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AN EVAULUATION OF GENDER DIFFERENCES

ON TESTS OF AUDITORY PROCESSING

by

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This is to certify that the thesis prepared by Elizabeth Daniel entitled An evaluation of Gender Differences on Tests of Auditory Processing in Typically Developing Children Ages 7-12 years has been approved by the thesis committee as satisfactorily completing the thesis requirements for the degree of Doctor of Audiology.

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ABSTRACT

When listening difficulties emerge despite a normal functioning peripheral auditory system and cognitive abilities, an auditory processing disorder (APD) can be diagnosed. This disorder can be seen in the older and younger populations, but it is more detrimental in children when language is being acquired. In addition, APD can present with other disorders affecting language, learning, and attention. In other developmental disorders, the prevalence of the disorder in males is higher than it is in females. The present study aimed to analyze gender differences on tests of auditory processing (AP). After a peripheral hearing assessment, children were tested in several areas to ensure they were typically developing. These areas included intelligence (Test of Nonverbal Intelligence – version 3, TONI-3), language (Clinical Evaluation of Language Fundamentals Screening Test – version 4, CELF-4), reading (Comprehensive Test of Phonological Processing, CTOPP), and attention (Integrated Visual and Auditory Continuous Performance Test, IVA-CPT). An AP test battery including dichotic digits test (DDT), frequency pattern test (FPT), duration pattern test (DPT), random gap detection test (RGDT), compressed and reverberated words (CRW), auditory figure ground +8 signal-to-noise ratio (SNR) (AFG+8), AFG 0 SNR, and listening in spatialized noise sentences test (LiSN-S) were utilized. No gender differences were observed in any of the AP tests. However, age differences were observed in almost every AP test. Further research is needed on a larger sample to help specify local normative data, by age and gender as warranted.

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KEY TO ABBREVIATIONS

AAA: American Academy of Audiology
ADHD: Attention Deficit Hyperactivity Disorder
AFG: Auditory Figure Ground
ANOVA: Analysis of Variance
AP: Auditory Processing
APD: Auditory Processing Disorder
ANSI: American National Standards Institute
ART: Acoustic Reflex Threshold
ASD: Autism Spectrum Disorder
ASHA: American Speech-Language-Hearing Association
BFT: Binaural Fusion Test
CANS: Central Auditory Nervous System
CAPD: Central Auditory Processing Disorder
CELF-4: Clinical Evaluation of Language Fundamentals (4th Edition)
CID-W22: Central Institute for the Deaf-Words
CNS: Central Nervous System
CRW: Compressed & Reverberated Words Test
CTOPP: Comprehensive Test of Phonological Processing
dB: Decibel
DDT: Dichotic Digits Test
DPT: Duration Pattern Test
DSI: Dichotic Sentence Identification
FPT: Frequency Pattern Test
GIN Test: Gaps in Noise Test
GSI: Grason-Stadler Instrument
HL: Hearing Level
IQ: Intelligence Quotient
IRB: Institutional Review Board
ISI: Inter-stimulus Interval
IVA-CPT: Integrated Visual and Auditory-Continuous Performance Test
LD: Learning Disability
LEA: Left Ear Advantage
LiSN Test: Listening in Spatialized Noise Test
LiSN-S Test: Listening in Spatialized Noise-Sentences Test
M: Mean
MLD: Masking Level Difference Test
NVLD: Nonverbal Learning Disorder
OAE: Otoacoustic Emissions
PE: Pressure Equalization
PPS: Pitch Pattern Sequence
REA: Right Ear Advantage
RGDT: Random Gap Detection Test
SD: Standard Deviation
SES: Socio-Economic Status

SLI: Specific Language Impairment
SNR: Signal-to-Noise Ratio
SRT: Speech Reception Threshold
SSW: Staggered Spondaic Words Test
SusAPD: Suspected of Auditory Processing Disorder
TEOAE: Transient Evoked Otoacoustic Emission
TONI-3: Test of Nonverbal Intelligence (3^{rd} Edition)
UK: United Kingdom
VA: Veterans Administration
WRS: Word Recognition Score

CHAPTER ONE

INTRODUCTION

There are some individuals, both young and old, that have trouble listening and understanding language despite normal peripheral hearing and cognitive abilities (Chermak, 2002; Moore, 2006; Witton, 2010). In the classroom, teachers often see children who appear to have difficulty listening, following directions, and are easily distracted (Jerger & Musiek, 2000; Moore, 2006; Singer, Hurley, & Preece, 1998; Yalçinkaya, Muluk, & Sahin, 2009). These children may also have a reading, learning, or attention disorder in conjunction with listening difficulties (Vanniasegaram, Cohen, & Rosen, 2004; Witton, 2010). The processing of auditory information can be described as "the efficiency and effectiveness by which the central nervous system (CNS) utilizes auditory information" (ASHA, 2005, p.2). It may appear that children with auditory processing (AP) difficulties are missing auditory information, or the auditory information they receive is distorted despite the presence of normal hearing (Chermak, 2002; Moore, 2006). Auditory Processing Disorder (APD) is the term used to describe this disorder (ASHA, 1996; 2005; Chermak, 2002; Moore, 2006). Access to auditory information is important, especially in childhood, when speech and language are developing (Bailey & Snowling, 2002).

Auditory processing difficulties can disrupt language development and hinder academic performance (Bailey & Snowling, 2002; Vanniasegaram et al., 2004; Yalçinkaya et al., 2009). It has been reported that APD can have a co-morbid presentation with other disorders of language, learning, or attention (Landerl & Moll, 2010; Sharma, Purdy, & Kelly, 2009; Moav, Nevo, & Banai, 2009). For that reason, an interest in AP abilities in children has been a focus in research (Cacace & McFarland, 1998; Sharma, Purdy, & Kelly, 2009; Vanniasegaram et al., 2004). Recently, Witton (2010) brought attention to APD and its links to developmental disorders, indicating APD may co-occur with other disorders. Likewise, developmental delays have received attention in their relationship to APD. Prevalence of developmental delays has been estimated at 32.8 per 1000, in children younger than 6 years of age (Lai, Tseng, & Guo, 2011). Analysis of gender differences indicated a higher prevalence in boys. These results are not surprising given boys are more prevalent than girls in other disorders (Lai et al., 2011). Despite the fact that both boys and girls are used in most research studies, many times the gender differences and/or make-up of the sample are not reported (Hällgren, Johansson, Larsby, & Arlinger, 1998; Keller, Tillery, & McFadden 2006; Walker et al., 2002; Watson & Miller, 1993). There is little research on the potential performance differences between genders on APD. Given the extent of comorbidity that can be present in many developmental disorders, as well as the dearth of evidence in the literature related to gender differences, further research is needed (Landerl & Moll, 2010).

CHAPTER TWO

REVIEW OF THE LITERATURE

Hearing requires the ability to detect, to discriminate, to categorize, to identify, and finally to apply meaning to sound (Phillips, 1995). The auditory system processes information in many steps that occur from the pinna to the brain. This process occurs in a brief period of time in a normally functioning auditory system (Bellis, 2003). The peripheral auditory system consists of the outer, middle, and inner ear. The peripheral auditory system is responsible for sending the information to the central auditory pathway, which ends at the auditory cortex where meaning can be applied.

The auditory system is complex and is still not fully understood (Bamiou et al., 2001; Bellis, 2003; Dawes & Bishop, 2009; Phillips, 2002). Due to the intricacy of the auditory pathway it is difficult to state that one auditory function is specific to a certain structure (Phillips, 2002). Auditory information is not merely carried through the auditory system, but rather the auditory system is configured to perform complex signal coding and processing along the way. Anomalies of any structure within the auditory pathway may prevent the signal from arriving at the auditory cortex intact. Dysfunctional AP in children has been hypothesized to be a consequence of structural changes and/or developmental delay in the central auditory nervous system (CANS) (Chermak, 2002). Understanding the normal function of a healthy auditory system is important in order to appropriately assess both the peripheral and central auditory pathways for dysfunction, prior to making a diagnosis (ASHA, 2005; Bellis, 2003; Colorado 2008).

The American Speech-Language-Hearing Association (ASHA) assembled a task force in 1993 to discuss APD (ASHA, 1996). One topic outlined in the technical report that resulted from this task force is the skills related to the AP of sound. The various auditory abilities include: temporal processing, dichotic listening, pattern recognition, localization, lateralization, discrimination, and auditory abilities with degraded and competing signals (AAA, 2010; ASHA, 1996; 2005; Chermak, 2002). It is evident from this extensive list of functions that the auditory system has a huge responsibility when it comes to processing verbal and non-verbal stimuli. Deficits in any of the functions or responsibilities of the auditory system not attributed to higher-level functions are observed in those with APD (AAA, 2010; ASHA, 1996; 2005; Jerger & Musiek, 2000; Yalçinkaya et al., 2009).

Current Terminology

There has been debate in the literature whether the disorder in AP should be labeled as Auditory Processing Disorder (APD) or Central Auditory Processing Disorder (CAPD). Although both are used interchangeably in the literature, there are differences that should be noted. Moore (2006) highlights that tests of AP are not known to evaluate central processes in isolation from peripheral influences. Abnormal AP can result from damage occurring not only in the central pathway, but within the periphery as well (Moore, 2006). The exclusion of the term 'central' was recommended at the Bruton Conference in consideration of these relations (Jerger & Musiek, 2000). Moreover, since all processing is completed centrally, the term CAPD is redundant (English, 2007). Therefore, it is more suitable to refer to this disorder as Auditory Processing Disorder (APD), due to potential interactions at both central and peripheral levels (Chermak, 2002; Jerger & Musiek, 2000; Moore, 2006). Taking this information into consideration Jerger and Musiek (2000) broadly define APD, "as a deficit in the processing of auditory information that is specific to the auditory modality" (p. 468). In line with the current accepted terminology this disorder will be referred to as APD throughout this manuscript.

What is APD?

Controversy has surrounded many aspects of APD involving the definition, diagnosis, and management (Bellis & Ferre, 1999; Cacace & McFarland, 1998; Dawes & Bishop, 2009; Moav, Nevo, & Banai, 2009; Moore, 2006; Rosen, 2005; Singer et al., 1998; Wilson et al., 2004). One reason for this debate is that there may be different types and associated causes of APD, making it more of a "catch-all" disorder based on the functional presentation (Moore, 2006; Witton, 2010). Another reason for this controversy is that assessments designed for screening purposes are being used to diagnose APD, producing false-positives and ultimately inaccurate diagnoses (Jerger, 1998). With a surplus of inappropriately labeled children, the existence of APD may be questioned by professionals (Jerger, 1998). Some believe APD exists as a single disorder affecting language and learning (Cacace & McFarland, 2005). Evidence has been presented supporting this theory (Cameron & Dillon, 2008; Jerger, 1998; Sharma et al., 2009), specifically with documented cases from studies on individuals with known lesions within the auditory pathway (Kimura, 1961a; Kimura, 1961b; Musiek, Baran, & Pinheiro, 1990; Musiek & Pinheiro, 1987). In contrast, some researchers and clinicians not only consider APD a distinct disorder, but also support the theory that APD should be expected to have a comorbid presentation (Witton, 2010).

Human communication is intricate and involves multimodal processing between complex auditory information, as well as cognitive and social processes (Werner, 2007). The processing of auditory information involves both low-level and high-level processes (Chermak, 2002; Moore, 2006). Some low-level functions include localization of sounds, detection of temporal gaps or changes, and volume perception (Phillips, 2002). Examples of high-level processing are auditory attention (Phillips, 2002) and auditory memory (ASHA, 2005). A general dysfunction (e.g. autism spectrum disorder [ASD], attention disorders, etc.) that affects several modalities could result in listening difficulties (ASHA, 1996; 2005; Cacace & McFarland, 1998; 2005; Chermak, 2002; Rosen, 2005; Silman, Silverman, & Emmer, 2000; Witton, 2010). Yet, Cacace and McFarland (1998; 2005) posited that APD should be diagnosed only when it is modality specific. Cacace and McFarland (2005) stated that there are modality specific regions within the cortex, but polysensory regions surround these areas. However, it is important to note that some research has concluded that there are few, if any, areas within the brain that process only one modality (AAA, 2010; ASHA, 1996; 2005; Bellis & Ferre, 1999). For that reason, the occurrence of only a modality specific form of APD may be too restrictive (ASHA, 2005; Dawes & Bishop, 2009). Considering APD can be present in isolation or in combination with other disorders, ASHA (2005) stated that an accurate diagnosis of APD is made when the most distinct deficits are seen in the auditory modality and that these deficits are not caused by another malfunctioning modality. It is expected, that as the knowledge of the brain and its complex functions grows, the diagnosis and management of disorders within the auditory system will continue to evolve (AAA, 2010; ASHA, 1996, 2005; Jerger, 1998; Jerger & Musiek, 2000; Rosen, 2005).

Prevalence

Official statistics on the prevalence of APD have yet to be reported (Cacace & McFarland, 1998; Hind, 2006; Jerger & Musiek, 2000). There are few data on the prevalence of APD (Chermak, Hall, & Musiek, 1999; Hind, 2006; Neijenhuis, Snik, & van den Broek, 2003). Reported estimates are variable (Hind, 2006), but the most recent estimates indicate that prevalence seems to increase with age (Chermak, 2002; Moore, 2006). Chermak and Musiek (1997) estimated a 2-3% prevalence rate of APD in American children (as cited in Witton, 2010). The United Kingdom (UK) has reported a prevalence, of APD, in some form, as high as 10% in children (Witton, 2010). Related to gender the prevalence of APD is reported to be higher in more males than females, with a 2:1 ratio in children (Chermak, 2002). Differences between prevalence estimates may be due to variability in assessments used to diagnose APD, pass/fail criteria, and in the participants included in the studies (Chermak, 2002).

Clinical Presentation

Auditory processing difficulties in children may result from developmental abnormalities and/or neurological disorders (Bamiou et al., 2001). Therefore, not only does the underlying cause vary between cases, but the clinical presentation of APD in individuals can vary as well (Bellis & Ferre, 1999; Dawes & Bishop, 2009; Musiek & Chermak, 1994; Putter-Katz et al., 2000; Yalçinkaya et al., 2009). Clinical presentation can range from simple sound processing issues to difficulty understanding oral communication. Children with APD have been characterized by parents and teachers as being easily distracted, misconstruing information, hearing selectively, and taking longer to comprehend directions given orally (Sharma, Purdy, & Kelly, 2009). Presentation of

APD may also include difficulty listening in the presence of background noise, following (multistep) directions, and comprehending degraded or rapid speech (Bamiou et al., 2001; Chermak, 2002; Jerger & Musiek, 2000; Musiek, Gollegly, & Ross; 1985; Witton, 2010). Furthermore, these issues may be intensified in noisy situations (ASHA, 2005; Bamiou et al., 2001; Chermak, 2002; Dawes & Bishop, 2009; Jerger, 1998; Jerger & Musiek, 2000; Vanniasegaram et al., 2004; Witton, 2010; Yalçinkaya et al., 2009). It is important to note, these problems are present despite the individual having normal hearing sensitivity (Chermak, 2002; Dawes & Bishop, 2009; Jerger, 1998; Jerger & Musiek, 2000; Moav et al., 2009; Moore, 2006; Musiek et al., 1985; Sharma et al., 2009; Vanniasegaram et al., 2004; Witton, 2010). Associated problems can spread from the auditory realm, impacting other areas such as attention or distractibility, as well as, spelling and reading difficulties which will also affect the presentation of APD (Bamiou et al., 2001; Sharma et al., 2009; Singer et al., 1998; Yalçinkaya et al., 2009).

The clinical presentation of APD in each child is influenced by many factors (Moav et al., 2009). The presenting characteristics may be representative of APD, or there may be other partial contributors. It has been documented that APD can co-occur with other disorders (ASHA, 2005; Baran, 2002; Chermak, 2002; Sharma et al., 2009; Silman et al., 2000; Witton, 2010). Furthermore, several disorders overlap in their identifying traits; some examples include: ASD, learning disabilities (LD), language impairment, Attention Deficit Hyperactivity Disorder (ADHD), reading disability, hearing loss, and so forth (AAA, 2010; ASHA, 2005, Bailey & Snowling, 2002; Chermak, 2002; Jerger & Musiek, 2000; Witton, 2010). Although behavioral checklists are utilized, diagnosis of APD should not be based solely on presenting symptoms due to the complexity of the disorder and potential for co-morbidity (AAA, 2010; ASHA, 2005).

Diagnosis

The combination of the behavioral presentation, comprehensive case history, and behavioral AP testing should be included in the assessment for an accurate diagnosis of APD (ASHA, 2005). Prior to an AP evaluation a thorough case history should be obtained (AAA, 2010); including reports from any other professional's evaluation, especially if there are suspicions of co-occurring disorders (ASHA, 2005; Jerger & Musiek, 2000). Evaluations from other professionals (e.g., Educational Psychologist, Speech-Language Pathologist, etc.) are often vital to the accurate diagnosis of the child (Jerger, 1998). Psychological disorders, intellectual disabilities, LD, and so forth may be excluded by these evaluations as other possible primary diagnoses, or included as co-occurring with APD (Jerger, 1998). In addition to other assessments, observations made by teachers and/or parents may assist in an accurate diagnosis (AAA, 2010; Jerger, 1998).

It is important to determine the child's hearing sensitivity prior to performing any tests of AP abilities (Jerger, 1998; Jerger & Musiek, 2000; Witton, 2010). This should be determined by using a variety of subjective and objective measures including, at a minimum, pure-tone audiometry, immittance measures, speech testing, and otoacoustic emissions (OAEs) (Chermak, 2002; Chermak, Hall, & Musiek, 1999; Jerger & Musiek, 2000). The presence of a hearing loss will impact whether or not AP tests can be performed, as well as which tests will be used in the test battery (Chermak, 2002).

Following a comprehensive case history and diagnostic audiologic assessment, an AP assessment is performed by a trained audiologist. A diagnosis of APD should never be made based on a single test (Moncrieff & Wilson, 2009). Instead, a core battery of tests should be utilized that evaluate various AP abilities. Tests are available to assess the following skill areas: temporal processing, dichotic listening, monaural low-redundancy, binaural interaction, and sound localization and lateralization (AAA, 2010; ASHA, 2005). The test battery should be catered based on the patient's complaints (AAA, 2010; ASHA, 2005). Additionally, the linguistic load of evaluations should be considered due to the possible co-morbid conditions (Chermak, 2002; Jerger & Musiek, 2000; Krishnamurti, 2000). It has been recommended that test batteries have a low linguistic load supplemented by linguistically loaded tests (when a language disorder has been ruled out) to make an accurate diagnosis of APD (AAA, 2010; ASHA, 2005; Jerger & Musiek, 2000). In order for the audiologist to diagnose APD, the child must show a deficit in performance that falls at least two standard deviations below the mean on at least two tests in the battery or a deficit that falls at least three standard deviations below the mean on one test in the battery (ASHA, 2005; Colorado, 2008; Dawes & Bishop, 2009; Kelly, 2007; Musiek & Chermak, 2007). To make an accurate diagnosis of APD it must be differentially diagnosed from other disorders, since APD can present as an isolated disorder or comorbid with another disorder.

