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DEVELOPMENT OF A SCREENING BATTERY FOR AUDITORY PROCESSING DISORDER IN 6-YEAR OLDS

by

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AUDIOLOGY DOCTORAL THESIS APPROVAL PAGE

This is to certify that the Audiology Doctoral Thesis prepared by Lindsay Sperling entitled: Development of a Screening Battery for Auditory Processing Disorder in 6-Year Olds has been approved by her committee as satisfactory completion of the Audiology Doctoral Thesis requirement for the degree Doctor of Audiology (Au.D.).

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ABSTRACT

Development of a Screening Battery for Auditory Processing Disorder in 6-Year Olds

Lindsay Sperling

Diagnostic assessment of Auditory Processing Disorder (APD) is currently limited to children 7 years of age and older (AAA, 2010; ASHA, 2005). This is due to the variability of auditory processing (AP) abilities in children younger than 7 years of age (AAA, 2010; ASHA, 2005; Bavin, Grayden, Scott, & Stefanakis, 2010; Dawes & Bishop, 2008; Stollman, van Velzen, Simkens, Snik, & van den Broek, 2003; Stollman, Neijenhuis, Jansen, Simkens, Snik, & van den Broek, 2004a; Stollman, van Velzen, Simkens, Snik, & van den Broek, 2004b). It has been recommended that children younger than 7 years of age who present with listening difficulties be screened for APD (Musiek, Gollegly, Lamb, & Lamb, 1990a). To explore the possibility of early identification through screening, this pilot study looked at the feasibility of screening 6-year-old children for APD. A battery of APD measures comprised of the Auditory Figure Ground + 8 dB SNR test, the Dichotic Digits Test (DDT), and a revised Pitch Pattern Sequence (PPS) test, was administered to 23 typically developing 6-year old children. With modifications to administration, stimuli and scoring, the battery was successfully administered to all participants. A moderate amount of variability was noted on both the DDT and the revised PPS test and a ceiling effect was noted on the AFG + 8 dB SNR test. Results suggest that with the addition of more data collected from a larger sample size, usable normative data ranges for the DDT and revised PPS test could be created for 6-year olds. Due to the ceiling effect noted on the AFG + 8 dB SNR test, a more

challenging speech-in-noise measure that better mimics a typical classroom environment should be administered in a future study. Participants with a history of Otitis Media with Effusion (OME) or Pressure Equalization (PE) tubes had poorer phonological processing abilities than those with unremarkable otologic histories; however all participants' language abilities were judged to be normal based on the results of two language screening measures administered as a part of this pilot study. No gender or age (6:0 to 6:5 versus 6:6 to 6:11) effects were found on language or AP abilities. It should be noted that this study had a small sample size; therefore these findings should be interpreted with caution. More research is needed with a larger sample size before this screening battery can be used clinically.

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KEY TO ABBREVIATIONS

ABR: Auditory Brainstem Response
ADHD: Attention Deficit Hyperactivity Disorder
ADHD-PI: Attention Deficit Hyperactivity Disorder- Predominantly Inattentive
AEP: Auditory Evoked Potential
AFG: Auditory Figure Ground
AP: Auditory Processing
APD: Auditory Processing Disorder
ASHA: American Speech-Language-Hearing Association
BSA: British Society of Audiology
(C)APD: (Central) Auditory Processing Disorder
CANS: Central Auditory Nervous System
CD: Compact Disc
CELF-4: Clinical Evaluation of Language Fundamentals-4
C.H.A.P.S.: Children's Auditory Performance Scale
CNS: Central Nervous System
COM: Chronic Otitis Media
CRST: Compressed and Reverberated Speech Test
CTOPP: Comprehensive Test of Phonological Processing
dB: Decibel
DDT: Dichotic Digits Test
DDT:L: Dichotic Digits Test: Left Ear
DDT:R: Dichotic Digits Test: Right Ear
df: Degrees of Freedom
DPT: Duration Pattern Test
ER-3A: Etymotic Research-3A
FM: Frequency Modulated
FPT: Frequency Pattern Test
GD: Gap Detection
GIN: Gaps In Noise
GSI-61: Grason-Stadler Inc. 61
HALL: Hearing and Listening Lab
HL: Hearing Level
Hz: Hertz
ICTS: Initial-Consonant-The-Same
IQ: Intelligence Quotient
IRB: Institutional Review Board
ISI: Interstimulus Interval
LI: Language Impairment
LIFE UK: Listening Inventory For Education- United Kingdom
MLR: Middle Latency Response
N: Sample Size

NU No.6: Northwestern University Auditory Test Number 6
NVLD: Non-Verbal Learning Disability
OME: Otitis Media with Effusion
PE: Pressure Equalization
PPS: Pitch Pattern Sequence
PPS-R: Pitch Pattern Sequence Test without Reversals Included as Correct
PPS+R: Pitch Pattern Sequence Test with Reversals Included as Correct
QUIL: Queensland University Inventory of Literacy
r: Pearson Product Moment Correlation coefficient
REA: Right Ear Advantage
RGDT: Random Gap Detection Test
SD: Standard Deviation
SES: Socioeconomic Status
SIFTER: Screening Instrument For Targeting Educational Risk
Sig. (2-tailed): p-value
SLP: Speech-Language Pathologist
SNR: Signal to Noise Ratio
SPSS 19: SPSS Statistics Version 19
t: t-value
TOWRE: Test of Word Reading Efficiency
VA: Veterans Administration
VLBW: Very Low Birth Weight
VU: Volume Unit

Chapter 1: Introduction

APD can be defined as listening difficulties due to a deficit in one or more areas of AP abilities including, but not limited to, dichotic listening, monaural low redundancy and temporal processing (AAA, 2010; ASHA, 2005). In ideal listening conditions, children with APD typically perform similar to their non-APD peers. In complex listening situations such as the classroom, when stress is placed on the auditory system (e.g. the presence of background noise or high levels of reverberation), children with APD tend to perform more poorly than their non-APD peers (Knecht, Nelson, Whitelaw, & Feth, 2002; Whitelaw, 2008). APD can be diagnosed in children or adults, but it is more commonly assessed in children because of their frequently changing acoustic environments and listening demands, which exacerbate the symptoms of APD (Bamiou, Musiek, & Luxon, 2001). While the estimated prevalence of APD in children is only 2-3%, its impact on academic performance can be substantial (Chermak & Musiek, 1997). In addition to the educational impact caused by an AP deficit, children with APD often exhibit co-occurring impairments in spoken language, reading and/or spelling abilities due to the complexity of the central auditory nervous system (CANS) and the neural networks responsible for these various functions (Dawes, Bishop, Sirimanna, & Bamiou, 2008; Sharma, Purdy, & Kelly, 2009). It should be noted that in such cases, APD is neither the cause, nor the result of, these higher order disorders (ASHA, 2005).

Current clinical practice guidelines for the diagnostic assessment of APD recommend a minimum test age of 7 years (AAA, 2010). This recommendation has been made due to the complexity of task instructions and a lack of published normative data on

AP abilities in children younger than 7 years of age (AAA, 2010; ASHA, 2005). Reliable normative data for children younger than 7 years of age are currently lacking because AP abilities have been shown to be highly variable in these young children (Stollman et al., 2003; Stollman et al., 2004a; Stollman et al., 2004b). The maturational course of the regions of the brain responsible for AP abilities contributes to this variability (AAA, 2010; ASHA, 2005). In general, AP abilities continue to improve until 12 to 13 years of age (Schochat & Musiek, 2006; Stollman et al., 2004b). The high variability in performance noted in young children has led to wide normative data ranges and questionable test validity (Jerger, 1998).

Since APD can have a significant impact on a child's schooling, children under the age of 7 years who present with listening difficulties may benefit from a screening to determine if they are at risk for APD (Musiek et al., 1990a). A screening measure can be used to identify appropriate management options for a child's difficulties. The earlier children are identified as at risk for APD, the sooner management and counseling can begin with the goal of decreasing the long-term impact of AP difficulties on academic performance (ASHA, 2005; Hurley & Singer, 1985). There is currently no agreement in the literature on how to screen for APD and only one APD screening measure, appropriate for use with children younger than 7 years of age, is commercially available for use clinically (ASHA, 2005; Jerger & Musiek, 2000). This screening measure, the SCAN-3:C: Tests for Auditory Processing Disorders in Children (Keith, 2009b) contains no measure of temporal processing, that can be administered to children younger than 7 years, and has a high linguistic demand. Strides towards creating more appropriate screening measures for this population have been made; however more research is needed

(Smart, Purdy, & Leman, 2012). The primary goal of the current pilot study was to develop an APD screening battery for 6-year olds that consisted of measures of all three main categories of AP abilities (dichotic listening, monaural low redundancy and temporal processing) and that had minimal linguistic demands. A secondary goal was to collect normative data on the screening battery from a sample of typically developing 6-year old children.

Chapter 2: Review of the Literature

Definition of APD

Some children have difficulty listening in the classroom despite normal peripheral hearing. For many of these children, the difficulty stems from an AP deficit or an inability of the central nervous system (CNS) to efficiently and effectively process what is heard (ASHA, 2005; Jerger & Musiek, 2000). AP abilities that children may have difficulty with include sound localization and lateralization, sound discrimination, pattern recognition, and speech understanding in the presence of competing noise or with less than ideal signal quality (ASHA, 1996; ASHA, 2005). When an acoustic environment is less than ideal, such as in many classrooms, stress is placed on the auditory system (Knecht et al., 2002; Whitelaw, 2008). The auditory system of a child with deficient AP abilities is less equipped to deal with acoustic stress than that of a child with normal AP abilities (Whilelaw, 2008). The most commonly reported symptom of children with AP deficits is difficulty understanding speech in the presence of background noise (Dawes et al., 2008).

