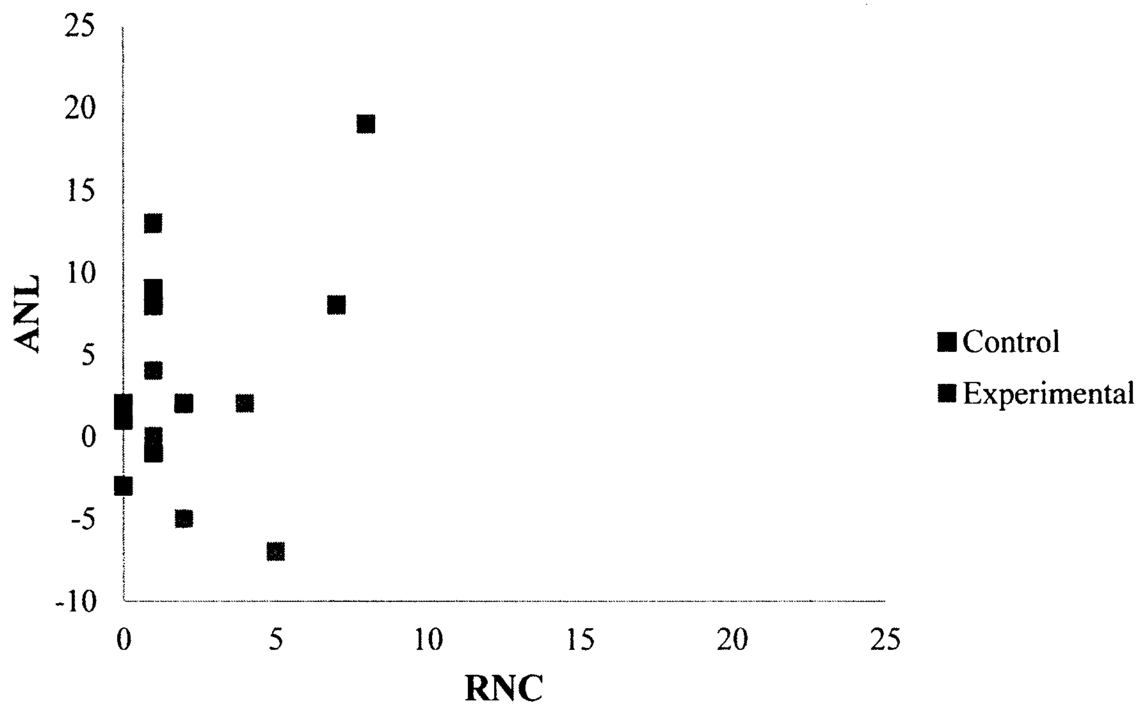

Figure 5. Correlation between the RNC condition of the SSW and ANL for each participant.