Differential diagnosis.

Children in the classroom may experience problems involving social and learning abilities as well as speech and language development; however, the difficulty is determining whether APD is the cause of these problems or the consequence of another co-occurring disorder (AAA, 2010; ASHA, 2005). There is debate regarding whether APD is a cause or consequence of the individual's problem. Part of this debate is whether

APD causes attention problems, attention problems cause APD, or if they co-occur (Rosen, 2005). Rather than a causal link, it is plausible that APD may co-occur with other disorders given environmental and genetic influences (Landerl & Moll, 2010; Witton, 2010). Many researchers agree that language or attention disorders may co-occur (ASHA, 2005; Cameron & Dillon, 2008; Chermak, 2002; Moore, 2006; Vanniasegaram, et al., 2004; Yalçinkaya et al., 2009). Published prevalence rates of comorbid disorders are limited and inconsistent (Landerl & Moll, 2010). Witton (2010) pointed out the similarities between APD and developmental disorders noting that, within other disorders, it is not uncommon to observe difficulty processing auditory information. Similarly, Landerl and Moll (2010) discussed the possibility that comorbity may be a result of environmental and genetic factors that are shared between disorders, as opposed to each having unique factors. Following this logic, it would not be surprising that other developmental disorders would be comorbid with APD (Witton, 2010).

Similarly, the differential diagnosis of APD is complicated by other disorders that influence auditory function including ASD, ADHD, poor intellectual functioning, language impairment, and disabilities in reading or learning (AAA, 2010; Jerger & Musiek, 2000). Another complication is that the behavioral presentation of APD may overlap with some disorders (AAA, 2010; Baran, 2002; Chermak, 2002; Dawes & Bishop, 2009; Jerger & Musiek, 2000; Sharma et al., 2009; Yalçinkaya et al., 2009). Regardless of whether APD presents as an independent disorder or one that is co-morbid with another disorder, differential diagnosis is still important for accurate diagnosis and treatment (Jerger, 1998).

Learning disabilities.

When looking at learning disabilities in general boys show a higher prevalence than girls (Badian, 1999; Wheldall & Limbrick, 2010). A longitudinal study of a school district including 1,008 children was followed for 13 years to determine prevalence of reading disorders as well as associated gender ratios and stability of the disorder (Badian, 1999). When looking at those children who were consistently diagnosed with reading disorders (2.7% of the sample) this study found a 3.2:1 male-to-female ratio. In this study females also displayed significantly better reading comprehension than the males, which may have attributed to the high gender ratio of males with reading disorders (Badian, 1999). A large longitudinal study in Australia looking at 1,133,988 children, analyzed the incidence of gender related reading problems (Wheldall & Limbrick, 2010). The sample was broken into two groups 590,532 third grade students (301,244 males and 289,308 females) and 543,456 fifth grade students (299,196 males and 244,260). Across all 10 years males obtained lower reading scores than females. The findings displayed a higher male-to-female gender ratio of 1.44:1 and 1.99:1 for both 3rd and 5th grade students respectively (Wheldall & Limbrick, 2010).

Children diagnosed with LD may also be evaluated for APD to determine if AP problems contribute to the presentation of the disorder (Silman et al., 2000). Previously researchers have assessed the AP abilities in children with language disorders (Keller et al., 2006; Vanniasegaram et al., 2004) and the language and reading abilities of children diagnosed with APD (Sharma et al, 2009; Walker, Shinn, Cranford, Givens, & Holbert, 2002; Watson & Miller, 1993; Yalçinkaya et al., 2009). Variable rates of co-occurring disorders have been reported, some of these studies will be discussed next.

Moav, Nevo, and Banai (2009) studied the performance, on a test battery with a low linguistic load, of 47 school-aged children with (n=20) and without (n=27) LD. Despite previous estimates of APD being more common in individuals with LD, Moav et al. (2009) found no significant performance differences between the groups (with or without LD). Based on this finding, employing a test battery with a low linguistic load may be able to diagnose the presence or absence of APD in children with LD (Moav, Nevo, & Banai, 2009).

It has been thought that reading, or more specifically phonological processing abilities, are influenced by auditory perception (Wastson & Miller, 1993). Watson and Miller (1993) studied auditory and phonological processing abilities in adults with (n=24; average age 24 years) and without (n=70; average age 22 years) reading disabilities. The gender make-up of the sample was not provided nor was gender differences examined. Participants were evaluated in several performance areas including reading, phoneme segmentation, intelligence, speech perception, auditory discrimination, temporal ordering, retrieval speed, and short- and long-term auditory memory. Although test scores were significantly different between groups for temporal processing tasks, the data failed to support the relationship between nonverbal AP and phonological processing (Watson & Miller, 1993). However, another study found significant results when comparing performance on temporal processing tasks between a reading disordered group (n=9) and controls with normal reading skills (n=9) (Walker et al., 2002). Eighteen college students between the ages of 19-26 years participated in this study. The sample had nine males and nine females, but gender differences were not examined. Participants were evaluated on reading and language abilities as well as temporal processing tasks including frequency and duration pattern tests and brief tone difference limen test. The reading disordered group displayed below average scores on the reading assessment. In addition, poorer scores were observed in both ears on the duration pattern test in the reading disordered group. Word identification ability, in both ears, was significantly correlated to the left ear's duration pattern performance in the reading disordered group. In contrast, the control group showed a significant correlation between word identification ability, in both ears, to the right ear's duration pattern score. The study concluded that adults with reading disorders may experience auditory temporal processing difficulties as found on the Duration Pattern Test (DPT) in this study (Walker et al., 2002).

Cameron and Dillon (2008) completed a relatively small study, comparing children suspected of APD (SusAPD; n=9 including 8 males) and children with learning or attention disabilities (LD; n=11 including 7 males) to established age matched normative data. Both groups were evaluated on both the Listening in Spatialized Noise-Sentence Test (LiSN-S) and a traditional APD test battery consisting of Dichotic Digits Test (DDT), Masking Level Difference (MLD), Pitch Pattern Sequence (PPS), and the Random Gap Detection Test (RGDT). The two groups of children (SusAPD and LD) were compared to normative data collected on a control group of children. The authors reported that, in general, the LD group showed no significant performance differences on the LiSN-S as well as on the traditional APD test battery when compared to the controls. This finding supports, in part, the hypothesis that APD is not due to higher-order functions. Almost all children in the SusAPD group passed the traditional test battery; however, about half of these children had scores that were outside normal limits on the

LiSN-S. These findings indicate that the LiSN-S examines another aspect of AP and this test contributes a new dimension to the AP battery (Cameron & Dillon, 2008).

Language disorder.

Just like LD, a language disorder can coexist within an individual (Baran, 2002; Chermak, 2002; Chermak et al., 1999; Sharma, Purdy, & Kelly, 2009; Vanniasegaram, Cohen, & Rosen, 2004; Witton, 2010). Some researchers suggest that if learning difficulties or language disorders are causing the child to perform poorly in reading, writing, listening and speaking, APD cannot be diagnosed (Cacace & McFarland, 1998; 2005; Vanniasegaram et al., 2004; Yalçinkaya et al., 2009). Other researchers (Keller et al., 2006; Sharma et al., 2009) have shown that individuals can have co-occurring disorders with APD and that comorbid conditions are likely (Witton, 2010).

Keller, Tillery, and McFadden (2006) assessed the prevalence of APD in children diagnosed with nonverbal learning disorder (NVLD) to determine whether APD is more prevalent in this population than in children without NVLD. The study evaluated 18 children between the ages of 6-18 years, all diagnosed with NVLD. The sample had 10 boys and eight girls, but gender differences were not examined. Participants were evaluated on the Staggered Spondaic Word Test (SSW), phonemic Synthesis, and speech-in-noise tests (with a 5 dB signal-to-noise ratio [SNR]). Eleven of the children with NVLD also met the diagnostic criteria for APD. These results display a higher incidence of APD (61%) within the population of children with NVLD than previous estimates. Performance differences were compared between groups of children with NVLD only to children with NVLD and APD co-occurring. Children with co-occurring conditions displayed significantly poorer performance on several tasks, with the largest differences on the Speech Sounds Perception test. The researchers suggest that this indicates when children with NVLD display poor performance on this test; there is a possibility for APD to co-occur (Keller et al., 2006).

Stollman, van Velzen, Simkens, Snik, and van den Broek (2003) studied AP abilities in 6-year-old children diagnosed with specific language impairment (SLI) and a group of age-matched controls. The sample included 20 children diagnosed with SLI (males = 14, females = 6) and 20 controls (males = 7, females = 13). The two groups were not significantly different in non-verbal intelligence. As expected, the SLI group had significantly lower language scores than the controls. The AP test battery used included tests of speech-in-noise, filtered speech, binaural fusion, frequency pattern test (FPT), DPT, temporal integration, auditory word discrimination, auditory synthesis, auditory closure, and number recall. This study found no gender differences on any test; however the researchers felt that their gender ratios in each group may have affected the findings. Statistical analysis found the language scores were significantly correlated to almost all AP tests, but the non-verbal intelligence was not (Stollman et al., 2003). These researchers concluded that there is a causal relationship between AP abilities and language proficiency due to significant correlations between the scores (Stollman et al., 2003). Although these researchers had a comprehensive test battery it may have been beneficial to use tests that were not linguistically loaded to get a good analysis as to whether or not these children had AP difficulties in addition to the diagnosis of SLI or whether these poor AP scores were a result of the SLI.

Sharma, Purdy, and Kelly (2009), aimed to determine if APD coexists with reading and/or language disorders and the associated types of processing deficits. All 68 children included in the study were 7-12 years old and were suspected of having APD or had been diagnosed with it. Children were evaluated in a range of areas including: memory, attention, reading, cognition, language, and AP tasks. APD was present in 72% of the population studied. It was found in this study that only three participants (4%) were found to not have any disorder. Only 11 participants (16%) were found to have APD, reading disorder, or language impairment in isolation. Any combination of two disorders co-occurring was found in 22 participants (32%). Lastly, just under half of their sample (32 participants) was found to have all three co-occurring conditions (Sharma et al., 2009). Based on the results from these studies, it is possible to see disorders co-occur with APD. Therefore, a comprehensive evaluation looking at multiple aspects of the child should be completed with a multidisciplinary team to avoid misdiagnosis.

Attention.

APD and ADHD can co-occur (Baran, 2002; Chermak, 2002; Chermak, Hall, & Musiek, 1999; Rosen, 2005; Vanniasegaram et al., 2004; Witton, 2010); however, it is often difficult to differentially diagnose APD vs. ADHD due to a similar presentation between the disorders (Chermak et al., 1999; Chermak, Somer, & Seikel, 1998). Chermak, Somer, and Seikel (1998) surveyed audiologists and pediatricians on the symptoms observed with APD and ADHD. Reported symptoms were ranked on their likelihood of being observed in each disorder (1 being most frequently observed). Then the rankings for each symptom were averaged across the professionals' surveys. Symptoms that fell within one standard deviation from the mean were included in the presenting characteristics for each disorder. Of the main behavioral symptoms observed in APD and ADHD, "inattention" and "distracted" were the only characteristics used to describe both disorders. However, these characteristics were listed least frequently for APD and most frequently for ADHD, highlighting the differences between the two disorders (Chermak et al., 1998). It is important to note that the attention deficit that may be associated with APD is typically seen within the auditory modality, whereas ADHD displays deficits that affect visual attention as well (Chermak et al., 1999). Overall, characteristics of APD had more symptoms that impact social and academic interactions, such as difficulty dividing attention or understanding auditory signals (Chermak et al. 1998). On the other hand, ADHD descriptors seem to involve a lack of self-control, such as excessive talking or interrupting others. Each disorder has its own diagnostic criteria; APD utilizes a test battery performed by an audiologist while ADHD relies solely on clinical presentation (Chermak et al., 1998). Although each condition can occur in isolation they can also occur together, in which case a comorbid diagnosis can be made (Chermak et al., 1999; Chermak et al., 1998).

ADHD has been reported in the literature as more prevalent in males than females (Bauermeister et al., 2007; Gershon, 2002). Bauermeister and colleagues (2007) completed a study in Puerto Rico examining gender relationships in ADHD. Child and parent pairs were randomly selected to be interviewed as a part of the study. The participants (children) ranged in age from 4-17 years. The large sample analyzed results of 978 males and 912 females. The Computerized Diagnostic Interview Schedule for Children, version IV was utilized to interview the parent and the child. After the results were age adjusted, there was a gender ratio of 2.3 to 1, indicating boys are more commonly diagnosed with ADHD than girls (Bauermeister et al., 2007). Another researcher analyzed gender differences in ADHD in meta-analytic study looking at 120 articles, which all studied children through adults that had been diagnosed with ADHD (Gershon, 2002). Significant gender differences were found displaying females were less impaired than males on all primary symptoms (hyperactivity, inattention, and impulsivity). These findings could suggest that ADHD has a more subtle presentation in females and for that reason males are more frequently diagnosed (Gershon, 2002).

Accurately diagnosing comorbid disorders may seem challenging, especially when the behavioral symptoms overlap (Baran, 2002; Chermak et al., 1999); however, it is with those cases that the importance of differential diagnosis is highlighted (AAA, 2010; ASHA, 2005). The evidence in the literature supports APD as a unique disorder, which can be differentially diagnosed from, but is often co-morbid with, other disorders. A comprehensive evaluation of the child can be performed to identify the main disorder and to help rule in or rule out possible underlying issues (McFarland & Cacace, 1995). Accurate identification of APD is best accomplished with a multidisciplinary team approach and targeted test materials, including low linguistic loaded AP tests (AAA, 2010; Dawes & Bishop, 2009; Jerger & Musiek, 2000). If the linguistic load, memory, and response method are controlled then APD can be differentiated from other disorders with similar presentation (Chermak, 2002; Jerger & Musiek, 2000).

Multidisciplinary team.

The most efficient way to obtain a differential diagnosis is by using a multidisciplinary team approach (AAA, 2010; ASHA, 2005; Bamiou, et al., 2001; Bellis & Ferre, 1999; Chermak, 2002; Chermak et al., 2007; Dawes & Bishop, 2009; Keith & Novak, 1984). A multidisciplinary team approach is a way to gather information on a patient from a professional in several specialty areas, thereby comprehensively evaluating the child and not just one aspect of the presenting behaviors (Bellis, 2003). Use of knowledge across professions may assist in a more accurate diagnosis compared with relying on one professional's opinion or diagnosis; this process may also optimize the development of an appropriate treatment/management plan (Baran, 2002; Chermak, 2002; Colorado, 2008; Keller et al., 2006; Moore, 2006; Sharma et al., 2009; Witton, 2010). Some researchers believe that professionals of different disciplines, working alone, may diagnosis the same child differently (Chermak, 2002; Dawes & Bishop, 2009; Moore, 2006; Sharma et al., 2009). Therefore, the importance of multidisciplinary teams is evident. Audiologists are an important member of the team, due to their involvement in the evaluation, diagnosis, and management of APD (AAA, 2010; ASHA 2005). Audiologists should select a variety of tests, assessing several AP skills, in order to accurately diagnose APD (ASHA, 2005; Witton, 2010). However, audiologists will often need assistance from other disciplines in differentially diagnosing APD from other disorders (AAA, 2010; Witton, 2010). Important team members to include are: speech-language pathologists, educational psychologists, and, when warranted, physicians (AAA, 2010; Chermak, 2002). With this collaboration of professionals the individual can be comprehensively evaluated in the auditory, developmental, educational, and social domains (Bamiou, et al., 2001; Baran, 2002).

Assessment

The auditory system has a variety of functions, and a vast number of structures involved in the processing of auditory information. Dysfunction can occur in any region within the pathway resulting in a diverse presentation. Therefore a wide range of tests that assess multiple areas within the auditory system as well as a variety of AP skills is needed to effectively evaluate for APD (Moav et al., 2009). Due to the complexity of AP, many tests have been developed to evaluate the multiple aspects of processing abilities (Musiek et al., 1985). Based on studies of individuals with known lesions, tests were developed that yielded high validity and effectiveness in their detection based on poor task performance (AAA, 2010; Musiek & Chermak, 1994). Although the early APD tests were developed based on lesion studies and were not specifically designed for diagnosing APD they have proven to be sensitive to dysfunction within the system (Hurley & Musiek, 1997; Musiek et al., 1990, Musiek & Pinheiro, 1987; Singer et al., 1998).

To sort out disordered auditory systems from the healthy, tasks that employ more complex stimuli are used to challenge the auditory abilities (Chermak, 2002; Musiek et al., 1985). Use of multiple tests can separate normal from abnormal auditory systems (Putter-Katz et al., 2002; Witton, 2010). A collection of tests, measuring various skills, is needed to determine whether there is a deficit in one or more areas of AP (Chermak et al., 1999). A variety of stimuli (verbal/nonverbal, degraded/normal), tasks (auditory/phonological/semantic), and presentation methods (binaural/dichotic/monotic) should be included in the test set (Putter-Katz et al., 2002). There are many aspects to the processing of auditory information; therefore, a battery of multiple tests should be used (AAA, 2010; Vanniasegaram, Cohen, & Rosen, 2004).

Dichotic listening.

Dichotic listening tasks are tasks that present different stimuli (numbers, words, or sentences) to both ears simultaneously (ASHA, 2005; Bellis & Ferre, 1999). The listener then repeats all the information presented (binaural integration) or attends to one ear while ignoring the information presented to the other ear (binaural separation) (Bellis

& Ferre, 1999). Lateralization can also be evaluated by comparing the individual's performance differences between the two ears (Hällgren, Johansson, Larsby, & Arlinger, 1998; Moncrieff & Musiek, 2002; Moncrieff & Wilson, 2009). Examples of tests that fall into this category are dichotic digits (Noffsinger, Martinez, & Wilson; 1994), competing sentences (Noffsinger, Martinez, & Wilson; 1994), and staggered spondaic word test (Katz. 1962). These assessments are sensitive to disruption within the corpus callosum and temporal lobes, even in individuals with mild to moderate hearing loss, if a correction factor is used for the hearing loss (Bellis, 2003; Musiek, Gollegly, Kibbe, & Verkest-Lenz, 1991).