A disagreement exists in the literature regarding how to label a deficit in AP abilities (Bellis, 2003). In the American Speech-Language-Hearing Association (ASHA) technical report published in 1996, the term *central auditory processing disorder* was used (ASHA, 1996). At a conference held a few years later in Dallas, Jerger and Musiek (2000) recommended use of the term *auditory processing disorder* (APD) to emphasize the interconnectedness of the peripheral and central auditory systems. The suggestion that the word "central" be removed from the label was met with controversy, thus ASHA

(2005) later recommended that the term “central” be placed in parentheses *((central) auditory processing disorder* ((C)APD)) and that APD and (C)APD be viewed as synonymous terms. For the purposes of this paper, the term APD will be used as it most effectively highlights the complexity and nonmodularity of the auditory system (Bellis, 2003).

APD in Children

APD is diagnosed in children and adults; however AP abilities are most frequently assessed in children and teenagers, ages 7 to 17 years (Emanuel, Ficca, & Korczak, 2011). APD typically manifests in children early in their schooling due to a change in their acoustic environment (i.e. transition from home to a classroom or from an enclosed classroom to a pod layout) or in later grade levels as curricula become more difficult (Bamiou et al., 2001). Very little is known about the prevalence of APD in children (Chermak & Musiek, 1997). Prevalence estimates range from 2% to 7% in the literature (Chermak & Musiek, 1997; Musiek et al., 1990a). The most recent prevalence estimate of APD in children in the USA is 2% to 3% (Chermak & Musiek, 1997). This estimate is based on prevalence data for disorders that frequently co-occur with APD (i.e. learning disabilities or otitis media) and clinical experience; thus additional research is warranted to generate prevalence data for APD in children for the purpose of furthering our understanding of the disorder and its impact on education (Chermak & Musiek, 1997).

Children with APD may report a variety of auditory complaints and/or academic difficulties due to the complexity of the CANS (ASHA, 2005; Witton, 2010). The CANS is comprised of a number of specialized structures at various locations between the brainstem and the cerebral cortex (Bellis, 2003). APD can be the result of insufficient processing at any of these locations; thus the symptoms associated with APD vary greatly from child to child (AAA, 2010). Since APD lacks a uniform presentation, it is labeled a heterogeneous disorder in the literature (ASHA, 2005). Frequently reported symptoms of APD in children include difficulty hearing in noisy or reverberant environments, trouble following directions (especially multi-step directions), frequently asking for repetition, the appearance of inattentiveness and/or distractibility, trouble discriminating between sounds, and/or trouble remembering what is heard (AAA, 2010; Chermak, Tucker, & Seikel, 2002). Children with APD tend to display difficulties with written language skills such as reading and/or spelling, which further highlights the complexity of the CNS (Dawes et al., 2008; Musiek et al., 1990a). Ferguson, Hall, Riley and Moore (2011) compared reading abilities in 29 children, ages 6 to 13 years, diagnosed with APD and 55 children, ages 6 to 11 years, with no listening difficulties. The Test of Word Reading Efficiency (TOWRE) (Torgesen, Wagner, & Rashotte, 1999) was administered and results revealed that children with APD had significantly poorer reading abilities than the control group (Ferguson et al., 2011). Dawes et al. (2008) reviewed the charts of 32 children with APD and compared their reported symptoms to 57 children with normal AP abilities. The five most commonly reported symptoms in the children with APD are listed in Table 1. Among these highly ranked symptoms were reading problems (47%) and spelling problems (37%) (Dawes et al., 2008).

Table 1

Common Clinical Symptoms of APD in Children and their Incidences of Occurrence Compared to non-APD Children

Reported Symptom	Incidence
Difficulty understanding speech in the presence of background noise	66%
Reading problems	47%
Difficulty following spoken instructions	34%
Spelling problems	37%
Lack of concentration	22%

Note. Adapted from "Profile and Aetiology of Children Diagnosed with Auditory Processing Disorder (APD)," by P. Dawes, D.V.M. Bishop, T. Sirimanna, & D-E. Bamiou, 2008, *International Journal of Pediatric Otorhinolaryngology, 72*, p. 486.

To a parent or teacher, the signs of APD can be easily confused with peripheral hearing loss or a behavior, learning or attention problem (AAA, 2010; Chermak et al., 2002; Jerger & Musiek, 2000). For example, APD and the inattentive form of Attention Deficit Hyperactivity Disorder (ADHD) have similar behavioral manifestations (Chermak et al., 2002). The behaviors most characteristic of the inattentive form of ADHD and APD, as ranked by pediatricians and audiologists respectively, are shown in Table 2. With both disorders, children tend to exhibit poor listening skills and appear withdrawn or inattentive leading to classroom difficulties. When specialists in each of these disorders, pediatricians and audiologists, were asked to rank characteristic behaviors associated with APD and ADHD however, the top ranked behaviors for each disorder were exclusive (Chermak et al., 2002). This highlights the importance of the differential diagnosis process (AAA, 2010).

Table 2

Top Ranked Behaviors Characteristic of Attention Deficit Hyperactivity Disorder-Predominantly Inattentive Type (ADHD-PI) and Auditory Processing Disorder (APD)

ADHD-PI	APD
Inattentive	Asks for things to be repeated
Academic difficulties	Poor listening skills
Daydreams	Difficulty following instructions given Orally
Distracted	Difficulty hearing in background/ambient Noise
Poor listening skills	Academic difficulties
Disorganized	Distracted
Asks for things to be repeated	Reduced rate of information processing
Auditory divided attention deficit	Auditory attention divided attention deficit
Difficulty hearing in background/ambient Noise	Auditory sustained attention deficit
	Poor memory
	Difficulty discriminating speech

Note. Adapted from "Behavioral Characteristics of Auditory Processing Disorder and Attention-Deficit Hyperactivity Disorder: Predominantly Inattentive Type," by G. D. Chermak, E. Tucker, & J. A. Seikel, 2002, *Journal of the American Academy of Audiology, 13*, p. 335. ADHD-PI= Attention Deficit Hyperactivity Disorder-Predominantly Inattentive, APD= Auditory Processing Disorder.

Etiology of APD

AP deficits can be the result of medical conditions, such as CANS lesions or otitis media with effusion (OME), or delayed CNS maturation (AAA, 2010; Jerger, Jerger, Alford, & Abrams, 1983; Musiek et al., 1990a; Talaat, Kabel, & Qatanani, 2009; Whitton & Polley, 2011). A large proportion of children who exhibit AP difficulties however, have normal peripheral hearing sensitivity and no identifiable CANS lesion or other medical condition that could be noticeably affecting their AP abilities (AAA, 2010). OME, which is highly prevalent in young children, can cause auditory signal degradation if the fluid is causing a conductive hearing impairment (Whitton & Polley, 2011). If auditory signals are degraded during critical periods of brain development, auditory deprivation may occur and in turn language, reading and/or AP abilities may be affected

(Dawes et al., 2008; Kindig & Richards, 2000; Nittrouer & Burton, 2005; Shriberg, Friel-Patti, Flipsen, & Brown, 2000; Whitton & Polley, 2011; Winksel, 2006; Zumach, Gerrits, Chenault, Anteunis, 2010).

Research investigating the long-term effects of recurrent OME on AP abilities in children is mixed. Jerger et al. (1983) found that children with a history of recurrent OME had poorer word intelligibility in competing speech than children with unremarkable otologic histories. Hall and Grose (1993) found that children with a history of recurrent OME had significantly reduced masking level differences (MLDs) when compared to children with unremarkable otologic histories. Some researchers would argue that recurrent OME has no long-term effect on AP abilities (Emerson, Crandall, Siekel, & Chermak, 1997; Hartley & Moore, 2005). Emerson et al. (1997) found no statistically significant difference in performance on the SCAN screening test between children with and without histories of recurrent OME. Similarly, Hartley and Moore (2005) found that temporal resolution abilities were similar in children with and without histories of recurrent OME (Hartley & Moore, 2005). Even though the exact relationship between OME and AP abilities is unknown at this time, researchers have suggested, to err on the side of caution, that children with a history of recurrent OME be treated as at risk for APD if listening concerns are present (Paradise et al., 1997).

The relationships between OME and language and/or literacy abilities are also under-researched; however some studies have suggested that children with recurrent OME are at risk for delays in these areas (Kindig & Richards, 2000; Nittrouer & Burton, 2005; Shriberg et al., 2000; Winksel, 2006; Zumach et al., 2010). Nittrouer and Burton (2005) found that children with a history of OME performed poorer on a measure of phonological awareness than children with unremarkable otologic histories (Nittrouer & Burton, 2005). If OME does not result in a hearing loss, language abilities may not be affected (Paradise et al., 1997). Since language abilities (i.e. phonological processing abilities) may be affected by OME in some children however; any children suspected of APD should undergo a language screening or assessment especially if concerns are present. Children with delayed CNS maturation (i.e. very low birth weight (VLBW) babies) are also at risk for AP deficits when compared to age-matched peers. It is believed that the AP abilities of children with delayed CNS maturation will improve over time as the anatomical structures, and associated physiology, underlying the AP abilities mature (Davis et al., 2001; Musiek, Gollegly, & Ross, 1985).

Diagnosis of APD

Prior to APD assessment, a thorough evaluation of the peripheral auditory system must be completed to rule out hearing loss or other auditory disorders as the reason for a child's listening difficulties (AAA, 2010). A comprehensive audiologic evaluation including pure tone testing, otoacoustic emissions, immittance measures, and word recognition testing must be completed to comprehensively evaluate this system (AAA, 2010).

Case history. The case history is an important tool in the assessment of APD (AAA, 2010; ASHA, 2005). The case history can assist in both the diagnosis of APD and the development of a management plan for those identified as having APD. At a minimum, information regarding pregnancy/delivery, the neonatal period, medical history, developmental milestones (speech, language, & motor), other diagnoses, social history, auditory behaviors, otologic history, educational history/academic strengths and weaknesses, family history of hearing loss and APD, genetic history, and cultural background should be obtained. With this information, the clinician can tailor the diagnostic test battery so that it is most appropriate for a child's developmental and cognitive level (AAA, 2010; ASHA, 2005).