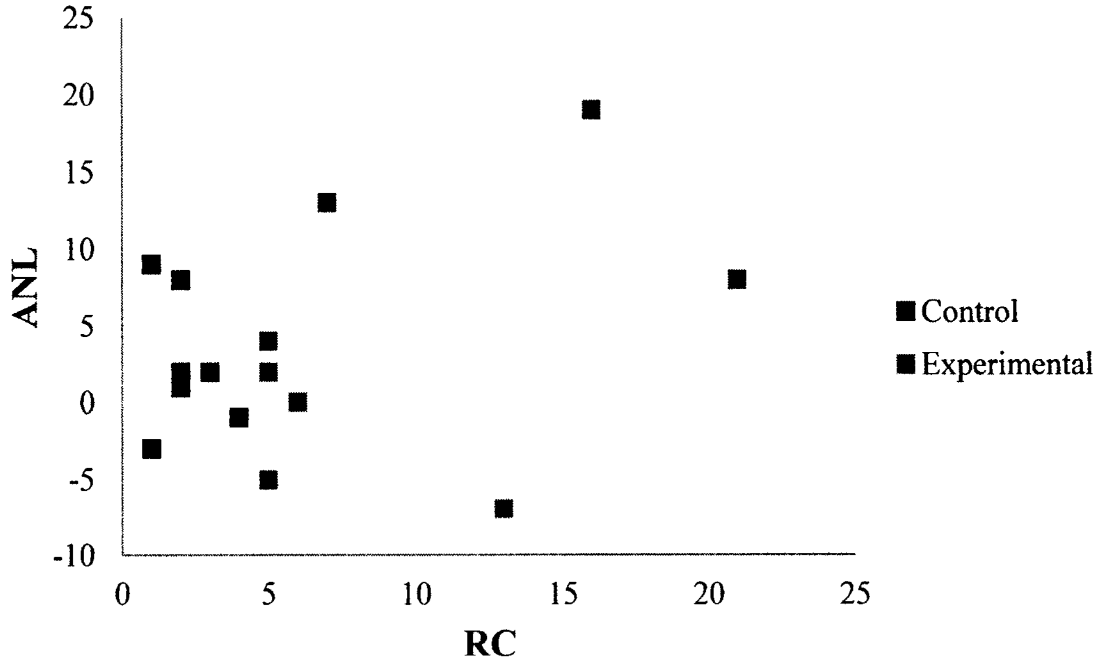

Figure 6. Correlation between the RC condition of the SSW and ANL for each participant.

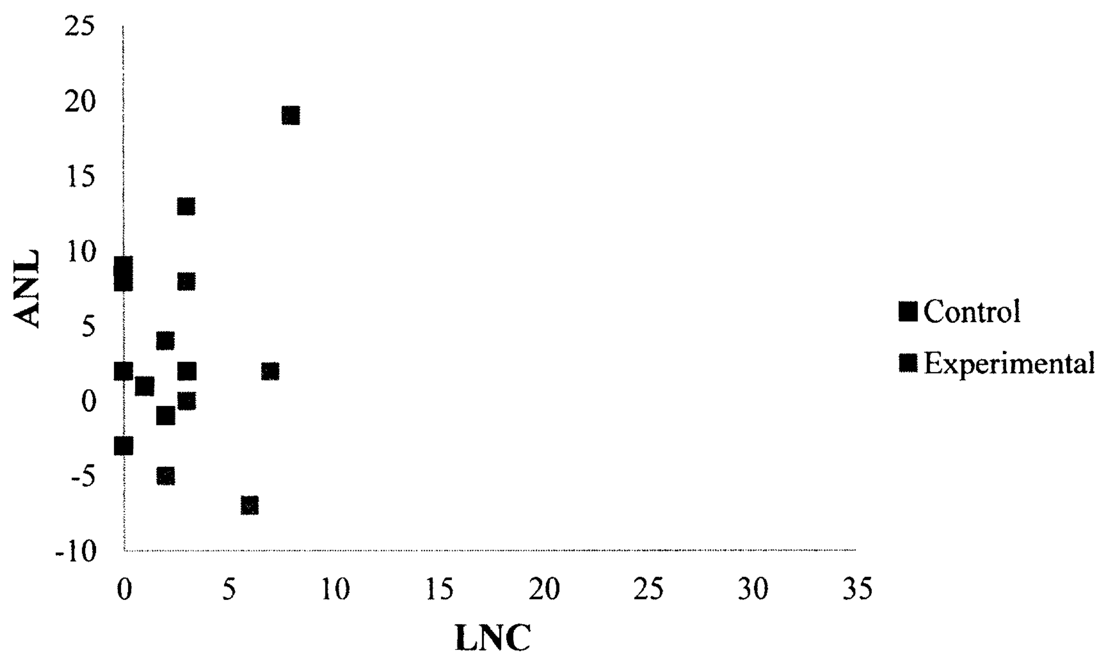

Figure 7. Correlation between the LNC condition of the SSW and ANL for each participant.