Noffsinger, Martinez, and Wilson (1994) provided stimuli and normative data for the Veterans Administration (VA) CD dichotic speech tests for digits, sentences, and nonsense syllables. In the DDT, four single-syllable numbers (ranging from 1 to 10, except 7) are presented, two to the right ear and two to the left ear (Noffsinger et al., 1994). The listener is required to repeat back all four digits in any order. This test evaluates the ability to identify competing information. This version of the DDT has several benefits including good test re-test reliability, good sensitivity to CANS dysfunction, it is relatively resistant to hearing loss, and administration time is short (Musiek et al., 1991).

A right ear advantage is often seen on the DDT (Bryden, 1963; Kimura, 1961a; Kimura, 1961b). The right ear advantage is explained by the left hemisphere dominance in language as well as the contralateral pathway being stronger than the ipsilateral pathway (Kimura, 1961a; Kimura, 1961b). Therefore, in most people, the input to the right ear crosses over directly to the left hemisphere to be labeled whereas the input to the left ear crosses over to the right hemisphere and then back to the left hemisphere to label what was heard (Bellis, 2003; Kimura, 1961a; Neijenhuis et al., 2003). This advantage has shown to be independent of presentation order (Bryden, 1963) and of site of lesion (Kimura, 1961a, Kimura, 1961b). It has been stated that the right ear advantage (REA) is larger in children under 12 years (due to the lack of maturation of the CANS) and the elderly (due to the aging process of the CANS), as opposed to in young adults and adults (Moncrieff & Wilson, 2009). Hällgren, Johansson, Larsby, and Arlinger (1998) used a variety of dichotic speech tests to assess abilities in 10 control children (4 female, 6 male) aged 11 years and 11 reading disordered children (3 females, 8 males) ranging in age from 9-12 years. Gender make-up of the participants was reported; however, gender differences were not examined. Significant performance differences between the two groups were reported for two tests: direct report of digits and delayed syllables. Although the normal children had a REA in the consonant vowel pairs test, the reading disordered group did not. Based on these results, these two dichotic tasks may be sensitive to identifying children with reading disorders (Hällgren, Johansson, Larsby, & Arlinger, 1998); however, this study was very small so further research is warranted.

Temporal processing.

Temporal processing tasks may assess the listener's ability to perceive an auditory pattern over time, evaluating frequency and/or duration discrimination, temporal ordering, linguistic labeling, temporal resolution, etc. (ASHA, 1996; 2005). These assessments are sensitive to disruption within the corpus callosum, temporal lobes, and some brainstem lesions depending on the task as well as the location of the lesion (Bellis, 2003; Hurley & Musiek, 1997; Musiek, Baran, & Pinheiro, 1990; Musiek & Pinheiro, 1987).

Gap detection tests assess temporal resolution or the amount of time between sounds (inter-stimulus interval, ISI) needed for the brain to perceive more than one sound (Chermak & Lee, 2005). The Random Gap Detection Test (RGDT; Keith, 2000) and Gaps-In-Noise Test (GIN; Musiek et al., 2005) are two currently available gap detection tests. In the RGDT, the stimuli are tonal pairs with varying ISIs (Keith, 2000). The listener needs to identify whether one or two tones are heard, after several pairs of tonal stimuli are presented. Chermak and Lee (2005) reported the results of a study of the difference between four temporal resolution tasks with 10 children with ages ranging from 7-11 years with the gender make-up not reported. The assessments include the Random Gap Detection Test (RGDT), Gaps-In-Noise (GIN), Auditory Fusion Test-Revised (AFTR), and Binaural Fusion Test (BFT).This small study found no clinically significant differences in performance across tests. Each test has strengths and weaknesses as well as differences in the administration and scoring; these factors may influence its clinical use (Chermak & Lee, 2005).

Temporal patterning tasks require the listener to identify non-speech patterns and repeat what is heard verbally or nonverbally. Examples of tests in this category are duration pattern (DPT; Musiek, 1994) and frequency pattern (FPT; Musiek, 1994) tests. In the FPT (Musiek, 1994); three tones are presented in a pattern of varying frequency. Each tone is a high frequency (1122 Hz) or low frequency (880 Hz) (Musiek, 1994; Musiek & Pinheiro, 1987). The listener is asked to identify the pattern heard by verbally labeling the tones (e.g. high-high-low). In the DPT (Musiek, 1994); three tones are presented in a pattern of varying lengths of time. Each tone was either short (250 ms) or long (500 ms) (Musiek, 1994). The person is asked to identify the pattern heard by verbally labeling the tones (e.g. long-short-long). The results from one study displayed patients with cochlear hearing loss performing comparable to the normal listeners; however, the performance of those in the group with known lesions displayed considerably poorer scores (Musiek et al., 1990). Results indicated good sensitivity and specificity for this test. This assessment uses non-speech stimuli, which allows it to be utilized with a variety of populations (Musiek et al., 1990).

Temporal tasks, that require the listener to identify order or duration differences, have identified variability in performance related to gender (Fink et al., 2005; van Kesteren & Wiersinga-Post, 2007). In a study by Fink et al. (2005), language competence and its relation to temporal processing was investigated. The study included 40 participants classified into two age groups (young range 20-35 years, older range 55-70 years). There were 10 female and 10 male participants in each group. The aims of this study were to acquire normative data on temporal-order thresholds, evaluate the test re-test reliability of these tasks, and examine gender and age effects. Four different conditions were used to obtain the thresholds, in each condition the stimuli (tones or clicks) and the presentation mode (binaural or alternating monaural) varied. Significant gender differences were observed in the initial evaluation with women showing greater average thresholds with a click stimulus; however, there were no significant difference between the performance of men and women on the re-tests (Fink et al., 2005).

Using the same methodology as Fink et al. (2005), van Kesteren and Wiersinga-Post (2007) examined the performance of 26 normal participants. Participants ranged in age from 19-37 years, with a gender composition of 13 males and 13 females. However, significant gender differences were not observed on the temporal-order task as previously reported. This does not rule out the possibility of males processing auditory information differently than females. The researchers outlined possible explanations for the variable results, which included: sample size, subject age, participant feedback, and the process used to acquire the temporal order threshold (van Kesteren &Wiersinga-Post, 2007). Another study examined gender and age effects on performance on temporal ordering tasks (Szymaszek, Szelag, & Sliwowska, 2006).This study had 33 participants divided into two groups: young, with ages ranging from 20-28 years and elderly, with ages ranging from 60-69 years. In the young group there were nine males and eight females and in the elderly group there were eight males and eight females. Significant effects on the temporal-order threshold were seen with age, gender, and training. Significant gender differences were observed with women having increased thresholds when compared to men, independent of age. Elderly subjects also displayed greater thresholds than younger subjects (Szymaszek et al., 2006). Performance improved in all subjects with practice, which can be attributed to becoming familiar with the task (Szymaszek et al., 2006).

Monaural low redundancy tasks.

Monaural low-redundancy speech tests evaluate auditory closure abilities when the signal is distorted or altered in some way, making it more difficult to understand (ASHA, 2005; Bellis & Ferre, 1999). These tests assess the listener’s ability to achieve closure or the ability of the brain to “fill in the blanks” when the auditory signal is degraded. In a healthy and normal auditory system, the brain can easily make sense of what is being heard even when the speech is less than optimal (Bellis, 2003). However, this is not a simple task for individuals with some type of AP difficulties. The stimuli are monosyllabic words that are degraded in some way such as reverberation, filtering, time-compressed, and so forth. The listener verbalizes what he/she hears. Examples of this test category are low-pass or high-pass filtered speech (Bornstein, Wilson, & Cambron, 1994), time-compressed speech with or without reverberation (Wilson et al., 1994), and speech-in-noise tests. Compressed and Reverberated Words (Wilson et al., 1994) include speech materials (NU-6 word lists) that have been time compressed (45%) and reverberated (0.3 seconds). Deficits in this area may result in difficulties understanding speech in a noisy environment. Wilson and colleagues (1994) evaluated the effect of the amount of compression (45-75%) on performance in normal listeners. Results indicated that as the compression ratio increased performance declined. The best performance was observed using the lowest compression rates (either the 45% or 65%) and with compression only; performance declined by adding in 0.3 s reverberation (Wilson et al., 1994). Another study looked at performance of 20 children aged 7-8 years old, who were suspected of having learning difficulties by their teacher. There were three conditions of the speech recognition task, using the PB-K 50 word list, with varying rates of time compression (Manning, Johnston, & Beasley, 1977). These results were compared to age-matched controls. The normal children's performance became increasingly worse from 0% compression to 30% compression to 60% compression. The children with suspected learning difficulties, showed reduced performance as the compression ratio increased; however, their scores were worse than the normal children (Manning et al., 1977).

Cameron et al. (2009) completed a study to obtain normative data on the North American Listening in Spatialized Noise –Sentences test (NA LiSN-S®) from 72 normal hearing children aged 6 years, 2 months, to 11 years, 10 months. Results showed that performance abilities increased with age. When results were compiled and corrected for age, no significant gender effects were observed between the 34 girls and 38 boys that participated in the study. In addition, both inter- and intra-participant variability was low (Cameron et al., 2009).

Binaural interaction.

Tests of binaural interaction assess how the individual's ears work together, which is the case for the auditory skills of localization, lateralization, speech understanding in noise, binaural fusion, and so forth (ASHA, 2005; Bellis, 2003). When each ear is simultaneously stimulated with a different portion of the same target message, the brain must use binaural fusion to complete the target message. (Bellis, 2003; Emanuel, 2002). Examples of this type of test are high-pass/low-pass binaural fusion tests, binaural fusion test (BFT), and MLD.

The brain must decode frequency, intensity, and timing cues to accurately process verbal and nonverbal information. Traditional hearing tests do not account for the timing aspect of hearing. Binaural fusion tests are used to evaluate this fusion skill. Davis and McCroskey (1980) evaluated the fusion point in children. They conducted a study of 135 children, ranging in age from 3-12 years was. The test stimuli were two identical tones; the variable being manipulated is the ISI between the two tones, which were adjusted throughout the test and administered in ascending and descending order. The stimuli were presented binaurally and at a specified intensity above a threshold. The average of all the trails combined in labeled the fusion point (Davis & McCroskey, 1980). These researchers found that performance improved as the child aged, then leveled out around

9-11 years of age (Davis & McCroskey, 1980). The fusion point was found to be unaffected by frequency; however, intensity impacted the performance across all ages. The louder the presentation level the shorter the fusion point. Gender differences were observed in this study with males having slightly shorter fusion values, most noticeable around 5 years of age (Davis & McCroskey, 1980).

A normative data study was conducted with 105 typically developing Dutch children aged 9-16 years old on an AP test battery which included the following tests words-in-noise, filtered speech, high-pass/low-pass binaural fusion, DDT, FPT, DPT, and backwards masking (Neijenhuis et al., 2002). Age differences were observed on all tests except the FPT. The only significant gender differences were observed on the filter speech and high-pass/low-pass binaural fusion tests, with girls having higher scores (Neijenhuis et al., 2002).

Minimum Test Battery

A test battery approach is often recommended in the literature for the evaluation of children's AP skills (AAA, 2010; ASHA, 2005; Bamiou et al., 2001; Bellis & Ferre, 1999; Chermak, 2002; Colorado, 2008; Dawes & Bishop, 2009; Jerger & Musiek, 2000; Musiek & Chermak, 1994; Moav et al., 2009; Neijenhui et al., 2003). It has been reported that the sensitivity of a test battery is impacted by both the category of tasks as well as the amount of tests included in the battery (AAA, 2010; Vanniasegaram et al., 2004). Therefore, there is a balance between conducting a comprehensive enough AP assessment (enough tests selected) and having a good specificity (not too many tests) (AAA, 2010), Jerger and Musiek (2000) summarized the results of an AP consensus group which suggested a minimum test battery should include: pure-tone audiometry, immittance measures, otoacoustic emissions (OAE), word recognition, auditory brainstem response (ABR) or middle latency response (MLR), a dichotic listening task, a temporal gap task, and a duration pattern task. Although this publication represents a consensus of AP experts, a survey of audiologists indicated that this minimum test battery was not being followed (Emanuel, 2002). When selecting an appropriate test battery for the evaluation and diagnosis of APD there is no "one size fits all" method. A minimum test battery, as defined by the Consensus Conference should, "provide the minimum amount of information necessary for a diagnosis of APD in school-aged children" (Jerger & Musiek, 2000, p. 471). A skilled clinician will select test to acquire further information from suspected areas with deficit. Emanuel, Ficca, and Korczak (2011) surveyed Audiologists, who acknowledge APD as an area of expertise. They found clinicians selected the AP test battery based on a number of factors including experience, a review of the literature, technical reports, seminars, etc. In general these professionals were found to use a minimum battery of tests, but included additional tests based on the patient's age and case history information (Emanuel, Ficca, & Korczak, 2011). In addition, a collection of tests that provide both good sensitivity and specificity is best; using the minimum number of test will decrease the test time and therefore increase clinical utility (AAA, 2010). The minimal test battery, or core battery, serves as a guideline of tests that assess many functions of AP (AAA, 2010). However, the clinician should use clinical judgment of when additional assessments should be performed (ASHA, 2005; Musiek & Chermak, 1994).

A study by Emanuel (2002) surveyed audiologists regarding their APD test battery for this population. Results from this survey found the vast majority of respondents reported using pure-tone audiometry, tympanometry, dichotic digit tests, and word recognition testing. The only APD test used by all respondents was the dichotic digits test. The most commonly reported AP tests utilized were dichotic and monaural low-redundancy speech tests (Emanuel, 2002). It was also noted that tests that were packaged with detailed instructions and normative data, like the SCAN-A/SCAN-C were more commonly utilized (Emanuel, 2002). Normative data specific to each clinician's setting and population has been recommended (Emanuel, 2002). Emanuel (2002) highlighted important points that may affect the tests used in an APD battery. Some AP assessments have limited availability and some of those that are available do not have or provide supporting literature or research. Additionally, some variability in test batteries is to be expected given the needs of each patient. Lastly, all practicing audiologists were not appropriately trained in their schooling so their knowledge of which tests to use and what tests are available may be limited (Emanuel, 2002).

Chermak, Silva, Nye, Hasbrouck, and Musiek (2007) performed a survey with respondents randomly drawn from AAA member directory and analyzed 90 respondents' answers. Of those respondents only 24 reported clinically assessing APD; therefore, conclusions from this study are limited due to the poor response rate. This study's findings included: improvement in professional education coursework in the past 10 years, most of the reported tests utilized have good sensitivity and specificity supported in the literature, elcectrophysiologic testing is being performed (but is uncertain whether this is in conjunction with the APD test battery or for other purposes), and for treatment patients are being referred to speech language pathologists. A surprising finding was that many clinicians are misusing acoustic reflex thresholds as the primary diagnostic tool of APD (Chermak et al., 2007). More education for current clinicians and Au.D. students on the diagnosis of APD is warranted based on these surveys findings. Emanuel et al. (2011) performed a large study (n = 195) surveying only those audiologist that acknowledge APD as an area of expertise. Results indicated audiologists are using an approach which includes screenings, audiologic evaluation, case history, and a battery of AP tests assessing a variety of AP skills. In addition, these experts value assessments from other disciplines in order to accurately diagnose and manage APD (Emanuel et al., 2011).

Confounding factors.

When it comes to assessing the child for APD there are many factors that can influence the AP test results (ASHA, 2005; Cacace & McFarland, 1998; Chermak, 2002; Dawes & Bishop, 2009; Jerger & Musiek, 2000; Moncrieff & Wilson, 2009; Moore, 2010; Musiek et al., 1985). Chermak (2002) lists possible patient factors including: age, intelligence, native language/language experience, peripheral hearing loss, comorbid conditions, motivation, medications, and fatigue. Since these factors have been known to influence results, clinicians and researchers have omitted tests when peripheral hearing loss, fatigue, and/or age factors are observed (Musiek et al., 1985). Age is a frequently discussed patient factor particularly in the pediatric population (Chermak, 2002; Neijenhuis et al., 2003; Szymaszek et al., 2006; van Kesteren & Wiersinga-Post, 2007). Assessments of AP may be too complex or difficult for young children, these behavioral tests should begin no sooner than 7 years of age (AAA, 2010). It is recommended that children younger than 7 years old should not be evaluated, due to the high variability in their scores (AAA, 2010). Silman, Silverman, and Emmer (2000) studied the effects of motivation on test performance and found that motivation could affect test performance therefore the clinician needs to ensure that their patient is motivated to do well on the tasks. By providing the child with a few breaks fatigue, attention, and cooperation can often be managed (Chermak et al., 1999).

As discussed previously, many research studies looking at AP abilities fail to indicate the gender composition of the sample used, putting a general label on the participants such as “children” or “adults”. Of the studies that do indicate the gender make-up of their sample, many neglect to analyze gender as a variable. There have been a few studies that report investigating gender differences. Inconsistent results have been noted in the limited research that has been reported. Witton (2010) discussed the similarities between developmental disorders and AP abilities and indicates these disorders should be expected to co-occur. In general, developmental disorders show a higher prevalence in boys versus girls. Therefore, it is plausible that there could be gender differences in APD as well.

Aims of This Study

Males have been shown to have a higher prevalence than females in several disorders including ASD (3.3:1; Nicholas et al., 2008), ADHD (2.3:1; Bauermeister et al., 2007), and reading disorders (3.2:1; Badian, 1999). Similarly, APD had been estimated to have a gender ratio of 2:1 (Chermak, 2002). Although males have a higher prevalence of APD, there is debate as to whether males and females differ in performance on AP tests. Given the limited information regarding gender differences for tests of AP, further research is necessary. This study aimed to identify if there were any gender differences on any of the tests of AP for typically developing children between the ages of 7-12 years. Additionally, this study aimed to establish local normative data on several tests of AP abilities. These normative data were collected on assessments using a core battery of minimal linguistic loading with supplemental tests linguistic loaded added to the battery.

CHAPTER THREE

METHODS

Participants

Thirty typically developing children, both male and female, between the ages of 7 years, 0 months to 12 years, 10 months were recruited to participate in this study. Participants were recruited from local schools and the community, as well as by word of mouth. Participation was on a volunteer basis. All participants were compensated for their time. This study has been approved by the Institutional Review Board (IRB) at Towson University. All interested parents and children received an informed consent form as well as a case history form to complete. Parents were required to sign the consent form and children were required to sign an assent form prior to beginning any testing.