Questionnaires. Questionnaires completed by family members and teachers should be used to obtain additional information about the functional impact of a child's auditory difficulties (AAA, 2010). There are several questionnaires available to help clinicians acquire subjective information about a child's listening abilities outside of the audiology test booth. The Children's Auditory Performance Scale (CHAPS), typically completed by a parent or guardian, is a subjective assessment of a child's listening abilities as compared to their age-matched peers (Smoski, Brunt, & Tannahill, 1998). This questionnaire inquires about a child's performance in several listening conditions (noise, quiet, ideal, multiple inputs, auditory memory, sequencing, and auditory attention span) (Smoski et al., 1998). Fisher's auditory problems checklist, typically completed by parents and/or teachers, is used to identify a child's auditory problems (Fisher, 1985). The Screening Instrument For Targeting Educational Risk (SIFTER) (Anderson, 1989) and the Listening Inventory For Education (LIFE UK) Teacher Appraisal of Listening (Canning, 1999) are screening tools designed specifically for completion by a child's teacher. The SIFTER assesses risk of hearing problems and their potential effect(s) on academic performance (Anderson, 1989). The LIFE UK asks a teacher to rate a child's behavior in the areas of listening, attention and comprehension (Canning, 1999). This tool is also useful in assessing benefit from personal Frequency Modulated (FM) systems (Purdy, Smart, Baily, & Sharma, 2009).

Observation. Clinical observation can be used to facilitate the diagnosis of APD (Jerger, 1998). Observing a child in the environment(s) in which they experience listening difficulties (i.e. the classroom) can provide helpful information regarding the nature and/or impact of their deficit (Jerger, 1998). If it is not feasible for a clinician to observe a child in such outside situations, observing a child's listening behaviors during the case history and/or diagnostic testing processes can also provide functional information regarding auditory difficulties (AAA, 2010).

Behavioral APD test battery. Behavioral APD tests are often grouped into the following major categories: dichotic listening, temporal processing, monaural low redundancy, binaural interaction, and auditory discrimination tests (AAA, 2010). Commercially available measures are lacking for binaural interaction and auditory discrimination assessment. The goal of diagnostic APD testing is to assess functioning at various levels of the CANS, thus the test battery should include at least one test from each of the three main categories: dichotic listening, temporal processing, and monaural low redundancy (AAA, 2010). According to Jerger and Musiek (2000), the diagnostic test battery should include, at a minimum, a dichotic listening test, a gap detection test, and a duration pattern test. The individual tests included in the test battery should have high sensitivity and specificity (Musiek, Chermak, Weihing, Zappulla, & Nagle, 2011). Unfortunately, there is no gold standard diagnostic test for APD to which behavioral tests can be compared to develop sensitivity and specificity data (ASHA, 2005). The preferred method of determining behavioral test efficiency is through lesion studies (ASHA, 2005). In these studies, the effectiveness of a test is determined by its ability to separate a group of individuals with confirmed CANS lesions from a group of individuals with no listening difficulties or CANS lesions (Hurley & Musiek, 1997; Musiek, Baran, & Pinheiro, 1990b; Musiek et al., 2011; Musiek, Gollegly, Kibbe, & Verkest-Lenz, 1991; Musiek & Pinheiro, 1987). In addition to being efficient, the tests administered should be reliable (ASHA, 2005). Behavioral APD test reliability however, is not highly researched because the brain is constantly changing (Bellis, 2003). With young children especially, the same test administered over time is not likely going to yield the same results due to maturation of the CANS (Bellis, 2003). As the CANS matures, scores on AP tests should improve (Schochat & Musiek, 2006; Stollman et al., 2004b).

In the U.S., it is recommended that the APD diagnostic test battery be comprised of both speech and non-speech tests to allow for assessment of different auditory processes, when a language disorder has been ruled out, to the extent possible, or is not suspected (AAA, 2010; ASHA, 2005; Baran, 2007; Johnson, Bellis, & Billiet, 2007). Diagnostic APD assessment should not be completed if a significant receptive and/or expressive language disorder is present (AAA, 2010; ASHA, 2005). To most effectively differentially diagnose APD, the potential impacts of fatigue, motivation, and attention on testing must be minimized (Jerger & Musiek, 2000). Moore (2011) and Moore, Cowan, Riley, Edmondson-Jones and Ferguson (2011) believe that AP abilities are significantly affected by attention and working memory abilities in young children. While attention and working memory abilities may have effects on APD test results, Sharma et al. (2009) found that they explained only a small amount of the variance noted in their test results. To control for potential effects of fatigue and attention, AAA (2010) recommends that total diagnostic test time not exceed 45 to 60 minutes. According to a recent survey, audiologists who specialize in APD use a test battery comprised of, on average, four to six tests (Emanuel et al., 2011). Typically, five or fewer tests are administered during pediatric assessment (Chermak & Musiek, 1997). Reinforcement (e.g. a sticker or small toy) should be used with children who appear unmotivated, to ensure that they are performing to the best of their ability (Silman, Silverman, & Emmer, 2000).

Monaural low redundancy tests. Monaural low redundancy speech tests assess a child's ability to process degraded speech signals in a monaural fashion (ASHA, 2005). Children with normal AP abilities can efficiently process speech that is filtered, distorted, or embedded in background noise to a certain degree (Bellis, 2003). Reducing the natural redundancy of speech, in any of these ways, assesses auditory closure and discrimination abilities (AAA, 2010). Children with deficits in monaural low redundancy abilities lack the proper closure abilities to fill in the gaps when speech is modified in such ways (Bellis, 2003). Commonly administered tests of monaural low redundancy abilities include high and low pass filtered speech tests, time compressed and time compressed and reverberated speech tests and speech-in-noise tests (Emanuel et al., 2011). Filtered speech materials are created using high- and low- pass cutoff frequency filters (Bornstein, Wilson, & Cambron, 1994). One version of this test, created by Bornstein et al. (1994) uses the Northwestern University Auditory Test Number 6 (NU No. 6) as speech materials and 1500 Hz and 2100 Hz as the low- and high- pass filter settings, respectively. Time compressed and reverberated speech materials were created by Wilson, Preece, Salamon, Sperry, and Bornstein (1994) using the NU No.6 word lists. The Compact Disc (CD) offers two time compression settings, 45% and 65%, and a 0.3 s reverberation option (Wilson et al., 1994). Speech-in noise tests are created by embedding speech stimuli in background noise. Examples of speech-in-noise measures are the AFG subtests of the SCAN, which are comprised of monosyllabic words embedded in competing multi-talker babble at fixed signal-to-noise ratios (SNRs) (Keith, 2009a, Keith, 2009b).

The most recent versions of the SCAN are the SCAN-3:A: Tests for Auditory Processing Disorders in Adolescents and Adults (Keith, 2009a) and the SCAN-3:C: Tests for Auditory Processing Disorders for Children (Keith, 2009b). The SCAN-3:C: Tests for Auditory Processing Disorders for Children can be administered to children between the ages of 5 and 12 years and includes three screening tests, three diagnostic tests, and two supplementary tests (Keith, 2009b). The AFG test at a +8 dB SNR is available as a screening test and as a diagnostic test. In the supplementary tests, the AFG is also available at a +12 dB SNR and a +0 dB SNR. Children who exhibit an AFG deficit often report difficulty listening in noisy situations (e.g. the classroom), where the background noise level is typically high (Knecht et al., 2002).The SNR of an occupied classroom has been shown to range from -7 to +15 dB SNR with an average SNR of 3.5 dB SNR; thus the AFG +0 dB SNR and AFG +8 dB SNR subtests are likely the most accurate reflections of a child's listening abilities in the classroom (Crandell & Smaldino, 2000; Houtgast, 1981; Larsen & Blair, 2008). Speech recognition abilities in noise may reach maturity by 6 years of age (Amos & Humes, 1998; Stollman et al., 2004b). Amos and Humes (1998) found that performance of first graders (mean age of 6:6 (years:months)) was equivalent to performance of third graders (mean age of 8:6) on the AFG + 8 dB SNR subtest of the SCAN (Keith, 1986). Similarly, Stollman et al. (2004b) found that 6-year olds performed similarly to children ages 7 to 12 years on a Dutch speech in noise measure.

Dichotic listening tests. Dichotic listening tests involve the presentation of different auditory stimuli to both ears at the same time (Noffsinger, Martinez, & Wilson, 1994). Speech stimuli include digits, syllables, words, and sentences (Noffsinger et al., 1994). Dichotic listening tests may be a more realistic measure of one's listening abilities than monaural listening tests since in the real world, one listens with two ears and is often in situations with competing auditory signals (Moncrieff, 2011). Auditory information presented monaurally, or in a non-competing fashion, travels to both hemispheres of the brain via the ipsilateral and contralateral auditory pathways (Noffsinger et al., 1994). During dichotic listening tests, the contralateral auditory pathways dominate and suppress the ipsilateral auditory pathways (Kimura, 1961). Specifically, auditory information presented to the right ear is sent initially to the left cerebral hemisphere and vice versa (Noffsinger et al., 1994). The left hemisphere is the dominant hemisphere for language and speech production in the majority of children; therefore performance on dichotic listening tests utilizing speech stimuli and requiring a verbal response is primarily reliant on the left hemisphere (Kimura, 1961). In children with left hemisphere language dominance, speech stimuli initially delivered to the left ear, and right hemisphere, must cross over the corpus callosum to the left hemisphere for speech processing (Noffsinger et al., 1994). In this context, right ear scores provide information on the integrity of the auditory areas in the left hemisphere, and left ear scores provide information on the integrity of the auditory areas of the right and left hemispheres as well as the corpus callosum (Bellis, 2003).