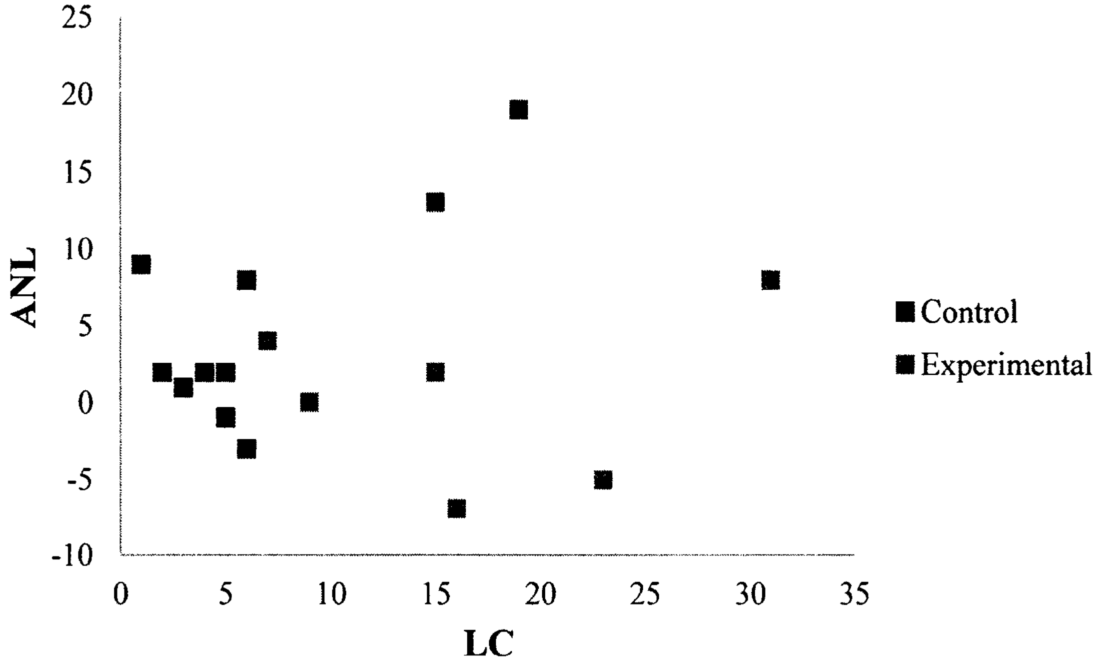

Figure 8. Correlation between the LC condition of the SSW and ANL for each participant.

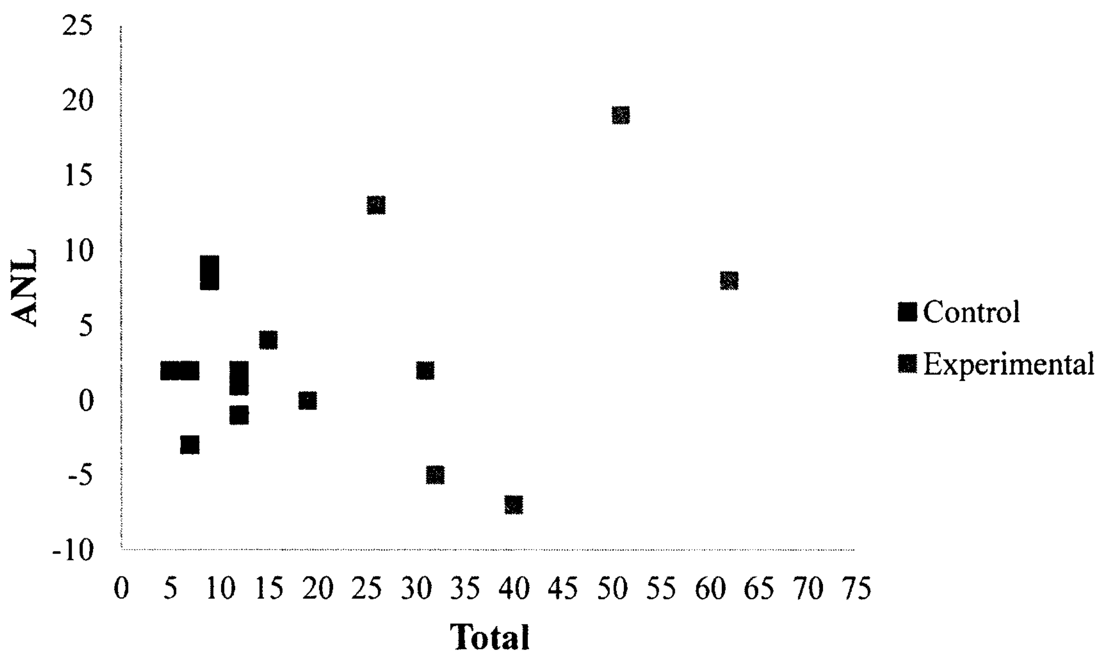

Figure 9. Correlation between the total score on the SSW and ANL for each participant.