Pre-Screening

Several pre-screening questions were asked to all parents of potential participants to determine if the child was suitable for this research study. Prior to scheduling the test sessions the following pre-screening questions were asked: (1) Is English the child's first language?, (2) Did the child meet all developmental milestones at the appropriate ages?, (3) Did the child meet all speech and language milestones at the appropriate ages?, (4) To the best of your knowledge, does the child have normal hearing, reading, speech and language abilities?, (5) Does the child have any diagnoses (i.e., ADHD), and (6) Has the child ever received therapy?

Equipment/Materials

Equipment utilized in the present study for auditory tests included: a Welch Allyn Otoscope, Grason-Stadler, Inc. (GSI) Tympstar Clinical Middle Ear Analyzer, GSI-61

Clinical Audiometer, Sony 5 Disc CD player, and Otodynamics ILO (version 6) OAE system. All equipment was calibrated to current American National Standards Institute (ANSI) standards. The compact discs utilized in the present study included: SCAN-3: C stimulus CD, Tonal & Speech Materials for Auditory Perceptual Assessment 2.0 CD, Random Gap Detection Test AUDiTEC CD, and the Comprehensive Test of Phonological Processing (CTOPP) stimulus CD. All CDs were calibrated according to their own calibration tones as warranted. Additional equipment/materials utilized in this study included: Dell laptop, CTOPP stimulus book and stopwatch, Test of Nonverbal Intelligence-Third Edition (TONI-3) picture book, Clinical Evaluation of Language Fundamentals-Fourth Edition Screening Test (CELF-4 Screening Test) stimulus book, Sennheiser HD215 circumaural headphones and the Phonak soundcard for the Listening in Spatialized Noise Sentences Test (LiSN-S). All auditory testing was completed in a double-walled soundproof test booth. All tests of AP were presented at 60 dB HL, a comfortable listening level, via EARTONE 3A insert earphones unless otherwise noted below.

Audiologic Assessment

To be included in this study, each subject must have a normally functioning peripheral auditory system, which was evaluated in several ways. A pure-tone hearing screening was performed assessing the frequency range of 250-8000 Hz (octaves) at a level of 15 dB HL. A WRS was obtained using four forms of the CID-W22 25-word lists, randomized for each participant. Immittance measurements were performed including tympanometry, for both ears, as well as ipsilateral and contralateral acoustic reflex thresholds (ARTs) evaluated at 500, 1000, and 2000 Hz. Transient evoked otoacoustic emissions (TEOAEs) were obtained for each ear individually.

Behavioral Auditory Processing Test Battery

In addition to the descriptions below, a comprehensive summary of the AP tests used in this study can be seen in Table 1.

Dichotic listening.

Dichotic double digits (DDT).

In the DDT (Noffsinger, Martinez, & Wilson, 1994; Noffsinger, Wilson, & Musiek, 1994) the listener is presented with four different single monosyllabic digits, ranging from 1-10 (excluding 7). Two digits are presented to each ear simultaneously. The listener is asked to repeat back all digits presented, order does not matter. Each participant was given three practice items. Once the examiner felt confident that the participant understood the task, 20 test items were administered. The participants' responses were recorded on the score sheet. The scores are determined on a percent correct basis, awarding one point per digit. The number of correct test items was divided by the total number possible. Each ear was scored separately; therefore, each participant's score per ear was divided by forty.

Temporal processing.

Frequency pattern test (FPT).

The FPT (Musiek, 1994) involves the presentation of three tones; all tones are 150 ms in duration. Two of the three tones are the same frequency and the other tone is different. The frequencies of the tones are either 880 Hz (low) or 1122 Hz (high). Between each tone presented there is a 200 ms inter-stimulus-interval. The ears were tested separately. The participant was requested to label the tones heard as “low” or “high” in the same sequence they were presented. An example of a participant’s verbal response would be: “high, high, low.” Each participant was given five practice items. Once the examiner felt confident that the participant understood the task, 15 test items were given. The participant’s responses were recorded on the score sheet. The scores are determined on a percent correct basis, awarding one point per correct pattern and then dividing the number of correct test items by fifteen. Each ear was scored separately.

Duration pattern test (DPT).

The DPT (Musiek, 1994) involves the presentation of three 1000 Hz tones. Two of the three tones are the same duration and the other tone is different. The duration of the tones is either 250 ms (short) or 500 ms (long). Between each tone presented there is a 300 ms inter-stimulus-interval. Ears were tested separately. The participant was requested to label the tones heard as “short” or “long” in the same sequence they were presented. An example of a participant’s verbal response would be: “short, long, short.” Each participant was given five practice items. Once the examiner felt confident that the participant understood the task, 15 test items were given to the first ear. The participant’s responses were recorded on the score sheet. The scores are determined on a percent correct basis, awarding one point per correct pattern and then by dividing the number of correct test items by fifteen. Each ear was scored separately.

Random gap detection test (RGDT).

The RGD (Keith, 2000) test is the binaural presentation of tones. The tone pairs are presented with an inter-stimulus-interval (ISI) which varies in duration (40, 30, 25, 20, 15, 10, 5, 2, and 0 ms). The participant was asked to indicate whether he/she heard one or two tones. The lowest ISI the participant can perceive two tones consistently was recorded as the lowest gap detection or threshold. In this study there was one practice trial using the practice/screening track on the CD. The next four trials were tones presented at: 500, 1000, 2000, and 4000 Hz. The ISIs in each test run are randomized. The stimuli were presented to both ears simultaneously. The participant's responses were recorded on the score sheet. The final threshold was obtained by averaging the gap thresholds from the four test runs for one overall RGD threshold. If a participant was inconsistent for one of the test runs then his/her RGD threshold was calculated using the remaining three runs.

Monaural low redundancy.

Compressed and reverberated words (CRW).

In this test, NU-6 words with 45% time compression plus 0.3 seconds of reverberation were presented to the participant (Wilson, Preece, Salamon, Sperry, & Bornstein, 1994). The participant was instructed to repeat the word even if they are uncertain about what they heard. Each ear was evaluated individually, using 50 different test items per ear. There were no practice items administered for this test. The participant's responses were recorded on the score sheet. The scores were determined on a percent correct basis by dividing the number of correct test items by fifty. Each ear was scored separately.

Auditory figure-ground (AFG) at +8 dB SNR & 0 SNR.

The AFG +8 and AFG 0 are two subtests of the SCAN-3: C (Keith, 2009). These tests evaluate listening abilities in background noise (multi-talker babble). For the AFG +8 the target signal is 8 dB above the noise, creating a +8 dB signal-to-noise ratio (SNR).

For the AFG 0 the target signal and noise are presented at equal intensities, creating a 0 dB SNR. Two practice items were given to each ear. Once the examiner felt confident that the participant understood the task the 20 test items were given. The participant's responses were recorded on the score sheet. The scores are determined on a percent correct basis, awarding one point per correct word and then dividing the total correct responses by the total possible points. Each ear was scored separately; therefore, the total score per ear was divided by twenty.

Localization/Auditory figure ground.

Listening in spatialized noise – sentences test (LiSN-S®).

The LiSN-S® test was completed on a laptop computer and connected with Sennheiser HD215 headphones by way of an external USB sound card (Cameron et al., 2009). This test creates a listener-perceived 3-D auditory environment, with a target speaker and a secondary speaker, by modifying the sound waves of speech, as they would change when they met the head. The target speaker verbalizes a sentence that the listener must repeat back while ignoring the second speaker (Cameron & Dillon, 2008). The listener's task is to repeat as many of the words from the target speaker's sentence as possible, while ignoring the background story. At least five sentences were given as practice. Up to 30 sentences were presented in each of the four simulated test conditions. The test is administered binaurally. The target stimulus is perceived as originating from the front of the listener under the headphones (0˚ azimuth). The masker (looped children's stories) was presented at a constant intensity of 55 dB SPL, but varied in perceived location (0˚ azimuth [front] or +90˚ [right] and -90˚ azimuth [left]). The voice of the competing stories can be the same voice of the target speaker or different. Initial presentation of the target signal (sentence) was 62 dB SPL and was increased or decreased based on the participant's response. The individual's Speech Recognition Threshold (SRT) and advantage measures were compared to age appropriate normative data and cut-off scores.

Table 1

Summary of Auditory Processing Test Battery

Test	Presentation Level	Stimuli	Presentation Mode	Process Assessed	Task
FPT	60 dB HL	880 Hz (low) or 1122 Hz (high) 150 ms tones	Monaural	Temporal Processing	Verbally state the pattern of 3 tones (low and high) Example: "high, high, low"
DPT	60 dB HL	250 ms (short) or 500 Hz (long) 1000 Hz tones	Monaural	Temporal Processing	Verbally state the pattern of 3 tones (short and long) Example: "long, long, short"
RGDT	60 dB HL	Pairs of 500, 1000, 2000, and 4000 Hz tones with random ISI from 0 to 40 ms	Binaural	Temporal Processing	Verbally state whether one or two tones were heard
DDT	60 dB HL	Digits 1 - 10 (excluding 7) Male speaker	Binaural	Dichotic Listening	Repeat all 4 numbers in any order
CRW	60 dB HL	Monosyllabic NU-6 words with 45% compression and 0.3 s reverberation Female speaker	Monaural	Monaural Low-Redundancy	Repeat the word after the carrier phrase
AFG +8 & 0 dB SNR	60 dB HL	Target words mixed in with multitalker speech babble as background noise	Monaural	Monaural Low-Redundancy	Repeat the word heard, while ignoring the background noise
LiSN-S	Target speech: 62 dB SPL (initially-manipulated throughout the evaluation) Competing speech: 55 dB SPL (constant)	A target sentence, with a competing masker (children's stories) presented at different locations Female speaker(s)	Binaural	Localization / Auditory Figure Ground	The target follows a warning tone. Repeat as much of the target sentence as possible, while ignoring the children's story

Note. FPT = Frequency Pattern Test; DPT = Duration Pattern Test; RGDT = Random Gap Detection Test; ISI = Interstimulus Interval; DDT = Dichotic Digits Test; CRW = Compressed and Reverberated Words; AFG=Auditory Figure Ground; SNR= Signal-to-Noise Ratio; LiSN-S= Listening in Spatialized Noise Sentence test

Modified from Dau, L. (2011).

Additional Tests

Cognition.

The Test of Nonverbal Intelligence-3rd edition (TONI-3) (Brown, Sherbenou, and Johnsen, 1997) is utilized to evaluate nonverbal intelligence through a language-free examination. This test was administered in a tidy quiet room, free of distractions from adjacent rooms and hallways. Establishing a rapport with the examinee was done prior to the test beginning; however, once the test began there was no verbal communication. The child was required to point to various pictures to “solve puzzles.” There are two equivalent forms of the TONI-3 (A & B), which were counter balanced between the participants in this study. The picture book was placed on a flat surface so it was visible to both the examiner and the examinee and easy for page turning. Administration and scoring was completed according to the manual and a scaled score was generated for each participant.

Language.

The Clinical Evaluation of Language Fundamentals-4th edition (CELF-4) screening test (Semel, Wiig, & Secord, 2004) was utilized to screen for language disorders. Test administration and scoring was conducted according to the manual. There are 47 items in this test, with multiple language tasks; however, the amount administered is age dependent. The first 28 items are administered to children from 5-8 years of age. For individuals ranging in age from 9-21 years, test items 14-47 are given. The test was administered in a quiet well-lit room. The examiner was positioned to the side of the participant in order to see both the child’s responses and the stimuli. A correct or logical response is awarded one point and an incorrect or no response is awarded zero points.

The total score and criterion score are compared to the age appropriate level (Semel et al., 2004). If the total score is at or above the criterion score, the screening is considered a pass.

Phonological processing.

Four subtests from the Comprehensive Test of Phonological Processing (CTOPP) (Wagner, Torgesen, & Rashotte, 1999) were utilized to assess the child's phonological awareness, phonological memory, and rapid automatic naming abilities. The following subtests were examined: elision, blending words, memory for digits, rapid digit naming, nonword repetition, and rapid letter naming. Test administration and scoring was conducted according to the manual.

Sustained attention.

Integrated Visual and Auditory – Continuous Performance Test (IVA-CPT) (Sandford & Turner, 1995 as cited in Sharma et al., 2009) gauged the child's sustained visual and auditory attention abilities. This test was administered on a laptop computer with an external mouse. The program has the number "1" or the number "2" appear on the screen as well as the number "1" or the number "2" verbalized. The program gives the examinee instructions to ignore the number "2" and attend to the number "1" by clicking the mouse each time "1" is seen or heard. Practice was given with feedback prior to the scored portion commencing. Upon completion of the task the data is analyzed and a scaled score is given for both sustained auditory and visual attention.

Exclusion Criteria

A failure observed on the hearing screening, the CTOPP, CELF-4, TONI-3, or any of the AP tests resulted in exclusion of the participant from data analysis. A failure was determined based on nationally published norms for each assessment.

Data Analysis

Once the data were collected descriptive statistics were computed and inferential statistics were analyzed using IBM SPSS Statistics version 20. Several aspects of the data were examined. Oneway ANOVAs were run to assess effects of age and gender separately. A paired samples *t*-test was used to analyze ear effects ear differences scores were also used to analyze ear effects using an MANOVA. A linear regression analysis was performed evaluating performance on the AP tests as a predictor of nonverbal IQ. An alpha level of < 0.05 was utilized to determine significance. Data were analyzed using Microsoft Excel 2008 for Mac version 12.2.3, Microsoft Excel 2007, and IBM SPSS Statistics version 20.

CHAPTER FOUR

RESULTS

Participants

Thirty participants were recruited and were included in the data analysis. The sample had equal representation of genders (males = 15, females = 15). Participants ranged from 7, 0 (years, months) to 12, 10 (years, months). Table 2 displays the mean age and standard deviation of the sample broken down by gender and divided into three age groups.

Table 2

Age and Gender Sample Descriptives

	Male		Female	
Age Group	*n*	M (SD)	*n*	M (SD)
7-8 y/o	5	8.02 (0.55)	6	7.47 (0.52)
9-10 y/o	6	10.08 (0.60)	4	10.00 (0.38)
11-12 y/o	4	12.04 (0.63)	5	12.13 (0.45)
Total	15	9.92 (1.70)	15	9.70 (2.11)

Note. M (SD) = Mean (standard deviation)

English was the primary language of all 30 children; one child was adopted and her first language exposure was Chinese. Seventeen children (56.67%) were carried full term without any complications, one child (3.33%) wasn’t full term but had no complications, and one child (3.33%) was adopted so her birth history is unknown. Five children (16.67%) were carried to full term but their parents’ reported additional complications (e.g., at risk due to maternal age, multiples, jaundice, neonatal intensive care unit (NICU) stay). The remaining 23.33% of children were not carried full term, reported complications included two unplanned c-sections; HELLP syndrome; mother was 7 months pregnant and had appendectomy under general anesthesia; mother had hypertension, placental abruption, pre-eclampsia (resulting in preterm birth). Two boys (6.67%) in this sample were diagnosed with ADD, no other children reported a previous diagnosis. Fourteen children (46.67%) reported no history of ear infections; fifteen children reported a history of ear infections (50%); one child's history of ear infections was unknown (3.33%). Only two children (6.67%) reported having pressure equalization (PE) tubes placed and both were getting adenoidectomies at the same time. Twelve children (40%) reported not playing a musical instrument and eighteen (60%) reported playing a musical instrument. Musical instruments played included: piano, violin, trumpet, guitar, clarinet, recorder, baritone, flute, drums, saxophone, and string bass. Two children were left-handed (6.67%) and one child was ambidextrous (3.33%) all others were right-handed (90%).

Audiologic Assessment

All participants passed the hearing screening and had excellent WRSs (scores $\geq$ 92%). The male participants had mean (with standard deviations [SD] in parentheses) WRS of 99.47% (1.41) and 98.93% (1.83), for the right and left ears respectively. The female participants had a mean (SD) WRS of 98.13% (2.97) and 99.20% (2.24), for the right and left ears respectively. With the exception of three participants, all children had Type A tympanograms. The abnormal tympanogram results were as follows: one boy had Type C in both ears, one girl had Type C in the left ear, and one girl had Type A_s in the left ear. These children passed the hearing screening and passed all other tests within the comprehensive test battery therefore they were included in the data analysis. All participants had present ART with the exception of two children, one boy and one girl.

No responses were changed to values of 115 dB to be included in the data analysis. Table 3 displays the means (SD) of each ART by gender for the sample.

Table 3

ART Mean and SD Between Gender

	Male		Female	
Stimulus	Right	Left	Right	Left
		Ipsi		
500 Hz	93.33 (7.72)	93.33 (6.99)	91.00 (5.73)	92.33 (6.78)
1000 Hz	93.00 (7.27)	93.33 (7.24)	91.33 (6.11)	91.33 (6.11)
2000 Hz	95.33 (6.67)	95.67 (6.78)	94.00 (5.73)	93.67 (7.19)
		Contra		
500 Hz	98.00 (4.55)	98 .00 (5.28)	100.00 (5.35)	100.67 (6.23)
1000 Hz	100.33 (4.81)	99.00 (4.31)	99.00 (5.07)	100.67 (4.95)
2000 Hz	99.00 (5.73)	97.00 (5.28)	99.33 (6.23)	100.67 (4.17)

Note. ART = acoustic reflex threshold. For both males and females n = 15. No Responses were given a value of 115 dB to be included in the data analysis. The table displays Mean (SD).

Table 4 displays the means and standard deviations of TEOAE results for all 30 participants, separated by gender.

Table 4

TEOAEs Mean and SD Between Gender

	Male		Female	
Frequency	Right	Left	Right	Left
1000 Hz	10.58 (7.84)	11.66 (6.30)	10.37 (9.63)	12.93 (6.83)
1400 Hz	14.74 (5.83)	11.36 (7.48)	14.28 (5.20)	14.99 (6.55)
2000 Hz	13.59 (4.53)	13.93 (5.38)	15.41 (6.21)	15.36 (5.95)
2800 Hz	11.83 (7.12)	12.33 (3.70)	15.53 (3.82)	16.08 (2.95)
4000 Hz	9.63 (5.63)	9.29 (5.59)	13.11 (5.95)	14.07 (3.99)

Note. Means (standard deviation)

Additional Tests

Additional tests were performed to further classify the group of 30 participants. The means and standard deviations for the additional tests were broken down into age groups as well as genders, as displayed in Table 5.