The corpus callosum is not fully myelinated until 10 to 12 years of age, which affects left ear dichotic listening performance with speech stimuli in young children who have left hemisphere language dominance (Musiek, Gollegly, & Baran, 1984). Since left ear performance on dichotic speech tests is dependent on the corpus callosum to transfer information, when the corpus callosum is not fully mature, dichotic speech test results show a right ear advantage (REA) (Bellis, 2003). This REA diminishes over time (Moncrieff, 2011). Moncrieff (2011) assessed dichotic listening abilities in children ages 5 to 12 years using digits, randomly presented in one, two or three digit pairs, and monosyllabic words. Results revealed the largest ear advantages in children ages 5 to 7 years suggesting that their corpus callosums were least mature when compared to the older children. Across all groups, a REA was evident in 73.8% of children on the test using digits and in 67.6% of children on the test using monosyllabic words (Moncrieff, 2011). Research has shown that children with recurrent OME demonstrate larger REAs on dichotic listening tests than children with no history of OME (Asbjornsen et al., 2000). Asbjornsen et al. (2000) investigated dichotic listening performance in children with and without a history of recurrent OME and PE tube insertion and found that children with a positive history displayed similar overall performance but greater REAs than those with a negative history. The authors suggest that this is due to an interruption in auditory input and development of the language centers in the brain caused by the OME and subsequent hearing deficit present in many cases (Asbjornsen et al., 2000). Performance on tests with linguistically loaded stimuli (e.g. sentences) takes longer to reach adult values than performance on tests with less complex stimuli (e.g. digits) (Bellis, 2003). For this reason, a dichotic listening test using digits is most appropriate for use with young children due to its minimal linguistic load (Bellis, 2003).

A commonly administered dichotic listening test, with a minimal linguistic load, is the Dichotic Digits Test (DDT) (Chermak, Silva, Nye, Hasbrouch, & Musiek, 2007; Emanuel, 2002; Emanuel et al., 2011). Each test item consists of four numbers between one and 10, excluding the number seven since it is a two-syllable word and its inclusion would result in an increase in linguistic demand (Musiek, 1983a). Two numbers are presented to each ear in a dichotic or overlapping manner. The child is instructed to repeat back all four digits in any order (Musiek et al., 1991). The DDT has been shown to be highly sensitive to CANS lesions (Musiek et al., 2011; Musiek et al., 1991). Using a cutoff criterion of ≤ 90%, abnormal performance on the DDT has been shown to accurately identify individuals with CANS lesions approximately 75% to 80% of the time (Hurley & Musiek, 1997; Musiek et al., 2011; Musiek et al., 1991). Musiek (1983b) found that the DDT was equally sensitive to cerebral and brainstem lesions. The specificity of the DDT has been shown to range from 83% and 89% (Hurley & Musiek, 1997; Musiek et al., 2011). Published normative data for the DDT are available for children and adults 7 years of age and older (Bellis, 2003).

Temporal processing tests. Temporal processing refers to the ability to perceive time-related characteristics of auditory stimuli (Rawool, 2007). Temporal processing is important for speech perception and melodic awareness, specifically the ability to perceive subtle phonemic or voicing differences in speech and recognize changes in either the frequency or duration of adjoining auditory stimuli in music (Bellis, 2003). It is one’s ability to analyze and process changes in auditory stimuli over time that enables one to understand speech in the presence of competing noise (Rawool, 2007). Temporal processing abilities can be subdivided into specific skills including temporal resolution (gap detection), temporal sequencing or patterning, temporal integration, and temporal masking (ASHA, 2005; Rawool, 2007). Emanuel (2002) and Emanuel et al. (2011) found that the most frequently administered tests of temporal processing are tests of temporal resolution and/or temporal sequencing abilities. Temporal resolution refers to one's ability to detect a change in the envelope of an auditory stimulus (i.e. a gap or brief pause in a stimulus) (Shinn, Chermak, & Musiek, 2009). Temporal resolution abilities mature throughout early childhood and reach adult-like levels at approximately 7 years of age (Dias, Jutras, Acrani, & Pereira, 2012; Shinn, et al., 2009). Commonly administered tests of temporal resolution include the Random Gap Detection Test (RGDT) (Keith, 2000) and a newer test called the Gaps In Noise (GIN) test (Musiek et al., 2005a).

Temporal patterning, or temporal sequencing, refers to one's ability to perceive and label acoustic differences in consecutive acoustic stimuli (Bellis, 2003). Both cerebral hemispheres as well as the corpus callosum are needed for temporal patterning tasks (Musiek, 1994). The right hemisphere is responsible for pattern recognition, the left hemisphere is responsible for verbal labeling of the pattern, and the corpus callosum is required for the sharing of information between hemispheres (Kimura, 1964). For this reason, an abnormal test result does not provide information on site of lesion (Musiek, 1994). Temporal patterning abilities mature until approximately 12 to 13 years of age, which is consistent with the maturational time course of the corpus callosum (Musiek et al., 1984; Schochat & Musiek, 2006; Stollman et al., 2004b).

Two tests of temporal patterning are the Frequency Pattern Test (FPT) (Musiek & Pinheiro, 1987) and the Duration Pattern Test (DPT) (Musiek et al., 1990b). The FPT is comprised of three-tone burst sequences, which are each 150 ms in duration (Musiek &

Pinheiro, 1987). The tone bursts are either low- (880 Hz) or high- (1122 Hz) frequency. The duration between the individual tones in the sequence is 200 ms and the interstimulus interval (ISI) is 7 s (Musiek & Pinheiro, 1987). The DPT is comprised of three-tone burst (1000 Hz) sequences with an ISI of 300 ms (Musiek et al., 1990b). The stimuli are either short (250 ms) or long (500 ms) in duration (Musiek et al., 1990b). For both the FPT and the DPT, the child is instructed to verbally label the patterns using the words, "high" and "low," or "short" and "long," respectively (Musiek et al., 1990b; Musiek & Pinheiro, 1987). The FPT has been shown to have a sensitivity of 83% and a specificity of 88.2% and the DPT has been shown to have a sensitivity of 86% and a specificity of 92% (Musiek et al., 1990b; Musiek & Pinheiro, 1987). Similarly, Musiek et al. (2011) found the FPT to have a sensitivity and specificity of 90% in identifying individuals with documented brain lesions. Published normative data for the FPT and DPT are available for children and adults 7 years of age and older (Bellis, 2003).

Auditec, an auditory test recording company, recorded a version of the FPT titled the Pitch Pattern Sequence (PPS) test, which is better suited for young children because it has longer tone burst durations, a greater frequency separation between low-and high-pitched stimuli, longer ISIs, and a greater time interval between individual tone bursts than the FPT (Pinheiro & Ptacek, 1971). As with the FPT, the PPS test assesses temporal patterning abilities in the frequency domain using three-tone burst sequences. Children are instructed to verbally label the patterns that they hear; there are six possible pattern combinations. The high-pitched tone burst in the PPS test is 1430 Hz as opposed to 1122 Hz in the FPT; thus the separation between the low-and high-pitched tone bursts is greater. The PPS test is characterized by 500 ms tones, a 300 ms interval between tone bursts, and an ISI of 9 s (Pinheiro & Ptacek, 1971). Normative data is available, through Auditec, for children between the ages of 6 and 9 years.

Additional tests: Electrophysiological tests. It has been recommended that electrophysiological measures be included in the APD diagnostic test battery when warranted (Jerger & Musiek, 2000). Auditory evoked potentials (AEPs) objectively assess the integrity of structures within the CANS (Baran, 2007; Jerger & Musiek, 2000). AEPs assess functioning at various levels of the auditory system ranging from the Auditory Brainstem Response (ABR), which assesses the cochlear nerve and brainstem pathways to the late/slow cortical AEPs, which assess higher cortical areas (AAA, 2010). Jerger and Musiek (2000) recommend minimally including the ABR and the Middle Latency Response (MLR) in the diagnostic APD test battery. Normative data is lacking for absolute MLR amplitude and latency measurements due to wide inter-subject variability in children and adults (Chambers & Griffiths, 1991; Suzuki, Hirabayashi, & Kobayashi, 1983). For this reason, intra-hemispheric (contralateral) amplitude comparisons have been investigated as a means for identifying CANS involvement (Musiek, Charette, Kelly, & Lee, 1999). These measurements have been shown to be the most sensitive (~80%) MLR measurements in the identification of dysfunction (Musiek et al., 1999).

AEPs however, are not typically included in APD assessment outside of laboratory settings due to cost, equipment restrictions, and little recognized clinical utility (AAA, 2010). A normal result obtained on an electrophysiologic measure does not rule out APD, while an abnormal result provides little information regarding a child’s functional auditory deficits (AAA, 2010). Emanuel et al. (2011) found that very few audiologists specializing in APD include electrophysiologic measures in their diagnostic test battery. If AEPs are going to be included in the test battery, they should be used in conjunction with behavioral APD tests to make an accurate diagnosis (Baran, 2007).

Diagnostic criteria. Performance more than two standard deviations below the mean on any two behavioral APD test measures or more than three standard deviations below the mean on any one behavioral APD test measure, in at least one ear, constitutes a diagnosis of APD (AAA, 2010; ASHA, 2005; Chermak & Musiek, 1997). Since this criterion was originally suggested, it has been adopted and supported by the main national governing bodies in the field of Audiology (AAA, 2010; ASHA, 2005). Through the administration of a comprehensive APD test battery, an auditory profile for each child is developed outlining the child's auditory strengths and weaknesses (Bellis, 2003; Witton, 2010). The auditory profile allows for construction of the most effective management plan (Bellis, 2003; Witton, 2010). A disparity with respect to diagnostic criteria exists in the literature surrounding the use of speech and non-speech tests (ASHA, 2005; Rosen, 2005; British Society of Audiology [BSA], 2007). In the U.K., practice guidelines state that APD cannot be diagnosed unless a deficit is noted on tests using non-speech stimuli (BSA, 2007). The BSA suggests that utilizing simple speech or non-speech stimuli more effectively evaluates the function of the auditory system in isolation while minimizing the possible confounding effect of language abilities (BSA, 2007). In the U.S however, no criteria regarding failure on speech vs. non-speech tests exists for diagnosing APD (ASHA, 2005).