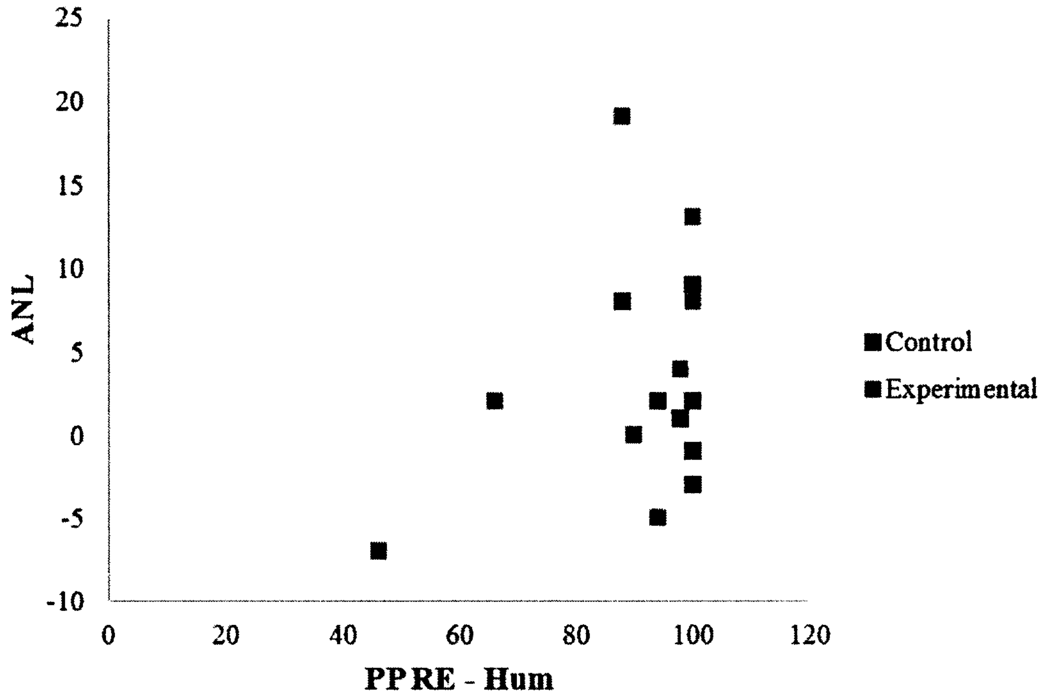

Figure 10. Correlation between Pitch Pattern right ear - hum response and ANL for each participant.