Table 5

Additional Tests Mean and SD of scores Between Gender and across Age Groups

	7-8 y/o (n=11)		9-10 y/o (n=10)		11-12 y/o (n=9)	
	Male (n=5)	Female (n=6)	Male (n=6)	Female (n=4)	Male (n=4)	Female (n=5)
TONI:Q	107.80 (5.89)	112.33 (16.13)	109.83 (8.75)	119.50 (15.42)	108.00 (14.90)	108.80 (14.04)
TONI: %	68.60 (11.48)	70.33 (26.19)	71.67 (19.25)	82.25 (19.87)	63.25 (24.19)	66.00 (25.11)
CELF: TS	22.80 (2.59)	22.67 (2.34)	25.50 (3.56)	24.50 (4.04)	27.00 (1.41)	28.40 (2.97)
CTOPP: PA	111.40 (11.70)	112.50 (14.00)	105.50 (9.93)	105.25 (10.78)	106.75 (2.87)	104.80 (7.82)
CTOPP: PM	108.40 (10.90)	103.00 (6.57)	98.00 (8.63)	102.25 (9.91)	102.25 (10.78)	104.80 (13.52)
CTOPP: RN	113.20 (8.90)	101.50 (6.77)	107.50 (8.64)	107.50 (7.14)	109.00 (12.73)	97.00 (12)
BrainTrain A	103.00 (4.64)	98.00 (15.52)	73.67 (29.84)	87.50 (51.60)	59.00 (32.52)	104.80 (11.86)
BrainTrain V	105.20 (9.91)	103.17 (21.29)	89.50 (17.72)	108.25 (9.39)	64.25 (39.85)	105.20 (7.56)

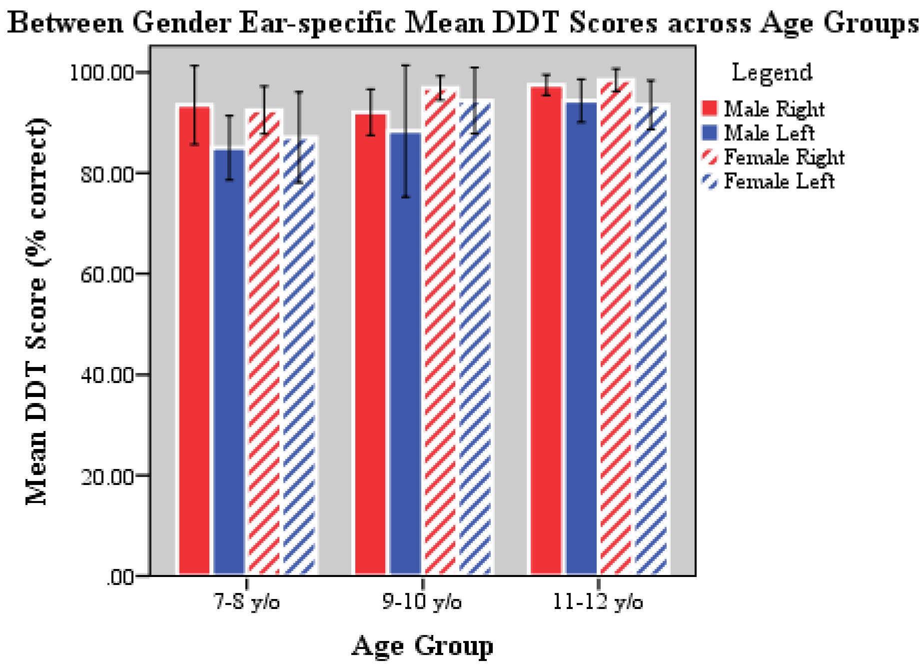
Note. TONI = Test of Nonverbal Intelligence, Q = quotient, % = percentile, CELF = Clinical Evaluation of Language Fundamentals, TS = total score, CTOPP = Comprehensive Test of Phonological Processing, PA = phonological awareness, PM = phonological memory, RN = rapid naming, A = auditory, V = visual

Behavioral Auditory Processing Test Battery

Dichotic listening.

Figure 1 displays the mean DDT scores; the error bars represent one standard deviation above and below the mean. The scores are divided between genders and across the three age groups. The right and left ear mean scores (with standard deviations in parentheses) for the males were 7-8 year olds 93.50% (7.83) & 85.00% (6.37), 9-10 year olds 92.08% (4.59) & 88.33% (13.10), and 11-12 year olds 97.50% (2.04) & 94.38% (4.27) respectively. The right and left ear mean (with standard deviations in parentheses) for the females were 7-8 year olds 92.50% (4.74) & 87.08% (9.00), 9-10 year olds 96.88% (2.39) & 94.38% (6.58), and 11-12 year olds 98.50% (2.24) & 93.50% (4.87) respectively.

Figure 1

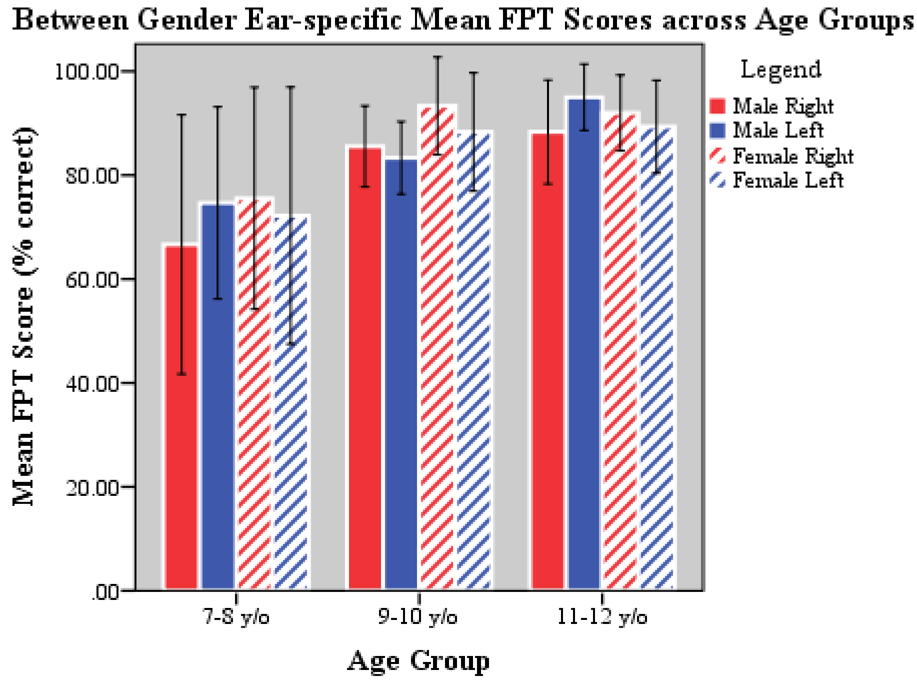


Note: Error bars represent 1 SD above and below the mean. DDT = dichotic digits test

Temporal processing.

Figure 2 displays the mean FPT scores; the error bars represent one standard deviation above and below the mean of the participants. The scores are divided between genders and across the three age groups. The right and left ear mean scores (with standard deviations in parentheses) for the males were 7-8 year olds 66.67% (24.94) & 74.67% (18.50), 9-10 year olds 85.56% (7.79) & 83.34% (7.00), and 11-12 year olds 88.33% (10.00) & 95.00% (6.38) respectively. The right and left ear mean scores (with standard deviations in parentheses) for the females were 7-8 year olds 75.56% (21.36) & 72.22% (24.73), 9-10 year olds 93.33% (9.43) & 88.33% (11.39), and 11-12 year olds 92.00% (7.30) & 89.33% (8.94) respectively.

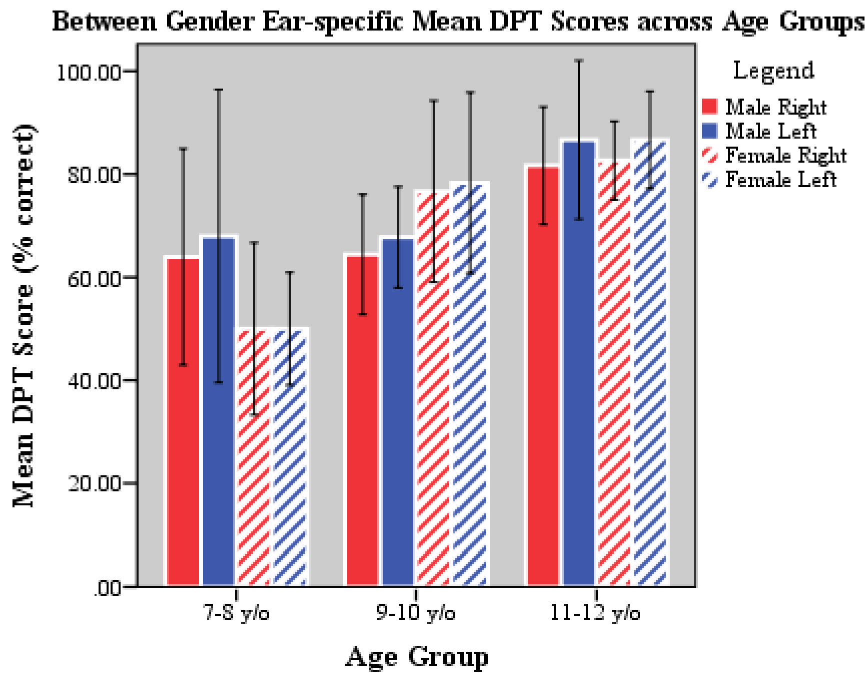
Figure 2



Note: Error bars represent 1 SD above and below the mean. FPT = frequency pattern test

Figure 3 displays the mean DPT scores; the error bars represent one standard deviation above and below the mean of the participants. The scores are divided between genders and across the three age groups. The right and left ear mean scores (with standard deviations in parentheses) for the males were 7-8 year olds 63.93% (21.00) & 68.00% (28.44), 9-10 year olds 64.44% (11.67) & 67.78% (9.81), and 11-12 year olds 81.67% (11.38) & 86.66% (15.40) respectively. The right and left ear mean scores ((with standard deviations in parentheses) for the females were 7-8 year olds 50.00% (16.73) & 50.00% (10.96), 9-10 year olds 76.66% (17.64) & 78.33% (17.53), and 11-12 year olds 82.67% (7.60) & 86.66% (9.43) respectively.

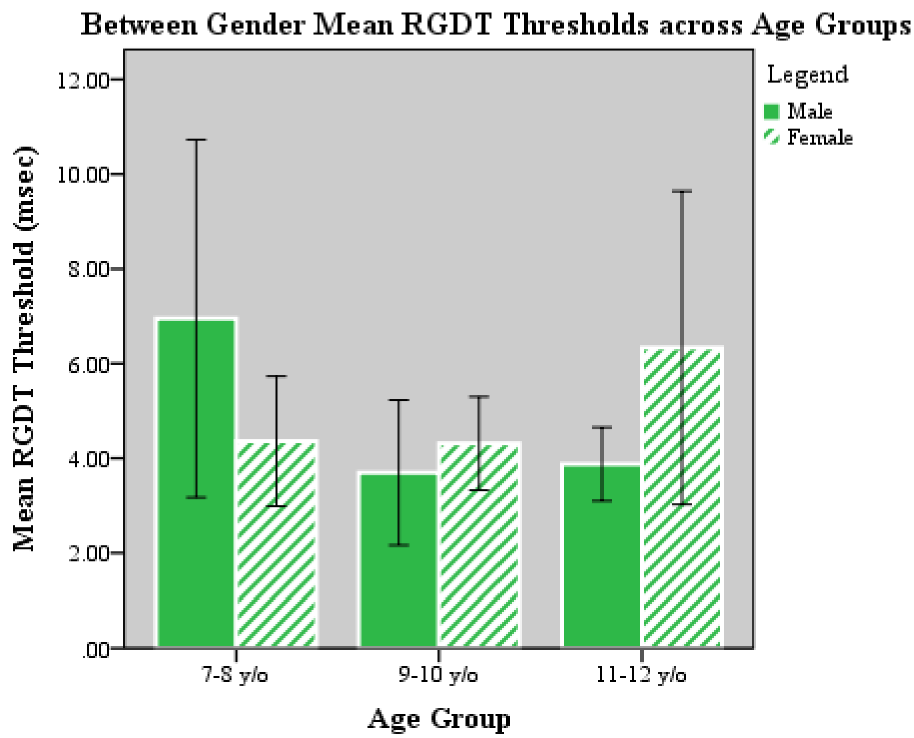
Figure 3



Note: Error bars represent 1 SD above and below the mean. DPT = duration pattern test

Figure 4 displays the mean RGDT thresholds; the error bars represent one standard deviation above and below the mean of the participants. The scores are divided between genders and across the three age groups. The mean thresholds (with standard deviations in parentheses) for the males were 7-8 year olds 6.95ms (3.76), 9-10 year olds 3.70ms (1.53), and 11-12 year olds 3.88ms (0.78). Mean thresholds (with standard deviations in parentheses) for the females were 7-8 year olds 4.36ms (1.37), 9-10 year olds 4.31ms (0.99), and 11-12 year olds 6.33ms (3.31).

Figure 4

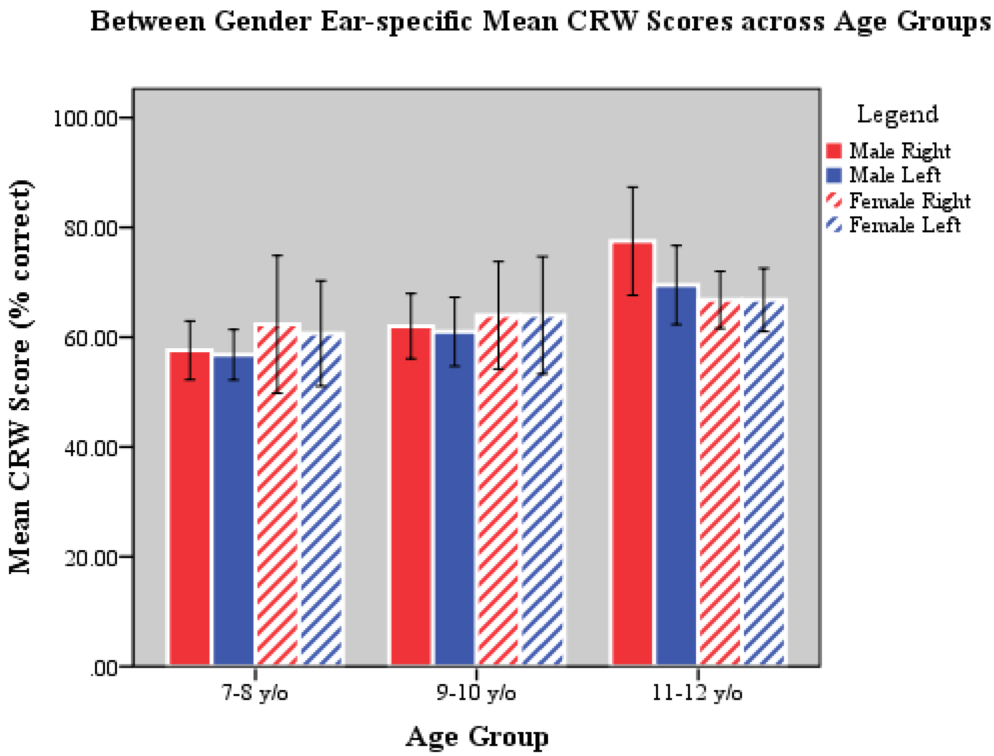


Note: Error bars represent 1 SD above and below the mean. RGDT = random gap detection test

Monaural low redundancy.

Figure 5 displays the mean CRW scores; the error bars represent one standard deviation above and below the mean of the participants. The scores are divided between genders and across the three age groups. The right and left ear mean scores (with standard deviations in parentheses) for the males were 7-8 year olds 57.60% (5.37) & 56.80% (4.60), 9-10 year olds 62.00% (5.93) & 61.00% (6.30), and 11-12 year olds 77.50% (9.85) & 69.50% (7.19) respectively. The right and left ear mean scores (with standard deviations in parentheses) for the females were 7-8 year olds 62.33% (12.55) & 60.66% (9.61), 9-10 year olds 64.00% (9.80) & 64.00% (10.71), and 11-12 year olds 66.80% (5.22) & 66.80% (5.76) respectively.

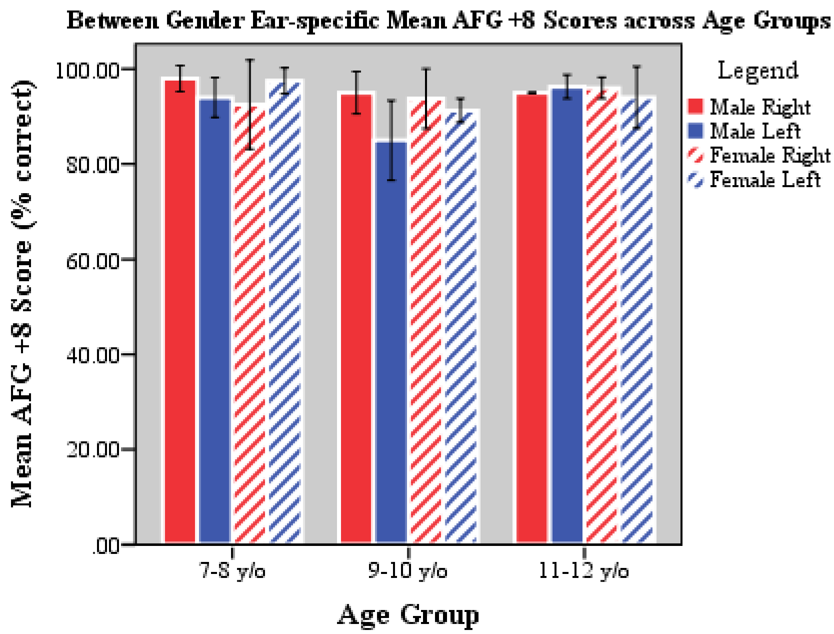
Figure 5



Note: Error bars represent 1 SD above and below the mean. CRW = compressed and reverberated words

Figure 6 displays the mean AFG +8 scores; the error bars represent one standard deviation above and below the mean of the participants. The scores are divided between genders and across the three age groups. The right and left ear mean scores (with standard deviations in parentheses) for the males were 7-8 year olds 98.00% (2.74) & 94.00% (4.18), 9-10 year olds 95.00% (4.47) & 85.00% (8.37), and 11-12 year olds 95.00% (0.00) & 96.25% (2.50) respectively. The right and left ear mean scores (with standard deviations in parentheses) for the females were 7-8 year olds 92.50% (9.35) & 97.50% (2.74), 9-10 year olds 93.75% (6.29) & 91.25% (2.50), and 11-12 year olds 96.00% (2.24) & 94.00% (6.52) respectively.