Comorbidity of APD

Children with APD often have other developmental disorders (Sharma et al., 2009; Witton, 2010). Similar to other developmental disorders, the underlying cause of APD is often unknown and can differ across children (Witton, 2010). In some cases, there may be a genetic predisposition to APD and other developmental disorders; however genetic research in this area is lacking (Witton, 2010). APD is frequently seen in children with language impairment, reading disorder, learning disability, dyslexia, and Attention Deficit Hyperactivity Disorder (ADHD) (Banai, Nicol, Zeker, & Kraus, 2005; Bradlow, Kraus, & Hayes, 2003; Fraser, Goswami, & Conti-Ramsden, 2010; Friederichs & Frederichs, 2005; Iliadou, Bamiou, Kaprinis, Kandylis, & Kaprinis, 2009; Keller, Tillery, & McFadden, 2006; Sollman et al., 2003, Sharma et al., 2009). The high incidence of co-occurrence or comorbidity of APD can be explained, at least partially, by the nonmodularity or multisensory nature of the brain, meaning that brain regions are not compartmentalized and that the CANS cannot be thought of as functioning in a "vacuum" (Ghazanfar & Shroeder, 2006; Musiek, Bellis, & Chermak, 2005b, p. 129).

The link between APD and other disorders is supported by several studies revealing AP deficits in children with language impairment (LI), dyslexia, non-verbal learning disability (NVLD), and ADHD (Fraser et al., 2010; Iliadou et al., 2009; Keller et al., 2006; Sollman et al., 2003). Stollman et al. (2003) found that a large proportion of children diagnosed with LI performed significantly poorer than control participants on tests of AP abilities. Fraser et al. (2010) evaluated AP skills in children ages 9 to 11 years identified as having either LI or dyslexia and found that both groups of children demonstrated poorer skills than control participants. Friederichs and Friederichs (2005) reported on several children with suspected APD and attention problems. Keller et al. (2006) assessed AP skills in 18 children, ages 6 to 16 years, with a NVLD, and results revealed a diagnosis of APD for 61% of the children. According to Bradlow et al. (2003), children with learning disabilities often display a monaural low redundancy deficit, more specifically; they tend to experience greater difficulty understanding speech in the presence of competing noise than non-APD children. Sharma et al. (2009) found that out of a group of 49 children diagnosed with APD, only three had a pure diagnosis of APD. Ten percent of children were diagnosed with APD and LI, 10% were diagnosed with APD and reading impairment, and 47% were diagnosed with APD, LI and reading impairment. They also reported that 30 of the children presented with deficits in auditory attention (Sharma et al., 2009).

The relationship between AP, language and literacy is a source of controversy in the literature (Wallach, 2011). Research has revealed a link between temporal processing abilities in infancy and early language development (Benasich et al., 2006; Benasich & Tallal, 2002; Benasich, Thomas, Choudhury, & Leppänen, 2002). While an underlying auditory deficit may play a role in LI and or reading impairment, the relationship between these disorders will continue to be a source of controversy until gold standard measures for diagnosis are developed (Sharma et al., 2009). In cases where APD coexists with other developmental disorders, the disorders should be viewed as coexisting and one disorder should not be viewed as principal (Witton, 2010).

The Importance of a Multidisciplinary Approach to Diagnosis of APD

Due to the high incidence of comorbidity seen in children with APD, diagnosis requires a multidisciplinary team approach (ASHA, 2005; Sharma et al., 2009; Witton, 2010). A multidisciplinary team approach involves the collaboration of professionals across disciplines to differentially diagnose APD (ASHA, 2005). Typical members of an APD multidisciplinary team include an audiologist, Speech-Language Pathologist (SLP), educator, psychologist, a child's parents, and/or a physician (Bellis, 2003). With school-age children, the school nurse may be the first person that a child approaches with listening difficulties, thus these professionals must be aware of the signs of APD and equipped with the information necessary to make appropriate referrals (Neville, Foley, & Gertner, 2012). Screening measures for higher order disorders including speech, language and/or learning disorders should generally be administered before an APD screening or diagnostic assessment (DeBonis & Moncrieff, 2008). Pending the results of these screening measures, referrals to specialists for diagnostic evaluations may be made (ASHA, 2004).

Two language measures that can be administered prior to APD screening or assessment, that are appropriate for use with young children, are the Clinical Evaluation of Language Fundamentals: Fourth Edition (CELF-4) screening test (Semel, Wiig, & Secord, 2003) and the Comprehensive Test of Phonological Processing (CTOPP) (Wagner, Torgesen, & Rashotte, 1999). The CELF-4 screening test is a measure that can be used to identify children and young adults, ages 5 to 21 years, who are at risk for a language disorder (Semel et al., 2003). The portion of the screening test appropriate for children ages 5 to 8 years, a total of 28 test items, consists of four different language tasks. These language tasks screen syntax, morphology, semantics, and working memory abilities (Semel et al., 2003). The CTOPP tests that have normative data for children ages 5 and 6 years assess three areas of phonological processing: phonological awareness, phonological memory, and rapid naming (Wagner et al., 1999). Through administration of the CTOPP, a clinician is able to identify children whose phonological processing abilities are below their average age-matched peers'. Phonological awareness, phonological memory, and rapid naming are all important skills for classroom learning specifically in the areas of reading, spelling, writing, math, and language comprehension.

Once a diagnosis or diagnoses have been made by the multidisciplinary team, the professionals must set individualized goals and devise an assessment and/or management plan for the child within their specialized scope of practice (Körner, 2010). The multidisciplinary team must work together to determine how the results obtained on standardized test measures translate to a child's functional abilities in the classroom (Wallach, 2011).

The role of the speech language pathologist on the multidisciplinary team. Due to the high incidence of comorbidity of AP problems and language and/or literacy problems, the SLP plays an important role on the multidisciplinary team involved in APD diagnosis (ASHA, 2005; Sharma et al., 2009). The primary roles of the SLP on the multidisciplinary team are ruling out higher order speech, language, and/or literacy problems to the extent possible, through diagnostic assessment, as the cause for a child's auditory difficulties and screening for APD (ASHA, 2005). The behavioral symptomology of APD and LI can be very similar (Ferguson et al., 2011). Ferguson et al. (2011) asked parents of children with diagnosed LI and parents of children with diagnosed APD to complete questionnaires inquiring about their child's communication and listening abilities. Results revealed that the two groups of children shared many behavioral characteristics. To a non-specialist, these disorders can be impossible to differentiate, which is why a full diagnostic speech/language assessment should be recommended if speech, language and/or literacy problems are suspected (Ferguson et al., 2011). Additionally, performance on tests using speech stimuli is influenced by the child's knowledge of and familiarity with the language in which they are recorded (Wallach, 2011). SLPs are challenged with "peeling the onion" or taking a closer look at a child's linguistic, metalinguistic, and literacy skills to make sure that a diagnosis of APD is not too broad (p. 279). The SLP will communicate the information about a child's language abilities to the diagnostic audiologist to facilitate development of an appropriate APD screening or diagnostic test battery (Wallach, 2011).

Since APD and LI present with similar symptomology, the SLP may be the first professional to see a child with APD. The SLP is qualified to administer a number of screening measures for APD including behavioral screening tests, questionnaires and checklists (ASHA, 2005). A recent survey administered to 145 SLPs with expertise in the area of AP, as a part of an unpublished thesis study, found that respondents viewed SLPs and audiologists as equally qualified to administer screening measures (Marczewski, 2012). The most commonly employed APD screening measures by SLPs are classroom observation and the SCAN-3:A: Tests for Auditory Processing Disorders in Adolescents and Adults (Keith, 2009a) or SCAN-3:C: Tests for Auditory Processing Disorders for Children (Keith, 2009b; Marczewski, 2012). Whether it is the SLP referring a child to the audiologist for diagnostic APD testing or the audiologist referring a child to the SLP for diagnostic speech, language and/or literacy assessment, the relationship between the SLP and the audiologist is an integral part of the multidisciplinary approach to APD diagnosis.

Finally, while management is not the focus of this paper, it is SLPs that primarily provide intervention services to children identified as having APD (Fey et al., 2011; Wallach, 2011). Since evidence for the effectiveness of auditory intervention strategies alone is currently lacking, use of a comprehensive intervention plan including speech, language, and/or literacy therapy is recommended making SLPs a critical member of the multidisciplinary team not only during the diagnostic processes but also during management (Fey et al., 2011).

Assessing Children Under 7 Years of Age

Currently, only children with a cognitive age of 7 years or greater can undergo diagnostic assessment for APD (AAA, 2010; ASHA, 2005). This minimum age requirement is due to concerns regarding task difficulty, attention, and working memory abilities and a lack of normative data for younger children (AAA, 2010; ASHA, 2005; Moore, 2011). Normative data for children younger than 7 years of age is not available for the majority of currently available behavioral APD measures because performance in this younger population has been shown to be highly variable (AAA, 2010; ASHA, 2005; Bavin et al., 2010; Dawes & Bishop, 2008; Dias et al., 2012; Jerger, 1998; Stollman et al., 2003; Stollman et al., 2004a; Stollman et al., 2004b). During APD assessment, performance is compared to normative data ranges (Jerger, 1998). When a normative data range is especially wide, as is often the case when testing children younger than 7 years of age, interpretation of results is difficult and test validity is questionable (Jerger, 1998). Stollman et al. (2003) assessed AP abilities in two groups of 6-year-old children; one group had diagnoses of LI and the other group served as control participants. In the control group, performance on the DPT and the FPT was highly variable. Specifically, scores (in terms of percent correct) ranged from 7% to 60% and 12% to 93% on the DPT and FPT, respectively (Stollman et al., 2003). The variability noted in the performance of younger children on AP tests is due in part to maturational effects (AAA, 2010).

Stollman et al. (2004b) reported on a longitudinal study that they conducted to examine the development of AP abilities in children from 6 to 12 years of age (Stollman et al., 2004b). A total of 40 subjects participated in the study. Twenty typically developing children were tested a total of five times over a period of six years and their results were compared to those obtained from a group of 20 normal hearing adults using the same test battery. Overall, composite scores improved with increasing age. Although the degree to which performance changed year to year differed between tests, results revealed that generally AP abilities don’t reach adult levels until 12 to 13 years of age (Stollman et al., 2004b). Although diagnostic APD assessment is limited to children 7 years of age and older, 6-year old children presenting with listening difficulties cannot be ignored. Screening tests, created specifically for use with young children, should be used to determine if these children are at risk for APD (Debonis & Moncrieff, 2008; Jerger & Musiek, 2000; Smart et al., 2012).