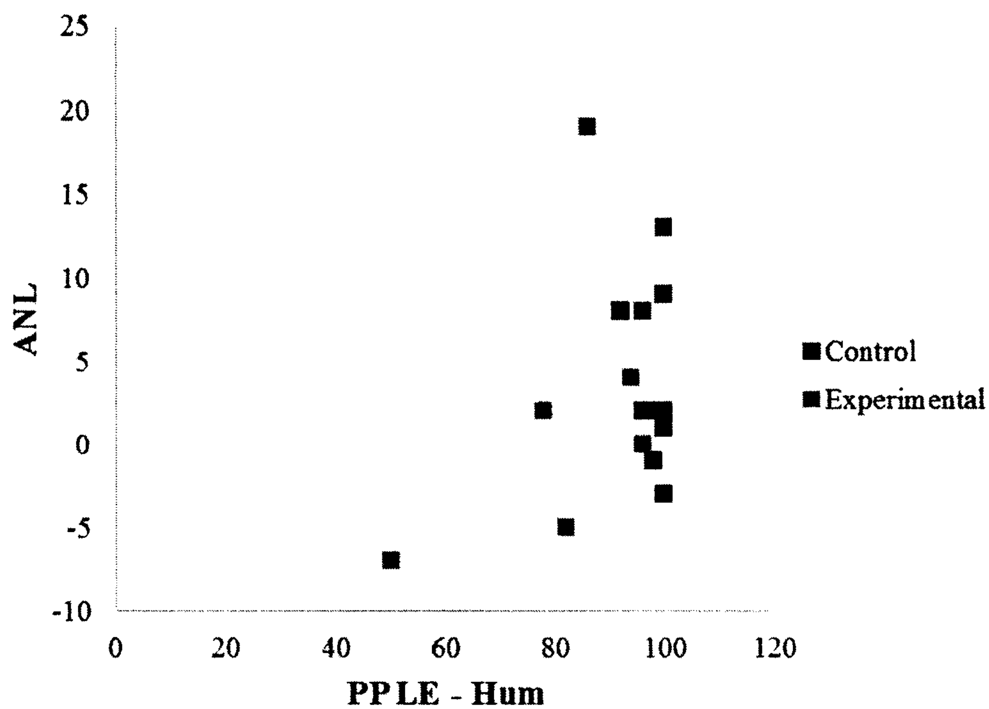

Figure 11. Correlation between Pitch Pattern left ear - hum response and ANL for each participant.

Chapter V

Discussion

The purposes of this study were (1) to determine if children with APD had similar ANLs when compared to children without APD and (2) to determine if ANL results correlated with the administered APD tests results for any particular APD test administered. A total of 16 participants, eight participants with normal processing abilities and eight participants with APD, were included in this study. A series of APD tests including the FW, CS, and AFG (0) subtests of the SCAN-3C, the SSW, and Pitch Pattern – hum response were measured on each participant. Furthermore, ANL was measured on each participant twice. If the results from the first two attempts were not within 4 dB, the ANL test was completed a third time. The results showed no difference between ANLs in participants with and without APD. Furthermore, the results showed no significant correlation between ANLs and any administered APD test.

First, the results indicated that children with APD had similar ANLs when compared to children without APD. It should be noted, however, that the mean ANL for children without APD was 2.5 dB (SD = 4.1) while the mean ANL for those with APD was 4.25 dB (SD = 8.8). Therefore, mean results seem to present a trend for higher ANLs for those with APD than those without. Furthermore, with more participants or less variance in the results in each group, these values might have been significant.

Secondly, the results indicated that ANLs were not correlated with the results for any of the administered APD tests. Therefore, ANL scores did not indicate performance on any particular APD test and vice versa. It should be noted, however, there may be a possible trend for the ANL scores as they relate to the LC and RC subtests and total score of the SSW. While there are some outliers to this trend, Figures 6, 8, and 9 show that those with higher ANLs seem to perform poorer on these tests. This trend should be further investigated with more subjects.

In comparison to other ANL studies, the results of this study were somewhat similar. First, Freyaldenhoven and Smiley (2006) determined mean ANLs for eight and 12 year old children to be 9.7 dB with a standard deviation of 6.2. Furthermore, Moore et al. (2011) determined mean ANLs for eight to ten year old children to be 7.82 dB with a standard deviation of 5.11. In the present study, the mean ANL for children without APD was 2.5 dB with a standard deviation of 4.1 while the mean ANL for those with APD was 4.25 dB with a standard deviation of 8.8. While the mean ANLs for children without APD were much lower when compared to previous studies, results of the present study are similar to other ANL studies conducted with children in that the standard deviation/variance in ANLs for children without APD were somewhat variable.

Clinical Implications

The trends presented in the data may be of clinical valuable to audiologists who perform APD testing. With more data, if the trend showed true, children with APD would likely exhibit higher ANLs than children without APD. This would mean that, children with APD accept less noise than children without APD and therefore would be expected to be less likely to "follow" the conversation/classroom material in noise. Furthermore, ANL testing could be added to the APD test battery to obtain more information on performance in background noise in children with APD. Also, if this trend showed true, it would suggest that children with APD may benefit from using an FM system in school to increase the signal to noise ratio. Furthermore, with more data, correlational ANL data may present with some interesting findings. For example, children with APD who have high ANLs may also perform poorly on the AFG (0) subtest of the SCAN-3C because the test evaluates performance in noise.

Limitations/Future Research

First, this study included a small sample size – only eight participants in each group. To this end, the overall means seem to present a trend for higher ANLs for those with APD compared to those without APD. Further research needs to be completed with a larger sample size to adequately explore this trend.