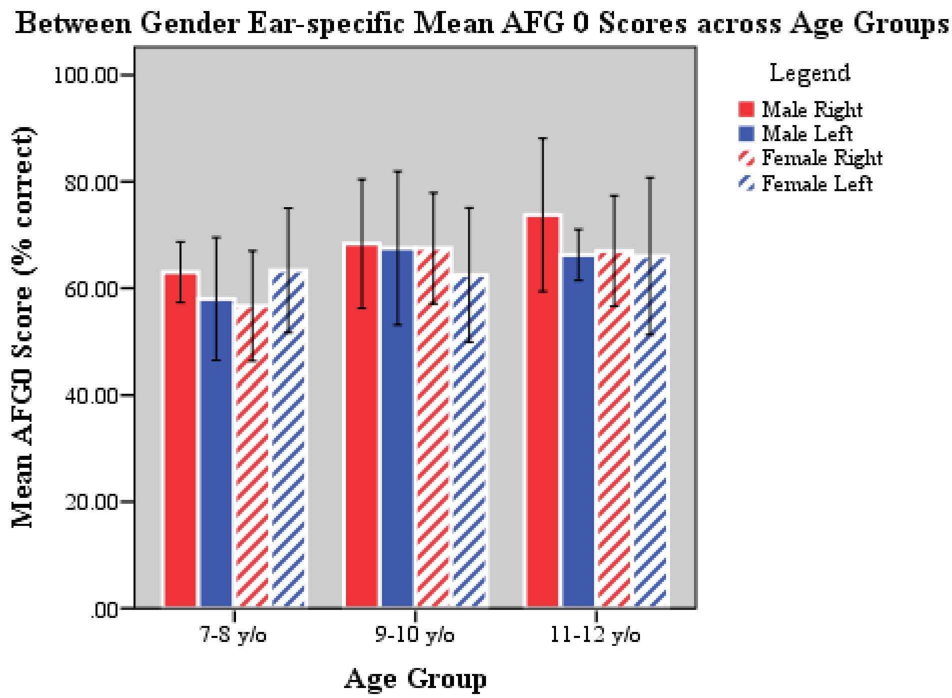
Figure 6



Note: Error bars represent 1 SD above and below the mean. AFG +8 = auditory figure ground with a +8 dB signal to noise ratio (SNR)

Figure 7 displays the mean AFG 0 scores; the error bars represent one standard deviation above and below the mean of the participants. The scores are divided between genders and across the three age groups. The right and left ear mean scores (with standard deviations in parentheses) for the males were 7-8 year olds 63.00% (5.70) & 58.00% (11.51), 9-10 year olds 68.33% (12.11) & 67.50% (14.41), and 11-12 year olds 73.75% (14.36) & 66.25% (4.79) respectively. The right and left ear mean scores (with standard deviations in parentheses) for the females were 7-8 year olds 56.67% (10.33) & 63.33% (11.69), 9-10 year olds 67.50% (10.41) & 62.50% (12.58), and 11-12 year olds 67.00% (10.37) & 66.00% (14.75) respectively.

Figure 7

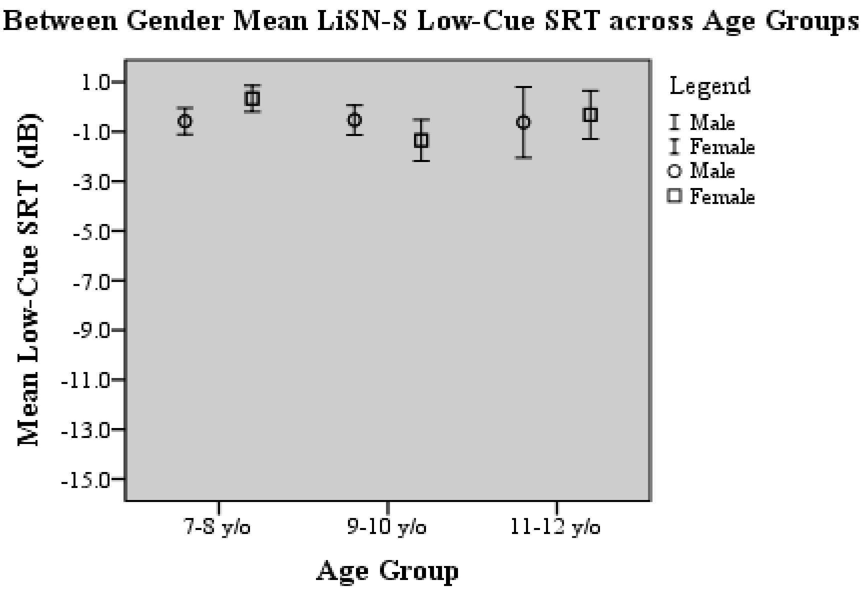


Note: Error bars represent 1 SD above and below the mean. AFG 0 = auditory figure ground with a 0 dB signal-to-noise ratio (SNR).

Lateralization/Auditory figure ground.

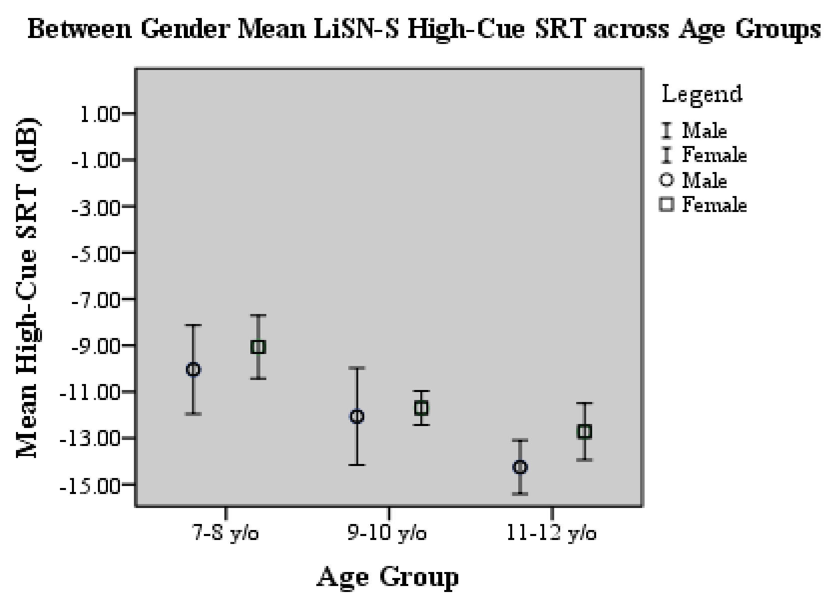
Figures 8 and 9 display the mean LiSN-S low-cue SRT and high-cue SRT measures respectively; the error bars represent one standard deviation above and below the mean of the participants. The scores are divided between genders and across the three age groups.

Figure 8



Note. Error bars represent 1 SD above and below the mean. LiSN-S = listening in spatialized noise - sentences, SRT = speech reception threshold

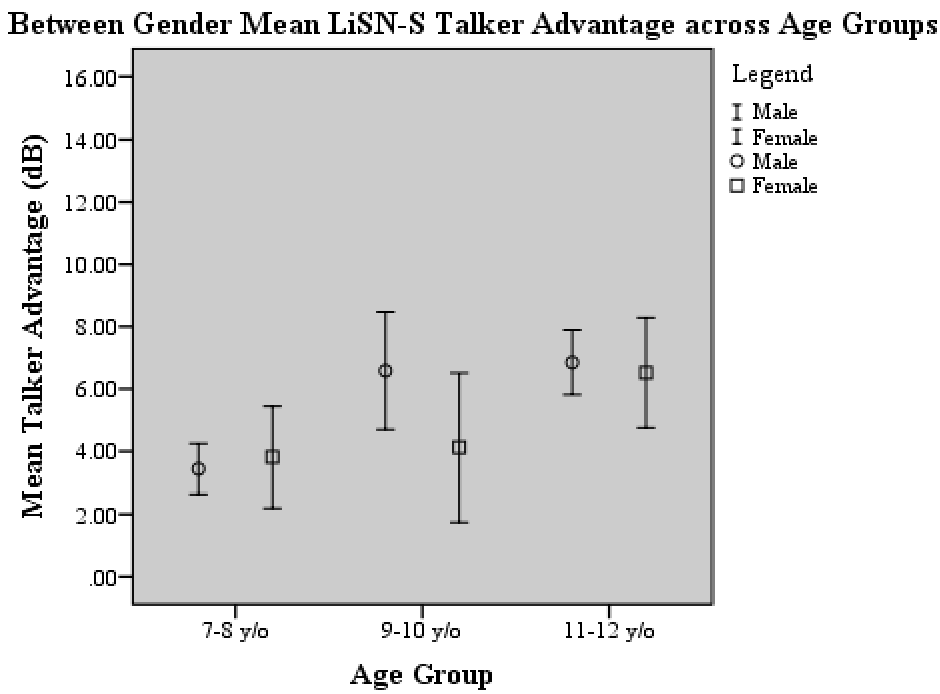
Figure 9



Note. Error bars represent 1 SD above and below the mean. LiSN-S = listening in spatialized noise - sentences, SRT = speech reception threshold

Figures 10, 11, and 12 display the mean LiSN-S advantage measures; the talker, spatial, and total advantage measures respectively. The error bars represent one standard deviation above and below the mean of the participants. The scores are divided between genders and across the three age groups. The means and standard deviations from Figures 9-13 are also displayed in Table 6 broken down by gender and age groups.

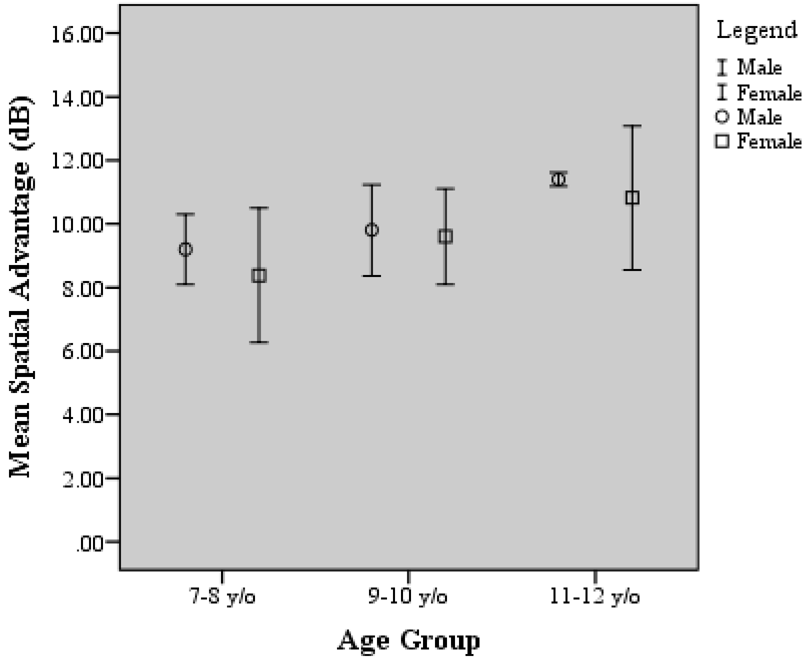
Figure 10



Note. Error bars represent 1 SD above and below the mean. LiSN-S = listening in spatialized noise - sentences

Figure 11

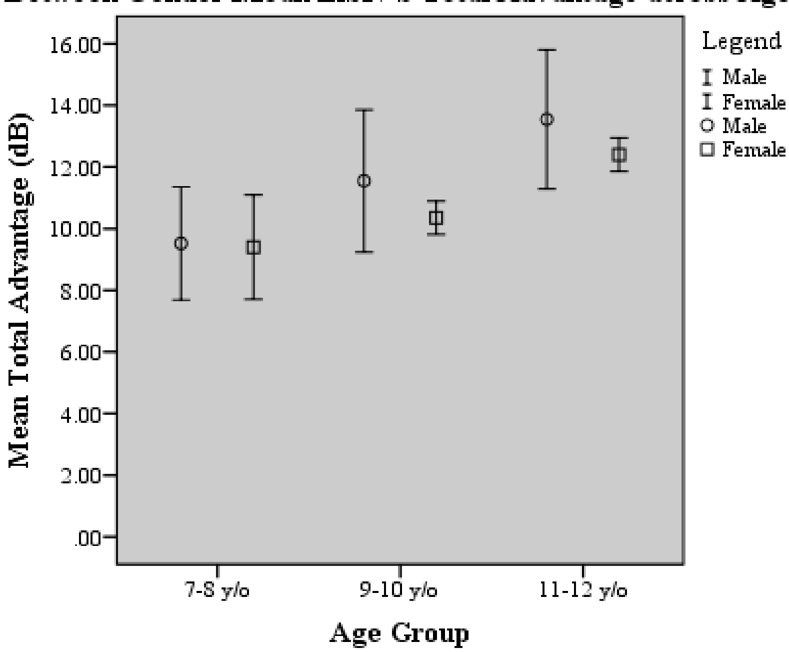
Between Gender Mean LiSN-S Spatial Advantage across Age Groups



Note. Error bars represent 1 SD above and below the mean. LiSN-S = listening in spatialized noise - sentences

Figure 12

Between Gender Mean LiSN-S Total Advantage across Age Groups



Note. Error bars represent 1 SD above and below the mean. LiSN-S = listening in spatialized noise - sentences

Table 6

LiSN-S SRTs and Advantage Measures Means (SDs) Between Gender and across Age Groups

	Male			Female		
	7-8 y/o	9-10 y/o	11-12 y/o	7-8 y/o	9-10 y/o	11-12 y/o
Low-Cue SRT	-0.58 (0.53)	-0.53 (0.60)	-0.63 (1.43)	0.33 (0.53)	-1.35 (0.83)	-0.32 (0.97)
High-Cue SRT	-10.04 (1.91)	-12.07 (2.09)	-14.25 (1.16)	-9.07 (1.36)	-11.70 (0.73)	-12.72 (1.23)
Talker Adv	3.44 (0.80)	6.58 (1.89)	6.85 (1.04)	3.82 (1.63)	4.13 (2.38)	6.52(1.77)
Spatial Adv	9.20 (1.10)	9.80 (1.43)	11.4 (0.22)	8.38 (2.12)	9.60 (1.50)	10.82 (2.26)
Total Adv	9.52 (1.83)	11.55 (2.31)	13.55 (2.26)	9.40 (1.69)	10.35 (0.54)	12.40 (0.55)

Note. LiSN-S = Listening in spatialized noise - sentences; SRT = speech reception threshold; Adv = Advantage. Means(SD) are in decibels (dB)

Gender Effects

To analyze the main effect of gender a one-way ANOVA was utilized and found there was a significant difference between genders on several assessments. One observed difference between males and females was on the ART displayed in Table 3. Different means were observed on the contralateral ART condition with the left ear stimulated at 2000 Hz between males (M=97.00) and females (M=100.67). Displaying a statistical significance of F (1, 28) = 4.458; p = .044, in which the females were elevated when compared to males. Another observed difference between males and females was on the TEOAEs displayed in Table 4. Different means were observed between genders in the left ear at 2800 Hz (male M=12.33, female M=16.08) and 4000 Hz (male M=9.29, female M=14.07). Displaying a statistical significance of F (1, 28) = 9.405; p = .005 and F (1, 28) = 7.267; p = .012, in which the females had larger responses when compared to males at 2800 and 4000Hz respectively. The additional tests were analyzed to see if there was a difference between genders; Table 7 shows the means and standard deviations for each test.

Table 7

Additional Tests Mean and SD of scores Between Gender

	Male	Female
Tests	M (SD)	M (SD)
TONI:Q	108.67 (9.26)	113.07 (14.79)
TONI: %	68.4 (17.54)	72.07 (23.53)
CELF: TS	25 (3.14)	25.07 (3.81)
CTOPP: PA	107.8 (9.13)	108 (11.26)
CTOPP: PM	102.6(10.32)	103.4 (9.48)
CTOPP: RN	109.8 (9.52)	101.6 (9.27)
BrainTrain A	79.53 (29.71)	97.47 (27.29)
BrainTrain V	88 (27.35)	105.2 (14.20)

Note. TONI = Test of Nonverbal Intelligence, Q = quotient, % = percentile, CELF = Clinical Evaluation of Language Fundamentals, TS = total score, CTOPP = Comprehensive Test of Phonological Processing, PA = phonological awareness, PM = phonological memory, RN = rapid naming, A = auditory, V = visual, Mean (standard deviation)

Significant gender differences were observed on two tests in the additional test battery. As shown in Table 7 means on the rapid naming section of the CTOPP were different between males (M=109.8) and females (M=101.6). Displaying a statistical significance of F (1, 28) = 5.712; p = .024, in which the males scored higher than the females. Also shown in Table 7, means on the visual attention aspect of BrainTrain were different between males (M=88.00) and females (M=105.2). Displaying a statistical significance of F (1, 28) = 4.672; p = .039, in which the females scored higher than the males. No significant gender differences were observed on any of the tests of auditory processing.

Age Effects

Oneway ANOVAs were run on the entire AP test battery to analyze differences across age groups. In order to include tests with ear specific data the right ear score and left ear score we added together and divided by two to get an average score for the test. Table 8 displays means and standard deviations of each age group for each AP test (averaged and those with binaural presentation) as well as *F* and *p* values. Since ear effects were found on the DDT and DPT, these tests could not be averaged. When looking at age effects on each ear individually the DDT displayed no significant differences with values of p = .053 and p = .121 for the DDT right and left ear scores respectively. However, the DPT did display significant age effects in both the left and right ears. Significant differences across age groups were found on several tests including the, FPT average (p = .011), DPT right and lefts ears ($F(2,27)$ = 7.150; p = .003 and $F(2,27)$ = 7.282; p = .003 for the right and left ears respectively), CRW average (p = .016), AFG+8 average (p = .012), LiSN-S high-cue SRT (p = .000), LiSN-S talker advantage (p = .002), LiSN-S spatial advantage (p = .011), and LiSN-S total advantage (p = .000).