Screening for APD

The earlier a child is identified as at risk for APD, the sooner management can begin (Hurley & Singer, 1985). Early intervention or management capitalizes on the high degree of CANS plasticity in young children and can lead to better speech, language, behavior, emotional, and social outcomes and ultimately greater academic achievement in children (ASHA, 2005; Hurley & Singer, 1985). The earlier a cause for a child’s classroom difficulties is identified, the sooner a parent, teachers, and/or caregivers can begin working with clinical practitioners on management of the child's listening difficulties (Musiek et al., 1990a). Management strategies may include preferential seating, reduction of background noise in the classroom, calendars, pre-teaching, visual aids, metacognitive activities, and/or an FM system (Chermak & Musiek, 1992; Hamaguchi, 1992). With the implementation of management strategies, appropriate counseling can begin with both the child and the parents regarding the nature of APD (Jerger, 1998). While at 6 years of age, the diagnostic label of APD cannot be given, a child can be labeled as at risk and treated as if they do have the disorder, for the purpose of management, until complete diagnostic testing can be performed (Musiek et al., 1990a).

The purpose of a screening is to identify children at risk for having APD and to cut back on the number of inappropriate referrals for diagnostic testing (Jerger & Musiek, 2000). To effectively assess AP skills, linguistic, cognitive, and attention demands must be minimized (Jerger & Musiek, 2000). Currently, only one APD screening measure, the SCAN-3:C: Test for Auditory Processing Disorders in Children (Keith, 2009b), is commercially available for use with 6 year old children and this measure is less than ideal (Jerger & Musiek, 2000). The SCAN-3:C: Tests for Auditory Processing Disorders in Children screening test battery contains no temporal processing measure that can be used with 6 year olds and has a rather high linguistic demand. (Keith, 2009b). This screening test has questionable reliability and very little information was provided in the manual regarding the study sample used to derive in-house sensitivity and specificity data. Additionally, this screening test lacks outside sensitivity and specificity data. Finally, the original version of this test, the SCAN-C Revised, which is highly debated in the literature, is still being used in some clinics (Keith, 2008). More appropriate APD screening measures need to be developed for use with children younger than 7 years of age. Strides towards creating appropriate screening measures have been made; however much more research is needed (Smart et al., 2012).

Smart et al. (2012) screened AP and phonological/phonemic awareness abilities in 29 typically developing 6-year old children. The test battery was comprised of Auditec's version of the PPS test, a Compressed and Reverberated Speech Test (CRST) and several subtests of the Queensland University Inventory of Literacy (QUIL), a phonological/phonemic awareness measure used in New Zealand. The screening battery was successfully administered to all 6-year old participants. Results of the QUIL subtests were similar to normative data confirming normal phonological/phonemic abilities. Results of the PPS test and the CRST were highly variable; however with some modifications to administration and scoring, the researchers found that PPS test performance was less variable than the data reported by Auditec, the manufacturer of the PPS test. The researchers included a training phase for the PPS test using the audiometer to facilitate participants' understanding of the task. Two scoring methods for the PPS test were compared, one in which pitch pattern reversals were included as correct, and one in which pitch pattern reversals were excluded. PPS test performance was significantly less variable when the scoring method including reversals as correct was utilized. A significant list effect was found on the PPS test, which was likely due to the uneven distribution of pitch patterns across lists. Pitch pattern difficulty was investigated and it was determined that LLH and HHL were the easiest pitch patterns for participants to identify and LHL and LHH were the hardest pitch patterns for participants to identify.

More research expanding on the findings of Smart et al. (2012) is needed to develop an appropriate APD screening measure for 6-year olds and the relationship between performance on phonological/phonemic awareness abilities and AP abilities should be further investigated due to the prevalence of coexisting APD and dyslexia and/or other reading disorders (Fraser et al., 2010; Sharma et al., 2009; Smart et al., 2012).

As previously mentioned, APD often presents after changes in educational environment or curricula take place (Bamiou et al., 2001). The transition from kindergarten to first grade, which occurs at approximately 6 years of age, is characterized by increased academic demands, changes in teaching style and instruction, and changes in social interaction (La Paro, Pianta, & Cox, 2000; Sink, Edwards, & Weir, 2007). Specifically, first grade marks the beginning of formal learning and the switch from one to multiple teachers for some children (Sink et al., 2007). Additionally, the classroom setting may switch from an enclosed room to a pod layout, where background noise levels and acoustic demands are likely greater. While 5 year olds are typically transitioning from home to Kindergarten, which is also marked by significant increases in acoustic and learning demands, research should focus initially on the development of screening measures for 6-year olds since significant brain maturation takes place between 4 and 6 years of age and 5-year olds have been shown to not be able to complete simple AP tasks (Thompson, Cranford, & Hoyer, 1999; Stollman et al., 2004a).

The main aim of the present pilot study was to develop an APD screening test battery for 6-year olds. The second aim was to collect normative data on typically developing 6-year old children to further evaluate the battery.

Chapter 3: Methodology

Participants

Twenty-three typically developing 6-year-old children participated in this pilot study. Institutional Review Board (IRB) approval was obtained (Appendix A). The participants were recruited through the use of a flier (Appendix B), social media, and by word of mouth. Participation in this study was voluntary and both parental consent (Appendix C) and child assent (Appendix D) were obtained prior to testing. The parents of each child were required to complete a brief case history questionnaire, created for this study, that inquired about the child's auditory behaviors, birth/neonatal history, developmental milestones (speech, language and motor), academic performance, otologic history, and major medical history (as seen in Appendix E). Participant race was also noted. Inclusion criteria were English as a primary language, normal language abilities as evidenced by performance on the CELF-4 screening test (Semel et al., 2003) and the phonological awareness subtests of the CTOPP (Wagner et al., 1999), and no known learning disorder. The primary teacher of each child was asked to complete the first 11 items of the LIFE UK questionnaire, which provided insight into the child's listening behaviors in the classroom (Canning, 1999). The last two items on the LIFE UK were removed since they inquire about noise levels in the classroom and not specifically a child's listening abilities. The LIFE UK questionnaire used in this study can be found in Appendix F. Audiometric inclusion criteria included Jerger Type A tympanograms and pure-tone thresholds ≤ 15 dB HL at 500, 1000, 2000, and 4000 Hz in both ears, which is in accordance with ASHA's practice guidelines for school-aged hearing screening

(ASHA, 1997; Jerger, 1970). Parents were provided with a summary of the hearing and language measure results at the end of the test session (Appendix G).

Materials

All hearing testing was conducted in a double walled sound booth. The tympanometry screening was performed using a GN Otometrics Madsen Otoflex 100 and the hearing screening and AP screening were performed using a two-channel Grason-Stadler Inc. 61 (GSI-61) diagnostic audiometer. All stimuli were delivered to the participants' ears via Etymotic Research-3A (ER-3A) insert earphones. The tympanometer and audiometer were calibrated to ANSI specifications. All AP tests were completed via reproduction of pre-recorded materials on a SONY 5-disc Compact Disc (CD) player routed to the audiometer.

The CELF-4 screening test stimulus book and examiner manual were used during administration and scoring of the CELF-4 screening test. The Blending Words subtest of the CTOPP was administered using the accompanying CD routed through a laptop computer. The CTOPP picture book was used during administration of the Sound Matching subtest of the CTOPP and the examiner manual was used for scoring. A comprehensive CD containing all three AP tests and their respective calibration tones was created for this study using Adobe Audition version 1.5. The stimuli for the DDT were taken from The Veterans Administration (VA) Compact Disc for Tonal and Speech Materials for Auditory Perceptual Assessment. The stimuli for the PPS test were taken from Auditec's version of the Pitch Pattern Sequence: Child Version CD and the stimuli for the AFG + 8 dB SNR test were taken from the SCAN-3:C: Tests for Auditory Processing Disorders in Children CD.

Procedures

Test sessions were held in the Hearing and Listening Lab (HALL) in Van Bokkelen Hall on Towson University's campus. Testing took place over one test session and took no longer than 1 hour 30 minutes including breaks, as needed. All language screening measures were administered while the participant was seated in a chair in the lab and all AP measures were administered while the participant was seated in a chair in the sound treated booth. A listening check was performed on the audiometer and CD player before each test date. Each test was calibrated before administration so that the respective calibration tone peaked at 0 dB HL on the audiometer Volume Unit (VU) meter. Stickers and small toys were given to the participants as rewards and reinforcement, as needed.

Hearing screening. Otoscopy was performed on both ears to rule out cerumen impaction. A tympanometry screening was performed using a 226 Hz probe tone to evaluate tympanic membrane mobility and middle ear pressure in both ears. Peripheral hearing sensitivity was screened at 15 dB HL at 500, 1000, 2000, and 4000 Hz in both ears. Hearing was screened at 500 Hz, even though this frequency is not included in the ASHA (1997) guidelines, because of the known effect of background noise on hearing at 500 Hz.

Language screening.

Syntax, morphology, semantics and working memory abilities. Items 1-28 of the CELF-4 screening test, appropriate for children ages 5 to 8 years, were administered to screen syntax, morphology, semantic, and working memory abilities (Semel et al., 2003). This screening test requires children to finish sentences, describe relationships between objects, follow multi-step directions, point to pictures, and repeat whole sentences. The screening test was administered according to the procedures outlined in the manual and practice items were administered prior to each subcategory as indicated in the test procedures. A total score was calculated and compared to the criterion score for the participant's chronological age.