Furthermore, for the current study, due to the lack of availability of subjects, placement in the experimental group was based solely on the presence of a binaural abnormality on SSW test. Specifically, participants who presented with an abnormal score on both the RC and LC or the RNC and LNC conditions of the SSW were classified as APD. It should be noted that this is not a typical classification of APD. The two models that are used for classification of APD in clinical audiology are the Buffalo and the Bellis/Ferre models. Additionally, the most common classification of APD according to the Buffalo model is the Decoding category (Katz et al., 1992; Stecker, 1998; & Jutras et al., 2007); therefore, it would be beneficial to complete ANL testing on children with APD defined by the Decoding category of the Buffalo model and compared those findings to children without APD. Likewise, the most common APD diagnosis seen using the Bellis/Ferre model is the Auditory Decoding category. The same could be done for this model where ANL testing is completed on children with APD defined by the

Bellis/Ferre model and compared to ANLs in those without APD. Future research should investigate these phenomenon.

Appendix A

IRB Approval

LOUISIANA TECH
UNIVERSITY

MEMORANDUM

OFFICE OF UNIVERSITY RESEARCH

TO: Dr. Melinda Bryan and Ms. Brandee Richardson

FROM: Dr. Stan Napper, Vice President Research & Development

SUBJECT: HUMAN USE COMMITTEE REVIEW

DATE: April 10, 2014

In order to facilitate your project, an EXPEDITED REVIEW has been done for your proposed study entitled:

"The Effect of Auditory Processing Abilities on Acceptable Noise Levels"

HUC 1201

The proposed study's revised procedures were found to provide reasonable and adequate safeguards against possible risks involving human subjects. The information to be collected may be personal in nature or implication. Therefore, diligent care needs to be taken to protect the privacy of the participants and to assure that the data are kept confidential. Informed consent is a critical part of the research process. The subjects must be informed that their participation is voluntary. It is important that consent materials be presented in a language understandable to every participant. If you have participants in your study whose first language is not English, be sure that informed consent materials are adequately explained or translated. Since your reviewed project appears to do no damage to the participants, the Human Use Committee grants approval of the involvement of human subjects as outlined.

Projects should be renewed annually. ***This approval was finalized on April 10, 2014 and this project will need to receive a continuation review by the IRB if the project, including data analysis, continues beyond April 10, 2015.*** Any discrepancies in procedure or changes that have been made including approved changes should be noted in the review application. Projects involving NIH funds require annual education training to be documented. For more information regarding this, contact the Office of University Research.

You are requested to maintain written records of your procedures, data collected, and subjects involved. These records will need to be available upon request during the conduct of the study and retained by the university for three years after the conclusion of the study. If changes occur in recruiting of subjects, informed consent process or in your research protocol, or if unanticipated problems should arise it is the Researchers responsibility to notify the Office of Research or IRB in writing. The project should be discontinued until modifications can be reviewed and approved.

If you have any questions, please contact Dr. Mary Livingston at 257-2292 or 257-5066.

A MEMBER OF THE UNIVERSITY OF LOUISIANA SYSTEM

P.O. BOX 3092 • RUSTON, LA 71272 • TEL: (318) 257-5075 • FAX: (318) 257-5079

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Appendix B

Human Subjects Permission Forms

HUMAN SUBJECTS PERMISSION FORM

The following is a brief summary of the project in which you have been asked to participate. Please read this information before signing below:

TITLE: The Effect of Auditory Processing Abilities on Acceptable Noise Levels

PURPOSE OF STUDY/PROJECT: This research study is designed to obtain normative data on children with and without auditory processing disorders acceptable noise levels (i.e., the level of noise that they can 'put up with' while listening to a story without becoming tense or anxious).

PROCEDURES:

Audiological evaluation- The participants will complete otosocopy, tympanometry, ipsilateral and contralateral acoustic reflexes, pure tone thresholds, and speech testing to determine hearing functioning and sensitivity.

Auditory processing evaluation- The participants will be administered an auditory processing disorder test battery including, Random Gap Detection, Pitch Pattern, Staggered Spondaic Words, and the Competing Sentences, Filtered Words, and Auditory Figure Ground (+0), subtests of the SCAN-3 for Children. The directions will be given during each subtest.