Table 8

Non Ear Specific Test Scores of AP Tests Across Age

	7-8 y/o	9-10 y/o	11-12 y/o	*F*	*p*
Tests	Averaged Scores				
FPT (A)	72.42% (20.00)	87.00% (7.93)	91.11% (7.26)	5.363	.011*
CRW (A)	59.54% (8.02)	62.50% (7.41)	69.78% (6.82)	4.800	.016*
AFG +8 (A)	95.45% (3.50)	91.00% (3.94)	95.28% (2.92)	5.214	.012*
AFG 0 (A)	60.23% (5.41)	66.75% (11.06)	68.06% (8.08)	2.56	.096
	Binaural Scores				
RGDT	5.54 ms (2.91)	3.94 ms (1.32)	5.24 ms (2.72)	1.245	0.304
Low-Cue SRT	-0.08 dB (0.70)	-0.86 dB (0.78)	-0.46 dB (1.12)	2.097	.142
High-Cue SRT	-9.51 dB (1.63)	-11.92 dB (1.62)	-13.40 dB (1.38)	16.048	.000**
Talker Adv	3.65 dB (1.27)	5.60 dB (2.34)	6.67 dB (1.41)	7.865	.002*
Spatial Adv	8.75 dB (1.70)	9.72 dB (1.38)	11.08 dB (1.63)	5.346	.011*
Total Adv	9.45 dB (1.67)	11.07 dB (1.85)	12.91 dB (1.56)	10.217	.000**

Note. A = Average; DDT = Dichotic Digits Test; FPT = Frequency Pattern Test; DPT = Duration Pattern Test; CRW = Compressed and Reverberated Words; AFG=Auditory Figure Ground; RGDT = Random Gap Detection Test; LiSN-S= Listening in Spatialized Noise Sentence test; SRT = speech reception threshold; Adv = advantage; ms = milliseconds; dB = decibel; Means(SD). The degrees of freedom are (2, 27) for each test included in the table.
* = significance of $p < .05$; ** = significance of $p < .001$

A post hoc analysis using Tukey's HSD was used to determine the direction of the main effect. On the FPT findings indicated the 11-12 year olds (M = 91.11%) performed significantly better (p = .013) than the 7-8 year olds (M = 72.42%). On the DPT right ear findings indicated the 11-12 year olds (M = 82.22%) performed significantly better (p = .002) than the 7-8 year olds (M = 56.33%) and the DPT left ear findings indicated the 11-12 year olds (M = 86.66%) performed significantly better (p = .002) than the 7-8 year olds (M = 58.18%). On the CRW findings indicated the 11-12 year olds (M = 69.78%) performed significantly better (p = .014) than the 7-8 year olds (M = 59.54%). On the AFG+8 findings indicated the 7-8 years olds (M = 95.45%) performed significantly better (p = .019) than the 9-10 year olds (M = 91.00%) and the 11-12 year olds (M = 95.28%) performed significantly better (p = .034) than the 9-10 year olds (M = 91.00%). On the LiSN-S high-cue SRT findings indicated the 9-10 year olds (M = -11.92 dB) performed significantly better (p = .004) than the 7-8 year olds (M = -9.51 dB) and the 11-12 year olds (M = -13.40 dB) performed significantly better (p = .000) than the 7-8 year olds (M = -9.51 dB). On the LiSN-S talker advantage findings indicated the 9-10 year olds (M = 5.60 dB) had significantly more benefit using vocal cues (p = .041) than the 7-8 year olds (M = 3.65 dB) and 11-12 year olds (M = 6.67 dB) had significantly more benefit using vocal cues (p = .002) than the 7-8 year olds (M = 3.65 dB). On the LiSN-S spatial advantage findings indicated the 11-12 year olds (M = 11.08 dB) had significantly more benefit using spatial cues (p = .008) than the 7-8 year olds (M = 8.75 dB). On the LiSN-S total advantage findings indicated the 11-12 year olds (M = 12.91 dB) had significantly more benefit using both vocal and spatial cues (p = .000) than the 7-8 year olds (M = 9.45

dB). No significant age effects were found on the AFG0 average, LiSN-S low-cue SRT, or on the RGDT in this sample.

Ear Effects

Using a paired samples *t* test lateralization was analyzed on tests with ear specific data which included the DDT, FPT, DPT, CRW, AFG+8, and AFG0. Table 9 displays means and standard deviations of ear specific test scores as well as *t* and *p* values and degrees of freedom. Two of the tests found a significant difference between the scores of the right and left ears. There was a significant difference in the scores for the DPT left ear (M = 71.33%, SD = 19.90) and the DPT right ear (M = 68.43%, SD= 18.21) conditions; *t*(29)= -2.106, *p* = .044. These findings on the DPT indicate the left ear scores are significantly better than the right ear scores. There was a significant difference in the scores for the DDT right ear (M = 94.83%, SD = 4.95) and the DDT left ear (M = 90.00%, SD = 8.54) conditions; *t*(29)= 3.397, *p* = .002. These findings on the DDT indicate the right ear scores are significantly larger than the left ear scores.

Table 9

Paired Samples t-test on AP Tests with Ear Specific Data

	Right Ear	Left Ear	*t*	df	*p*
DDT	94.83% (4.95)	90.00% (8.54)	3.397	29	.002*
FPT	82.89% (17.13)	82.89% (16.02)	-0.001	29	1.000
DPT	68.43% (18.21)	71.33% (19.90)	-2.106	29	.044*
CRW	64.47% (9.78)	62.73% (8.03)	1.541	29	0.134
AFG +8	95.00% (5.25)	92.83% (6.52)	1.352	29	0.187
AFG 0	65.50% (11.17)	64.00% (11.70)	0.568	29	0.574

Note. AP = Auditory processing; DDT = Dichotic Digits Test; FPT = Frequency Pattern Test; DPT = Duration Pattern Test; CRW = Compressed and Reverberated Words; AFG=Auditory Figure Ground; Means(SD); df = degrees of freedom; * = significance of $p < .05$

In addition, lateralization was performed on tests with ear specific data, which included the DDT, FPT, DPT, CRW, AFG+8, and AFG0. The differences in ear scores were analyzed across age groups. For each test a difference score was computed by subtracting the left ear score from the right ear score of each participant. A MANOVA was run to analyze whether the difference score was significantly different between age groups. No main effect of age was found on any of the difference scores.

Overall Statistics

A MANOVA was run to examine main effects of age, gender, and age-gender interaction across all AP tests within the battery. Tests with ear specific scores (DDT, FPT, DPT, CRW, AFG+8, and AFG0,) were given an average score by adding the right and left ear and dividing by two, to eliminate ear effects. Since ear effects were found on the DDT and DPT, these tests could not be averaged and therefore were not included in the analysis. The RGDT and the LiSN-S Spatial Advantage did not pass Levene's Test of Homogeneity, an assumption of the MANOVA; therefore, the test was re-run excluding those two tests. The only significant main effect found within the AP test battery was of age, F (15, 34) = 3.558; p = .001; Wilk's λ = .138; partial η^2 = .628; observed power = .995. Table 10 displays the degrees of freedom, F, p, effect size (partial η^2), and observed power for all AP tests included in the analysis.

Table 10

Main Effect of Age on AP Tests

	df	*F*	*p*	partial η^2	Observed power
FPT (A)	(2, 20)	5.070	.015*	.297	.767
CRW (A)	(2, 20)	5.224	.013*	.303	.780
AFG +8 (A)	(2, 20)	4.319	.025*	.265	.694
AFG 0 (A)	(2, 20)	2.298	.122	.161	.421
Low-Cue SRT	(2, 20)	2.517	.102	.173	.455
High-Cue SRT	(2, 20)	16.266	.000**	.575	.999
Talker Adv	(2, 20)	8.407	.002*	.412	.941
Total Adv	(2, 20)	10.130	.001*	.458	.973

Note. A = Average; DDT = Dichotic Digits Test; FPT = Frequency Pattern Test; DPT = Duration Pattern Test; CRW = Compressed and Reverberated Words; AFG=Auditory Figure Ground; LiSN-S= Listening in Spatialized Noise Sentence test; SRT = speech reception threshold; Adv = advantage; df = degrees of freedom; η = eta; partial η^2 = effect size
* = significance of $p < .05$; ** = significance of *p* = < .001

Intelligence

A linear regression was used to determine if performance on any of the AP tasks was a significant predictor of nonverbal IQ, measured by the TONI quotient. The CRW was found to be both a significant predictor of nonverbal IQ, β = .455, $t(28) = 2.701$, $p = .012$, and explains a significant proportion of the variance, adjusted $R^2 = .178$, $F(1, 28) = 7.296$, $p = .012$.

Musical Training

In the present study 18 children (60% of the sample) reported playing a musical instrument and 12 children (40% of the sample) did not play a musical instrument. A Spearman rank order correlation was performed on musical instrument use to determine if musical training influenced any of the AP task performances. The FPT was the only test that showed a small correlation on both ears with correlation coefficients (r_s) of 0.567 in the right ear and 0.368 in the left ear. Right ear FPT means (SD) are 90.74% (7.97) and 71.11% (20.56) for children who did and did not play a musical instrument respectively.

Left ear FPT means (SD) are 88.15% (9.58) and 75.00% (20.52) for children who did and did not play a musical instrument respectively. In addition, the DDT scores were also correlated to musical instrument use with a correlation coefficient (r_s) of 0.599 in the left ear only. Left ear DDT means (with standard deviations in parentheses) are 93.75% (5.96) and 84.38% (8.93) for children who did and did not play a musical instrument respectively. These findings suggest that children that play musical instruments are correlated to better performance of the FPT (both ears) and DDT (left ear only) tests.

CHAPTER FIVE

DISCUSSION

The literature supports a higher prevalence for disorders such as ASD (Nicholas et al., 2008), ADHD (Bauermeister et al., 2007), and reading disorders (Badian, 1999; Wheldall & Limbrick, 2010) in boys than in girls. Similarly, it has been estimated that the prevalence of APD has a gender ratio of 2:1 (Chermak, 2002). Although boys have a higher prevalence of APD, there is debate as to whether boys and girls differ in performance on AP tests. Some researchers report gender differences (Davis & McCroskey, 1980; Fink et al., 2005; Neijenhuis et al., 2002; Szymaszek et al., 2006), while others report no performance differences (Cameron et al., 2009; Keith, 2000; Moncrieff & Wilson, 2009; Stollman et al., 2003, van Kesteren & Wiersinga-Post, 2007). This study aimed to collect data on 30 typically developing children to analyze gender differences on tests of AP. A minimum AP test battery, to assess for dysfunction, should include tests that assess a variety of auditory processing skills (AAA, 2010; ASHA, 1996; 2005; Jerger & Musiek, 2000) as well as have low linguistic loading (AAA, 2010; ASHA, 2005; Jerger & Musiek, 2000).

The present study employed a test battery including tests of dichotic listening (DDT), temporal processing (FPT, DPT, and RGDT), monaural low redundancy (CRW, AFG +8, and AFG 0), and lateralization/auditory figure ground (LiSN-S). The test battery had a low linguistic load (DDT, FPT, DPT, and RGDT), but was supplemented with more linguistically loaded tests (CRW, AFG +8, AFG 0, and LiSN-S). All 30 participants recruited were included in the data analysis. The data analysis specifically looked at effects of gender, age, and ear. Other supplemental statistical analyses were run to examine IQ and musical training and the effects of AP test performance.

Audiologic Assessment

In the audiologic test battery, a few significant gender differences were found. One finding was that females had significantly higher ARTs with left ear stimulation at 2000 Hz than the males. This is inconsistent with the literature, which reports no gender differences on ARTs (Fielding & Rawool, 2002; Rawool, 1996; Rawool, 1998). One study looked at children from 6-10 years with normal peripheral hearing and found ARTs measurements were similar to young adults, with no significant ear differences and no gender differences (Fielding & Rawool, 2002). Another study looked at normal hearing individuals within the age range of 10-80 years (Osterhammel & Osterhammel, 1979). Their results showed no significant differences between age and gender; however in the young group (children 10-12 years old) the researchers reported elevated thresholds (of 100-110 dB) were not uncommon despite normal peripheral hearing thresholds (Osterhammel & Osterhammel, 1979). This finding was also observed in the children of the present study.

Another finding in the current study was that females had significantly larger TEOAEs in the left ear at 2800 Hz and 4000 Hz than the males. This is consistent with the literature (Aidan, Lestang, Avan, and Bonfils, 1997; Moulin, Collet, Veuillet, & Morgon, 1993). A study of TEOAEs in neonates found females to have significantly larger SNR than males (Aidan et al., 1997). In addition they found right ear responses to be significantly larger than left ear responses (Aidan et al., 1997), which was not found in the present study. Moulin, Collet, Veuillet, and Morgon (1993) attributed the gender difference to the fact that more females had spontaneous OAEs than males.

Tests of Auditory Processing – Gender Effects

No significant gender differences were found on any of the AP tests, which is consistent with the literature (Cameron et al., 2009; Keith, 2000; Moncrieff & Wilson, 2009; Stollman et al., 2003, van Kesteren & Wiersinga-Post, 2007). Although some researchers have reported significant gender differences, many were on tests not included in the present study's test battery including temporal ordering thresholds (Fink et al., 2005; Szymaszek et al., 2006), filtered speech (Neijenhuis et al., 2002), and binaural fusion tests (Davis & McCroskey, 1980; Neijenhuis et al., 2002).

The variability in reported gender differences between studies may be due to the AP tests utilized, sample size, gender make-up of the sample, sample studied, and age of the sample. The present study's results of AP test performance did not indicate that gender differences existed for this sample. Since the present study did not utilize AP tests that have been reported to have gender differences, consideration should be given to adding some of the above-mentioned tasks to the battery, Further research is needed to explore gender differences on AP abilities. Although the present study had equal numbers of male and female participants in each age group, no significant gender differences on AP tests were found. This may have been due to the relatively small sample (n = 30; 15 boys). Gender related performance differences on AP tests cannot be completely ruled out until a larger sample can be analyzed. Another possibility is that the present study did not find gender related performance differences since the participants were typically developing children. Consequently, another aspect to be investigated is gender related performance differences in those diagnosed with APD. Lastly, there has been variability reported in gender related performance differences across age groups on AP tests. Some studies reported significant gender differences in adult participants (Fink et al., 2005; Szymaszek et al., 2006) while others reported differences studying children (Davis & McCroskey, 1980; Neijenhuis et al., 2002). Alternatively some studies found no gender differences in adult participants (van Kesteren & Wiersinga-Post, 2007) or child participants (Cameron et al., 2009; Keith, 2000). Determining whether gender related performance differences are present on any of the AP tests is important. If these differences exist, like age related performance differences, then gender related normative data should be developed.

Tests of Auditory Processing - Age Effects

This study found significant age group differences (7-8, 9-10, 11-12 year olds) on performances of AP tests. Specifically, significant differences across age groups were observed on eight AP measurements including the FPT, DPT (right and left ears separately), CRW, AFG +8, LiSN-S high-cue SRT, LiSN-S talker advantage, LiSN-S spatial advantage, and LiSN-S total advantage, which is consistent with the literature (Bellis, 2003; Cameron et al., 2009; Keith, 2000; Moncrieff & Wilson, 2009; Neijenhuis et al., 2003). Overall findings were that the oldest age group (11-12 year olds) performed significantly better than the youngest age group (7-8 year olds). Overall these findings indicate that as children age their auditory processing skills improve, which is consistent with the literature (Bellis, 2003; Cameron et al., 2009; Davis & McCroskey, 1980; Keith, 2000; Moncrieff & Wilson, 2009; Neijenhuis et al., 2002). However, in larger studies these age differences were observed between more age groups rather than just the two extreme groups. On both the LiSN-S measurements of high-cue SRT and talker advantage, not only did the oldest age group (11-12 year olds) perform significantly better than the youngest age group (7-8 year olds), but the 9-10 years olds also performed significantly better than the 7-8 year olds, which is similar to the findings of Cameron and colleagues (2009). Since improvements were observed between the youngest and oldest age groups for these two measures, the results seem to further support that children's auditory systems mature as they age (ASHA, 2005; Cameron et al., 2009; Jerger & Musiek, 2000; Moncrieff & Wilson, 2009; Moore, 2002; Neijenhuis et al., 2003; Werner, 2007). The only exception to this general finding was on the AFG +8 test, where the 7-8 year olds as well as the 11-12 year olds performed significantly better than the 9-10 year olds. This is inconsistent with the literature, which has reported steady improvement in performance across the ages of 5 years to 12 years of age (Keith, 2000). Due to the small sample size used in this study, this finding should be considered with caution.

Moore (2002) stated that maturation of the CANS occurs over time in childhood; consequently, over several years the function of how the CANS processes acoustic cues improves. This supports the present study's LiSN-S high-cue SRT and talker advantage findings which displayed significant improvement between the 9-10 year olds and 7-8 year olds as well as between the 11-12 year olds and the 7-8 year olds. This caveat may explain why no significant age differences were found in the most difficult test conditions with speech in noise including the AFG 0 and the LiSN- S low-cue SRT. The LiSN-S has constant distracter speech, but it provides a tonal cue to allow the listener to know the target is about to come. In the easier conditions, the vocal cues, spatial cues, or both were enough to cause age differences (i.e. the older children made better use of these cues than the younger children). However, in the more difficult conditions (low-cue SRT) the results for older and younger children were not statistically different from each other. The present sample may have been too small to detect any possible effects on the most difficult condition.

No age effects were observed on the DDT, AFG 0, RGDT, and LiSN-S low-cue SRT. The non-significant finding on the low-cue SRT is inconsistent with the literature (Cameron et al., 2009). Several factors could have impacted these results including the difficulty of the task (too hard), high variability of test performance, or the small sample size. Regardless, a larger study is needed to determine whether these findings are still prominent in a larger sample. Based on this information, age adjusted normative data is warranted.