Phonological processing. Three subtests of the CTOPP were administered to evaluate phonological awareness abilities (Wagner et al., 1999). The CTOPP is commonly used in the clinical environment, easy to administer and score, and has been shown to have good reliability and moderate to strong correlations with reading abilities (Wagner et al., 1999). The phonological awareness subtests were chosen for the present test battery because of the common comorbidity of APD and reading disorders (Fraser et al., 2010; Sharma et al., 2009). Practice items were administered prior to each subtest consistent with the recommendations highlighted in the manual (Wagner et al., 1999). The Elision, Blending Words and Sound Matching subtests were administered according to the procedures outlined in the manual. The Elision subtest requires that children repeat whole words and then break the words into parts. The Blending Words subtest requires that children put sounds together to make whole words. The Sound Matching subtest requires that children identify words that start and end with target sounds. Total raw scores were calculated and translated into standard scores. The sum of the standard scores was then calculated and a composite phonological awareness standard score was derived (Wagner et al., 1999).

Behavioral APD screening measures. The AP screening test battery screened three categories of auditory processing abilities: dichotic listening, temporal processing, and monaural low redundancy. The order of test administration was randomized for each participant. Additionally, list and ear assignments and the order in which the individual conditions were presented were randomized for the monaural tests, the PPS test and the AFG +8 dB SNR test, prior to testing. All randomization was completed using www.random.org. All AP measures were administered at a comfortable listening level of 60 dB HL. Practice items were administered prior to each test to ensure task understanding.

Test of monaural low redundancy. To assess monaural low redundancy abilities, the AFG + 8 dB SNR subtest of the SCAN-3:C: Tests for Auditory Processing Disorders in Children (Keith, 2009b) was administered because it uses simple speech stimuli and performance on the AFG +8 dB SNR has been shown to be mature by 6 years of age (Amos & Humes, 1998). The AFG + 8 dB SNR test is characterized by monosyllabic words presented in the presence of multi-talker noise. The tester gave brief verbal instructions followed up by the instructions provided on the CD. Children were instructed to repeat back the words that they heard. Two practice items were administered to each ear prior to testing. Twenty test items were presented to each ear. Ear specific percent correct scores were calculated.

Test of dichotic listening. To assess dichotic listening abilities, the DDT was administered because it is has a low linguistic load and uses digits, which are familiar stimuli to young children (Musiek, 1983a). During this test, four digits ranging from 1 to 10, excluding 7, were presented to both ears in an overlapping manner. The children were instructed to repeat back the four digits that they heard in any order. Five practice items were administered prior to testing. Twenty test items (40 digits per ear) were presented and ear specific percent correct scores were calculated.

Test of temporal processing. To assess temporal processing abilities, a revised version of Auditec's PPS test, a test of temporal patterning or sequencing, was administered because it is appropriate for use with young children and has a low linguistic load (Pinheiro & Ptacek, 1971). Based on the recommendation of Smart et al. (2012), two lists containing the same 20 pitch patterns but in a different order were created using Adobe Auditon version 1.5 and Auditec's PPS stimuli. Each list consisted of three HHL, LLH, LHH and LHL pitch patterns and four HLH and HLL pitch patterns. These lists can be found in Appendix H. A training phase was employed in the current study as recommended by Smart et al. (2012). During the training phase, low- (750 Hz) and high- (1500 Hz) frequency tones were presented through the audiometer in isolation, two-tone pairs, and three-tone pairs to teach the participant the task. Once the participant demonstrated competence with the audiometer training, six computer generated practice items were administered. Twenty test items were presented to both ears monaurally with no visual aids. The children were instructed to verbally label the patterns of tones that they heard using the words "high" and "low." Humming of responses was not permitted. Ear specific percent correct scores were calculated using two different scoring methods, one excluding reversals and the other including reversals as correct.

Statistical Analyses

Descriptive statistics were calculated for case history variables, LIFE UK results, language measure performance, and AP measure performance. SPSS Statistics Version 19 (SPSS 19) was used for all statistical analyses. An alpha level of 0.05 was used to determine statistical significance for all analyses. A bivariate correlation was performed to evaluate the relationship between case history variables, LIFE UK results and language and AP measure performance. Independent t-tests were performed to examine the effects of gender and age (6:0 to 6:5 versus 6:6 to 6:11) on language and AP measure performance and paired t-tests were performed to examine the effects of ear, scoring method, and list on language and AP measure performance when applicable. A series of paired t-tests were performed to assess difficulty of the six individual pitch patterns. An overview of the screening test battery, the stimuli involved, and the required patient responses can be found in Table 3.

Table 3

Overview of the Test Battery

	Test Measure	Stimuli	Participant Response
Hearing Screening	Tympanometry	226 Hz probe tone	None
	Hearing Screening	500, 1000, 2000 & 4000 Hz pure tones	Hand raising
Language Screening: Phonological/Phonemic Awareness	CTOPP: Elision	Mono-and di-syllabic words	Repetition of whole words and parts of the words
	CTOPP: Blending Words	A series of individual sounds routed through laptop speakers	Combining individual sounds and stating the whole word that they form
	CTOPP: Sound Matching	A series of pictures and target sounds	Stating the word that begins or ends with a target sound
Language Screening: Syntax, Moprhology, Semantics & Working Memory	CELF-4 Screening	Picture book and sentences	Pointing, Repeating sentences & providing descriptions
AP Tests	AFG + 8 dB SNR	Monosyllabic words embedded in background noise	Repetition of words
	PPS test	High (1430 Hz) and low (1122 Hz) tones	Verbal labeling of patterns
	DDT	Digits (1-10; excluding 7)	Repetition of digits

Note. The tests that were administered, the stimuli that they were comprised of and the responses required from the participant. Hz= hertz, CTOPP: Comprehensive Test of Phonological Processing, CELF-4= Clinical Evaluation of Language Fundamentals-4, AP= auditory processing, DDT= Dichotic Digits Test, PPS= Pitch Pattern Sequence, AFG + 8 dB SNR= Auditory Figure Ground + 8 dB Signal to Noise Ratio

Chapter 4: Results

Participants

This pilot study investigated the AP abilities of 23 typically developing 6-year old children. The participants ranged in age from 6:0 to 6:11 (years:months). A total of 12 males and 11 females were assessed. The overall mean ages of the participants were 6.53 (0.28) for the male group and 6.30 (0.32) for the female group. In addition to whole group analysis, performance on the language and AP measures was analyzed in age bands (6:0 to 6:5 and 6:6 to 6:11). A total of 13 children aged 6:0 to 6:5 and 10 children aged 6:6 to 6:11 were assessed. Specific chronological ages of the 23 participants and overall mean ages of the male and female participant groups can be seen in Table 4. Twenty-two of the 23 participants were Caucasian.

Case History Information

Case history forms were completed by each participant’s parent/guardian prior to testing. No concerns regarding hearing abilities were reported for any of the 23 children. One parent reported that their child had language difficulties and that they were receiving therapy to improve descriptive abilities. Since there were no other concerns regarding this child’s language abilities and he went on to perform above average on both language measures, this child was included in further statistical analyses. There was only one significant report regarding medical history; one child had Meningitis and a respiratory disease as an infant. Otologic history was positive for eight children that had a history of ear infections and three children that had a history of PE tubes.

Teacher Observation

The LIFE UK was distributed to the primary teachers of each participant by their parent/guardian. Fifteen of the participants were currently enrolled in Kindergarten and eight of the participants were currently enrolled in first grade. Of the 23 questionnaires distributed, 17 were returned. Non-compliance was reportedly due to either the teacher not returning the questionnaire or request for medical necessity to complete the questionnaire by the participant's school. Questionnaire responses were translated into a numerical scale ranging from one (very poor) to five (very good). Mean responses to each of the 11 questions are displayed in Figure 1.

Table 4

Participant Statistics

Participant # (n=23)	**Males (n=12)**	**Females (n=11)**
1	6.00	6.67
2	6.75	6.42
3	6.75	6.92
4	6.92	6.67
5	6.67	6.08
6	6.50	6.25
7	6.42	6.08
8	6.42	6.00
9	6.67	6.00
10	6.17	6.17
11	6.83	6.08
12	6.25	-
Range	**6.00-6.92**	**6.00-6.92**
Mean Age	**6.53**	**6.30**
SD	**0.28**	**0.32**

Note. The exact chronological ages of the 23 participants, displayed in years, are listed according to gender groups. The ranges and means were calculated for male and female participants and standard deviation values are expressed in parentheses. N= sample size, SD= standard deviation.

Figure 1.

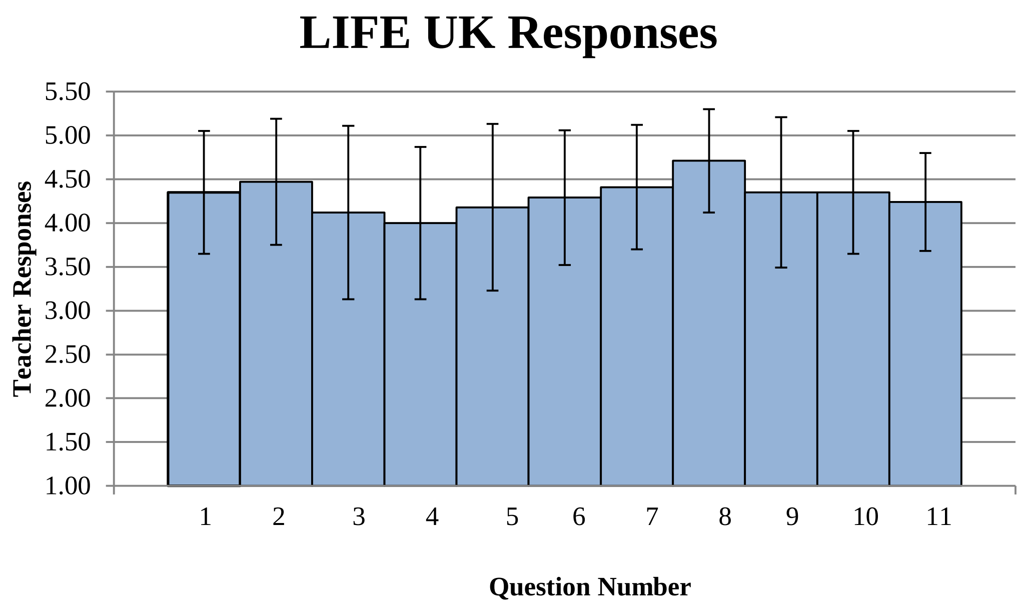

Figure 1. The mean LIFE UK responses for each of the 11 questionnaire items are displayed above. Standard deviations are depicted using the standard error bars. LIFE UK= Listening Inventory For Education United Kingdom.