Acceptable Noise Level (ANL) – The participants will be instructed to listen to a story that they will set at their most comfortable listening level. Then, speech babble background noise will be introduced at about the same level as the speech. The participants will be asked to set the background noise at a comfortable level for them as if they are going to have to listen to both the noise and the story for a long time. The noise is not supposed to be too loud as to cause any tension or anxiety to the participant.

Furthermore, your child will be asked to assent to participate in this research. He/she can refuse to participate without any penalty by telling the investigator that he/she does not want to continue with the activity.

INSTRUMENTS: The subject's identity will not be used in any form in the analysis or representation of the data. Only numerical data such as percent correct will be used in the presentation of the results.

RISKS/ALTERNATIVE TREATMENTS: There are no known risks to subjects. All procedures will be conducted at normal conversational speech levels and are similar to clinical audiometric measures. Participation is voluntary with parental consent. The participant understands that Louisiana Tech is not able to offer financial compensation nor to absorb the costs of medical treatment should you be injured as a result of participating in this research.

BENEFITS/COMPENSATION: Each participant will receive a free audiological and APD evaluation. Furthermore, the scientific and research communities will benefit from this information.

I, ______________________________, attest with my signature that I have read and understood the above description of the study, "The Effects of Auditory Processing abilities on Acceptable Noise Levels," and its purposes and methods. I understand that my and my child's participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University or Louisiana Tech Speech and Hearing Center. Furthermore, I understand that I may withdraw my child at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results will be confidential, accessible only to the project director, principal experimenters, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

I hereby give my permission for my child, ________________________, to participate in the above mentioned study.

______________________________ ______________________________

Signature of Parent or Guardian Date

CONTACT INFORMATION: The principal experimenter listed below may be reached to answer questions about the research, subject's rights, or related matters:

Melinda Bryan, Ph.D., CCC-A Department of Speech

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:

Dr. Stan Napper Dr. Mary Livingston Barbara Talbot

Louisiana Tech University
Child Assent Form

The Effect of Auditory Processing Abilities on Acceptable Noise Levels

The following script will be used to secure the child's assent, prior to conducting the study.

> ________, my name is <u>Student Name</u>. I am doing a project in school to try to find out some information about children's hearing. The purpose of this project is to find out how much background noise a child can stand while trying to listen to a story. You have been asked to be in this study to help me find the answers to my listening activity on children that have normal hearing. The activity will take place here at the Louisiana Tech Speech and Hearing Center and will last no longer than three hours. First, I will do two tests to make sure your hearing is normal. Then, we will go in the sound room, and I will do a hearing evaluation to make sure that your hearing is normal. Then, I will do some more tests to see what group of participants you will be in. Then, I want you to participate in a listening activity with me. I will tell you everything you need to know when we get in the sound room (like where to sit and what to do with the buttons that I give you). Your mom or dad (or parents or guardians) said that it is okay for you to be in this research study. You do not have to be in this study if you don't want to. You can change your mind at any time by telling your parents or me.

_______No, I do not want to be in the study   _______Yes, I want to be in this study

______________________________   ______________
Name or Signature of Participant (Optional)   Date

______________________________   ______________
Signature of Person Obtaining Assent   Date

Appendix C

ANL Instructions

Instructions for establishing MCL:

I'm going to play a story for you to listen to through the loudspeaker in front of you. I want you to use the buttons to turn the story up until it is too loud. Now, I want you to use the button to turn the story down until it is too soft. Now, I want you to turn the story up until it is at your perfect listening level. For example, if this was a television, and these buttons were your remote control – I want you to turn the story up until you think it's at a perfect level for you. Remember if it gets too loud, you can turn it down a little by pushing the softer button. When it gets just right, give me a thumbs-up. Then I'll tell you what else we are going to do.

Instructions for establishing BNL:

Now I'm going to put some noise through the same speaker. The man that was telling you the story is going to stay at the same loudness level that he was before the noise was introduced. I want you to use the buttons to turn the noise up until it is too loud and you cannot follow the story. Now, I want you to use the buttons to turn the noise down until the story is very clear. Now, I want you to turn it up until you think, "I could 'put up with' that noise for a long time if I had to, but if it is any louder then it would probably get on my nerves." It is important that you can also still follow the story that the lady is telling you through the speaker.

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