Tests of Auditory Processing - Ear Effects

In order to analyze scores between ears on the six AP tests with ear specific data (DDT, FPT, DPT, CRW, AFG +8, and AFG 0), the means of each ear were compared. Only two of these tests were found to be significantly different, the DDT and the DPT. The DDT test revealed a strong right ear advantage (REA). This REA on the DDT is consistent with the literature (AAA, 2010; Bellis, 2003; Bryden, 1963; Hällgren et al., 1998; Keith, 2000; Kimura, 1961a; Kimura, 1961b; Moncrieff & Wilson, 2009; Neijenhuis et al., 2002; Neijenhuis et al., 2003; Nelson, Wilson, & Kornhass, 2003). However, on the DPT a left ear advantage (LEA) was noted. This finding has not been reported in the literature. An LEA advantage has been reported for the DDT (Moncrieff, 2011). This study found a LEA on the DDT and posited that either: (a) in that population more children had right-hemisphere dominance for language or (b) the ear advantage direction is less stable in younger years (Moncrieff, 2011). Kimura (1961a) noted that the ear that is opposite to the language dominant cerebral hemisphere showed the larger ear advantage. Although it is more common for humans to have left-hemisphere language dominance (Kimura, 1961a), it is possible that the present study included children with right hemisphere dominance, for whom a LEA dominance is expected. However, this is unlikely since the DDT scores showed a very strong REA. Another factor that may have impacted these results could be the difficulty of the task, which resulted in large variability on test performance. Regardless, a larger study is needed to determine whether these findings are still present in a larger sample. This analysis did not look across age.

In this study, ear difference scores were computed by subtracting the left ear score from the right ear score and examined across age groups, this method is consistent with what has been used in the literature (Keith, 2000; Moncrieff & Wilson, 2009). This study did not find significant ear difference scores as reported in the literature (Keith, 2000; Moncrieff & Wilson, 2009). The lack of significant findings of ear differences scores across age could be due to the small sample size or the variability in the ear difference scores among children. A larger study is needed to further investigate ear difference scores.

Musical Training

The present study identified that 60% of children in this sample played a musical instrument. Data analysis found musical training to be marginally correlated to performance on the DDT (left ear only) and the FPT (both ears). The correlation of the left ear DDT scores and musical training is inconsistent with the literature (Nelson et al., 2003). FPT was the only test where both ears were marginally correlated to playing musical instruments. Musical training has been found to change the auditory cortex (structurally) and how it responds to auditory input (functionally) (Kraus & Chandrasekaran, 2010). These findings from their study have been shown to be dependent on the number of years of experience with music (Kraus & Chandrasekaran, 2010). Another study found musical expertise improved pitch discrimination, especially to small frequency changes, in adults when compared to other non-musical adults (Besson, Schon, Moreno, Santos, & Magne, 2007). These researchers also found 6 months of musical training improved children's ability to detect small frequency changes in music and speech than before training (Besson et al., 2007). When assessing the function of the brainstem to encode pitch information, those with long-term music exposure were able to do so more faithfully than non-musicians (Wong, Skoe, Russo, Dees, & Kraus, 2007). Not only does musical training increase frequency discrimination, but it has also been found to increase auditory attention (Strait, Kraus, Parbery-Clark, & Ashley, 2010). It is important to identify if the ability to play a musical instrument can predict how a child will perform on AP tests, as test batteries may need to be modified for children with musical training to accurately assess their auditory processing abilities.

Study Limitations

This study had several limitations. The major limitation was the small sample size. With a small sample size, significant findings are more difficult to achieve because the power is so small. Although data analyses revealed several significant findings, these results should be interpreted with caution. Running a large number of one-way ANOVAs increases the risk of type I error; therefore, there is a greater probability of a significant finding due to chance. To analyze interaction effects (between age, gender, and ear) sacrifices degrees of freedom (participant data). Further dividing this already small sample makes it difficult to find any interaction effects. A larger sample is needed so when interaction is analyzed there are more participants in each sub-group, allowing for true differences to be found.

Recruitment was another limitation. Children were difficult to recruit into the study. Participant recruitment was mainly by word of mouth by a doctoral student and her friends, family, and professors, so the sample studied may not accurately represent the Baltimore area population. This study did not ask participants about ethnicity or the SES so an analysis of the sample for these factors cannot be conducted. In this sample, intelligence was higher than average and did not follow a normal distribution. The TONI-3 accepts quotients of 80 or better as normal. Quotients of participants in this study ranged from 95-135, with age and gender specific averages ranging from 107.80 (in 7-8 year old males) to 119.50 (in 9-10 year old females). Having an abnormal distribution of scores may have impacted results; further research is needed on a larger more diverse population.

Clinical Relevance

The present study is one-fourth of a larger study. The larger study aims to develop regional normative data, as recommended in the literature (Colorado Department of Education, 2008; Emanuel, 2002; Florida Department of Education, 2001). Clinicians who regularly perform AP evaluations have been urged to use AP tests that have adequate normative data (AAA, 2010). There are different versions of the same tests available; therefore clinicians have been urged to collect their own normative data to use in clinical practice (Emanuel, 2002). Using one's own test materials and the local population can provide regional normative data that combats the inadequacy of normative data as well as regional dialects (Emanuel, 2002).

It has been recommended that test batteries incorporate a variety of AP tests that assess a range of AP skills (AAA, 2010; ASHA, 2005; Jerger & Musiek, 2000). Tests with low linguistic loading should be able to differentially diagnose those with language or learning disorders from those with APD or co-occurring diagnoses (AAA, 2010; ASHA, 2005; Jerger & Musiek, 2000). The present study utilized additional assessments (IVA-CPT, TONI-3, CELF-4, and CTOPP) to ensure children were typically developing. Audiologists are not able to, due to time constraints and scope of practice limitations, assess for these additional areas therefore, this study highlights the fact that audiologists should utilize other professionals to ensure an accurate diagnosis is made. When a team of professionals is not available, clinicians are encouraged to use low linguistically loaded tests when other diagnoses that could confound APD test results have not been ruled out.

When comparing the normative data is this study to other established norms, results are comparable overall (Bellis, 2003; Cameron et al., 2009; Keith, 2000; Kelly, 2007). Of interesting note, the RGDT results are well within the normal range (presently normal is < 20 ms for all ages). This study revealed that clinicians could use a more conservative normative value < 15 ms.

Future Directions

Based on results from this study future studies should:

1. Analyze a larger sample to further analyze gender, age, and ear differences. A larger study could further breakdown the age groups, allowing age and gender to be analyzed more closely. Additionally, a larger sample is needed to determine if gender differences are observed on any of the AP tests included in this study. Future researchers may also wish to include other AP tests that have found significant gender differences which include temporal ordering thresholds (Fink et al., 2005; Szymaszek et al., 2006), filtered speech (Neijenhuis et al., 2002), and binaural fusion tests (Davis & McCroskey, 1980; Neijenhuis et al., 2002) to determine if gender specific normative data are warranted. In future studies, researchers should try maintain an age and gender balance so each group is equal.

2. Further breakdown age groups into single years, instead of using 2-year age groups. This would be more ideal since it is common for researchers to publish normative data based on single years (Bellis, 2003; Cameron et al., 2009; Keith, 2000). This breakdown would allow more detailed local normative data to be created (Emanuel, 2002) as well as make the data comparable to established normative data.

3. Analyze gender prevalence in children diagnosed with APD, regardless of whether or not gender differences are observed on AP tests. This would support or refute the present 2:1 gender ratio of males-to-females with APD (Chermak, 2002), as well as determine if it is more common in boys (similar to other developmental disorders).

4. Investigate how IQ and musical training influence AP test performance. Further investigation is warranted into IQ and its role on AP test performance since there is little

information in the literature on this topic. Future studies may wish to inquire more regarding musical training, possibly in the form of a proficiency rating. Since musical training, specifically years of experience, influence AP abilities (Besson et al., 2007; Kraus & Chandrasekaran, 2010; Strait et al., 2010; Wong et al., 2007).

Although this study did find some significant effects of age and ear on AP tests, it is clear that further research is needed. A larger study will identify if more age-, ear-, and gender- related performance differences exist on AP tests that this study may have been too small to detect. Determining if the significant effects found in this study are present across smaller age groups (i.e. 7 years, 0 months to 7 years, 11 months versus 7 years, 0 months to 8 years, 11 months.) will help specify the local normative data. All this information will aid in the development of accurate age-dependent local normative data, specifying the norms based on gender and ear as warranted.

APPENDIX A

IRB

TOWSON UNIVERSITY

Date: Wednesday, January 27, 2010

NOTICE OF APPROVAL

TO: Jennifer Smart **DEPT:** ASLD

PROJECT TITLE: *Auditory Processing Abilities in Typically Developing School-Aged Children*

SPONSORING AGENCY:

APPROVAL NUMBER: 10-A035

The Institutional Review Board for the Protection of Human Participants has approved the project described above. Approval was based on the descriptive material and procedures you submitted for review. Should any changes be made in your procedures, or if you should encounter any new risks, reactions, injuries, or deaths of persons as participants, you must notify the Board.

A consent form: [✓] is [ ] is not required of each participant

Assent: [ ] is [ ] is not required of each participant

This protocol was first approved on: 27-Jan-2010
This research will be reviewed every year from the date of first approval.

Justin Buckingham
Towson University Institutional Review Board
WRP

TOWSON UNIVERSITY

APPROVAL NUMBER: 10-A035

To: Jennifer Smart
8000 York Road
Towson MD 21252

From: Institutional Review Board for the Proctection of Human Subjects Justin Buckingham

Date: Wednesday, January 27, 2010

RE: Application for Approval of Research Involving the Use of Human Participants

APPROVED JAN 27 2010 JB/wp TOWSON IRB

Office of University Research Services
Towson University
8000 York Road
›n, MD 21252-0001
t. 410 704-2236
f. 410 704-4494

Thank you for submitting an Application for Approval of Research Involving the Use of Human Participants to the Institutional Review Board for the Protection of Human Participants (IRB) at Towson University. The IRB hereby approves your proposal titled:

Auditory Processing Abilities in Typically Developing School-Aged Children

If you should encounter any new risks, reactions, or injuries while conducting your research, please notify the IRB. Should your research extend beyond one year in duration, or should there be substantive changes in your research protocol, you will need to submit another application for approval at that time.
We wish you every success in your research project. If you have any questions, please call me at (410) 704-2236.

CC: L.Dau, T. Colon, E. Daniel
File

APPENDIX B

INFORMED CONSENT

INFORMED CONSENT FORM

Project title: Assessing Auditory Processing Abilities in Typically Developing School-Aged Children

Principal Investigators:
Jennifer L. Smart, Ph.D. and Diana C. Emanuel, Ph.D.
Towson University
Dept. of ASLD
8000 York Road
Towson, MD 21252

Purpose of the Study:
Children who have difficulty with auditory processing sometimes have problems with language tasks such as following spoken instructions and understanding speech in difficult listening situations (e.g., a noisy classroom), even when they have good hearing and intelligence. The purpose of this project is to obtain local normative data for several routine tests of auditory processing.

Procedures:
If your child participates in this study, a series of assessments will be performed. This will involve two sessions lasting a total of approximately four hours. During these sessions your child will participate in a number of different listening, learning and language tasks. For some tasks your child will be asked to report back what they hear through earphones. Short breaks will be provided as needed during testing to avoid fatigue. These sessions will take place at Towson University Speech-Language and Hearing Clinics (TUSLHC) or in Dr. Smart's research laboratory. Children usually enjoy the variety of listening games and activities so we anticipate that they will be excited about this study. But if, at any time, your child decides he/she does not want to participate the testing will cease immediately.
Risks/Discomfort:
There are no known risks for participating in this study. The tests included in this study are a part of routine clinical testing.

Benefits:
Currently there are no local norms for many of the currently available tests of auditory processing; therefore, the goal is to obtain this information. The data collected during this research study will not only be used to assist in the identification of children with auditory processing disorder but it will also be used to support future research studies at the university when normative data is required.

Participation:
Participation in this study is voluntary. Your child is free to withdraw or discontinue participation at any time.

Compensation:
All participants of this study will receive a $30.00 gift card upon completion of the study.

Confidentiality:
Participation in this study is voluntary. All information will remain strictly confidential. Although the descriptions and findings may be published, at no time will the name or identifying information of any participant be disclosed.

Please indicate whether or not you wish to have your child participate in this project, by checking a statement below and returning it to us in the enclosed self-addressed stamped envelope.

_____ I grant permission for my child, ____________________________________ to participate in this project.

_____ I do not grant permission for my child,______________________________________ to participate in this project.

_____ Affirmative agreement of child

____ _____________

Parent/Guardian's signature Date

Home address: ____

____

____

Home phone number: ___________________________________

Email address: ____

Upon receipt of this form we will call you to set-up an appointment.

__________________________________ _____________

Principal Investigator's Signature Date

If you have any questions regarding this study please contact the Principal Investigator, Dr. Jennifer L. Smart, phone: (410) 704-3105 or email: JSmart@towson.edu or the Institutional Review Board Chairperson, Dr. Debi Gartland, Office of University Research Services, 8000 York Road, Towson University, Towson, Maryland 21252; phone: (410) 704-2236.

THIS PROJECT HAS BEEN REVIEWED BY THE INSTITUTIONAL REVIEW BOARD FOR THE

PROTECTION OF HUMAN PARTICIPANTS AT TOWSON UNIVERSITY (PHONE: 410-704-2236).

APPENDIX C

INFORMED ASSENT

INFORMED ASSENT FORM

Project title: Assessing Auditory Processing Abilities in Typically Developing School-Aged Children

Principal Investigators:
Jennifer L. Smart, Ph.D. and Diana C. Emanuel, Ph.D.
Towson University
Dept. of ASLD
8000 York Road
Towson, MD 21252

Information Sheet for Participants

(To be read aloud to each participant)

Purpose of study

You are participating in this study in order to help us gather information about auditory processing, or in other words, how we hear.

What tests does the study involve?

First of all, we will complete activities like pointing to patterns in a book, clicking the computer mouse any time you see an image on the screen, and pushing a button when you hear a beep. These activities will help us to learn more about your language, learning, hearing, and attention.

We will then play a series of listening games. We will play sounds like beeps or words to you through earphones. You will have to press a button or tell me what you hear. All of the sounds will be presented at a comfortable volume.

You can ask for a break at any time you need one.

Visits

You will come to see us two times at Towson University to complete the tasks I described. Each visit will last about 2 hours.

Child Assent Form

(To be read aloud to the child and signed by researcher if child agrees to participate)

Title of Project: Auditory Processing Abilities in Typically Developing School-Aged Children

Primary Investigators: Jennifer Smart, Ph.D. and Diana Emanuel, Ph.D.

If you are happy to do this study, I will need you to write your name on this piece of paper. First, I will ask you some questions, just to make sure that you are happy to do this. Say 'yes' if you agree with what I am saying. If you do not agree with the statement, tell me 'no.'

- I have had the information sheet read out loud to me.
- I understand that you want to find out about my listening and how I hear sounds.
- I understand that I can decide to stop at any time.
- I understand that some of my answers will be used in a report, but that people reading the report will not know that the answers are mine, because my name will not be written on it.
- I understand that my answers will be kept for a long time in a safe place.
- I have had a chance to ask questions.

If you would like to do this, please write your name and I will sign below.

……………………………………………………
………………………………………………

Child's Name Researcher's Signature

Today's date:……………………………………

If you have any questions regarding this study please contact the Principal Investigator, Dr. Jennifer L. Smart, phone: (410) 704-3105 or email: JSmart@towson.edu or the Institutional Review Board Chairperson, Dr. Debi Gartland, Office of University Research Services, 8000 York Road, Towson University, Towson, Maryland 21252; phone: (410) 704-2236.

THIS PROJECT HAS BEEN REVIEWED BY THE INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN PARTICIPANTS AT TOWSON UNIVERSITY (PHONE: 410-704-2236).

APPENDIX D

CHILD CASE HISTORY FORM

Department of Audiology, Speech Language Pathology and Deaf Studies
Towson University-8000 York Road-Towson, MD 21252-0001
Voice or TTY: 410-704-3105

CHILD CASE HISTORY FORM

Child's Name: ____________________
Date of birth: Age: _________
Home Address:
Home phone: ______________________Parent Work or Cell phone: ______________________
Parent/Guardian names:_______
School & Teacher: __Current Grade:
Name of person filling out this form and relationship to participant:

I. BIRTH HISTORY

A. Pregnancy and Delivery:

1. Was pregnancy full term? Yes _____ No_____

2. Were there any complications during the pregnancy *or* delivery? *Yes _____ No _____

*If yes, please explain:
____
____

3. List all medications (prescription and Over The Counter) taken during pregnancy:

____
____

3. Delivery by Caesarian? Yes _____ No _____

B. Neonatal Period (check where appropriate):

1. Normal: Yes _____ No _____
2. Cyanotic (blue): Yes _____ No _____
3. Jaundiced: Yes _____ No _____

4. Neonatal Intensive Care Unit? Yes _____ No _____
5. Other complications? *Yes _____ No _____
*If yes, please explain:
____
____
What was the birth weight? _____lbs. ____oz
Were there any feeding problems? Yes _____ No _____
Was the baby's activity level: Average _____ Overactive _____ Underactive _____

II. DEVELOPMENTAL HISTORY

Development:

1. Motor Development: Normal _____ Delayed _____

2. Speech/Language Development: Normal _____ Delayed _____
a. Child's primary (first) language? _______________________________________

b. Is the child fluent in any other languages? If so, please specify _______________
3. Handedness: Right _____ Left _____ Ambidextrous (both) _____

4. Does your child play any musical instruments? Yes ___** No___

If yes, which instrument? ____________________________________

III. MEDICAL HISTORY

A. Major Childhood Illnesses:

Age
1. Mumps ____

2. Measles ____

3. Chicken Pox ____

4. Seizures ____

Allergies (medications, foods, seasonal, etc.) *Yes _____ No _____
If yes, please explain:____
____

B. Other diagnoses:

Has your child been diagnosed with any of the following disorders or difficulties? If yes, please note specific diagnosis, date, and professional who made the diagnosis. Thank you.
Hearing loss: Yes____ No ____ comments:___________________________________
Dyslexia: Yes ____No ____ comments:___________________________________
Reading disorder: Yes ____No ____ comments:___________________________________
Learning disability: Yes ____No ____ comments:___________________________________
ADD/ADHD: Yes ____No ____ comments:___________________________________
Language Disorder: Yes ____No ____ comments:___________________________________
Autism Spectrum Disorder: Yes ____No ____ comments:______________________________
Asperger Syndrome: Yes ____No ____ comments:___________________________________
Anxiety Disorder: Yes ____No ____ comments:___________________________________
Other:_________________

IV. OTOLOGICAL HISTORY
Yes No How many? Which ear(s)? Age(s)
Ear infections: ____ ____ __________ ___________ ___________
Ears draining: ____ ____ __________ ___________ ___________
Chronic colds: ____ ____ __________ ___________
Has the child had the following:
Yes No Age(s) Pressure Equalization (P.E.) Tubes? ____ ____ ______
If yes, which ear(s): ____?
Tonsillectomy? _____ _____ ______
Adenoidectomy? _____ _____ ______

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Professional Memberships

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