Audiologic Screening

Otoscopic examination revealed impacted cerumen in one participant. This participant consulted their Pediatrician for cerumen removal and was tested at a later date. Hearing was screened at the beginning of each test session using both pure tones and Immittance testing. One male participant did not pass the hearing screening, thus only data from 22 participants were included in statistical analyses.

Language Screening

Syntax, morphology, semantics and working memory abilities. Raw scores on the CELF-4 screening test ranged from 17 to 26 with an average score of 21.77 (2.54). The criterion score for children ages 6:0 to 6:5 was 12 and the criterion score for children ages 6:6 to 6:11 was 14. All children passed the CELF-4 screening test. Descriptive statistics are displayed in Table 5. Results of an independent t-test investigating the effect of gender (independent grouping variable) on mean CELF-4 screening test performance (dependent variable) showed no statistically significant effect of gender ($p = 0.94$). Results of an independent t-test investigating the effect of age (independent grouping variable) on mean CELF-4 screening test performance (dependent variable) showed a statistically significant effect of age ($p = 0.02$). An alpha value of 0.05 was used to determine significance for both t-tests. T-values, degrees of freedom (df), and p-values are contained in Table 6.

Phonological processing. Composite phonological awareness standard scores ranged from 91 to 134, with an average score of 112.18 (9.19). All children performed within normal limits compared to same age-peers on the phonological awareness subtests of the CTOPP. Descriptive statistics are displayed in Table 5. Results of an independent t-test investigating the effect of gender (independent grouping variable) on mean CTOPP performance (dependent variable) showed no statistically significant effect of gender ($p = 0.34$). Results of an independent t-test investigating the effect of age (independent grouping variable) on mean CTOPP performance (dependent variable) showed a statistically significant effect of age ($p = 0.04$). An alpha level of 0.05 was used to determine significance for both t-tests. T-values, degrees of freedom (df), and p-values are contained in Table 6.

Table 5.

Descriptive Statistics for Language Measures

Test	Min.	Max.	Mean	SD.
CELF-4 Screening Test	17	26	21.77	2.54
CTOPP	91	134	112.18	9.19

Note. Minimum, maximum, and mean scores and standard deviations for the CELF-4 screening test and phonological awareness subtests of the CTOPP are displayed above. Min.= minimum score, Max.= maximum score; SD.= standard deviation, CELF-4 Screening Test: Clinical Evaluation of Language Fundamentals- 4th Edition: Screening Test, CTOPP: Comprehensive Test of Phonological Processing.

Table 6.

Independent T-test Results for Gender and Age Effects on Language Measure Performance

Effect	CELF-4 Screening Test	CTOPP
Gender		
t	0.08	0.97
df	20	20
Sig. (2-tailed)	0.94	0.34
Age		
t	2.46	2.19
df	20	20
Sig. (2-tailed)	0.02*	0.04*

Note. The statistical findings of the independent t-tests investigating effects of gender and age on language measure performance. T= t-value, df= degrees of freedom, Sig. (2-tailed)= p-value, CELF-4 Screening Test= Clinical Evaluation of Language Fundamentals- 4th Edition: Screening Test, CTOPP= Comprehensive Test of Phonological Processing, *= $p< 0.05$.

Behavioral APD Screening Measures

Ear specific descriptive statistics for the AFG + 8 dB SNR test, DDT and revised PPS test are displayed in Table 7. An alpha level of 0.05 was used to determine significance for all t-tests involving AP measures. T-values, degrees of freedom (df), and p-values for all t-tests are contained in Table 8. Mean percentage scores for the AP measures administered as a part of this pilot study are displayed in Figure 2. Results were collapsed across gender, ear, age, list, and scoring method when appropriate based on t-test results.

Table 7.

Descriptive Statistics for Behavioral APD Measures

Test	Ear	Min.	Max.	Mean	SD.
AFG +8	Right	75.00	100.00	88.64	5.60
	Left	75.00	100.00	90.68	7.45
DDT	Right	35.00	100.00	85.57	13.27
	Left	45.00	95.00	75.80	13.28
PPS	Right	10.00	100.0	52.27	32.14
	Left	5.00	100.0	55.91	29.71

Note. Descriptive statistics for the three measures of auditory processing according to ear are displayed above in the form of percent correct. Min.= minimum value, Max.= maximum value, SD.= standard deviation, AFG + 8 dB= Auditory Figure Ground + 8 dB SNR, DDT= Dichotic Digits Test, PPS= Pitch Pattern Sequence test.

Table 8.

T-test Results for Gender, Age, Ear and Scoring Effects on APD Measure Performance

Effect	**AFG**	**DDT**		**PPS**
Gender		***R***	***L***	
t	0.83	0.20	1.82	1.63
df	42	20	20	42
Sig. (2-tailed)	0.41	0.85	0.08	0.11
Age		***R***	***L***	
t	-0.28	-0.64	-0.57	0.43
df	42	20	20	42
Sig. (2-tailed)	0.78	0.53	0.57	0.67
Ear				
t	-0.95	3.68		-1.92
df	21	21		21
Sig. (2-tailed)	0.35	< 0.01*		0.07
List				
t	-	-		1.39
df				21
Sig. (2-tailed)				0.18
Scoring				
t	-	-		-7.84
df				43
Sig. (2-tailed)				< 0.01*

Note. The statistical findings of the independent t-tests investigating effects of gender and age on auditory processing measure performance and the paired t-tests investigating the effects of ear, list and scoring method on language and auditory processing measure performance. T= t-value, df= degrees of freedom, Sig. (2-tailed)= p-value, R= right ear, L= left ear, AFG= Auditory Figure Ground, DDT= Dichotic Digits Test, PPS= Pitch Pattern Sequence, *= p< 0.05.

Figure 2.

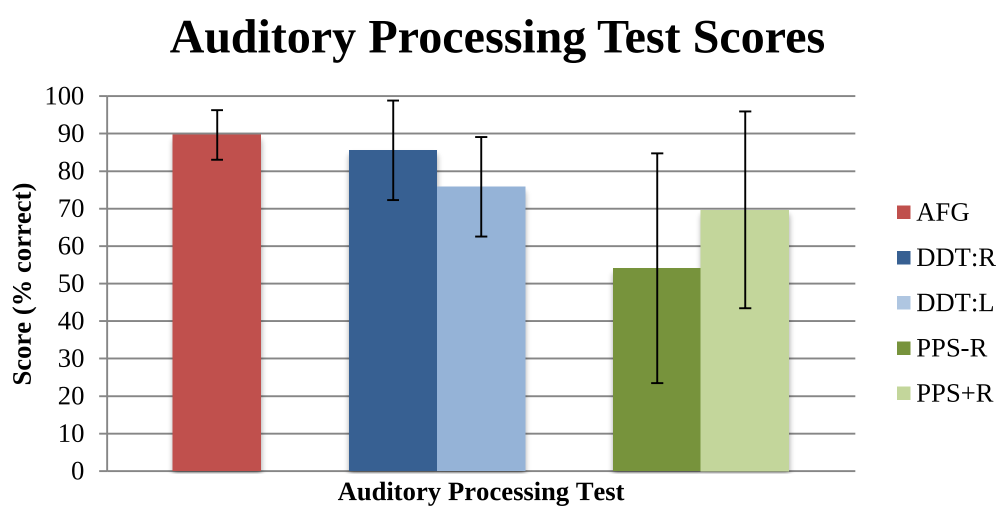

Figure 2. The mean percentage scores, in percent correct, for the auditory processing tests administered as a part of this study. Standard deviation values are depicted using the standard error bars. AFG= Auditory Figure Ground + 8 dB SNR, DDT: R= Dichotic Digits Test: Right Ear, DDT: L= Dichotic Digits Test: Left Ear, PPS-R= Pitch Pattern Sequence Test without Reversals Included as Correct, PPS+ R: Pitch Pattern Sequence Test with Reversals Included as Correct.

Test of monaural low redundancy. Scores for the AFG + 8 dB SNR test were categorized according to ear and expressed as an overall percentage correct. Right ear scores ranged from 75% to 100% with a mean score of 88.64% (5.60). Left ear scores ranged from 75% to 100% with a mean score of 90.68% (7.45). Results of a paired t-test investigating the effect of ear (independent variable) on mean AFG +8 dB SNR test performance (dependent variable) showed no statistically significant effect of ear ($p = 0.35$); therefore scores were collapsed for further analyses. Total scores ranged from 75% to 100% with a mean score of 89.66% (6.59). Results of independent t-tests investigating the effects of gender and age (independent grouping variables) on mean AFG + 8 dB SNR overall performance (dependent variable) showed no statistically significant effect of gender ($p = 0.41$) or age ($p = 0.78$) on overall performance.

Test of dichotic listening. Scores for the DDT were categorized according to ear and expressed as an overall percentage correct. Right ear scores ranged from 35% to 100% with a mean score of 85.57% (13.27). Left ear scores ranged from 45% to 95% with a mean score of 75.80% (13.28). Results of a paired t-test investigating the effect of ear (independent variable) on mean DDT performance (dependent variable) showed a statistically significant effect of ear ($p < 0.01$). Results of independent t-tests investigating the effects of gender and age (independent grouping variables) on mean DDT performance (dependent variable) showed no statistically significant effect of gender ($p > 0.05$) or age ($p > 0.05$) on DDT right ear performance and no statistically significant effect of gender ($p > 0.05$) or age ($p > 0.05$) on DDT left ear performance.

Test of temporal processing. Scores for the revised PPS test were categorized according to ear and expressed as an overall percentage correct. Right ear scores ranged from 10% to 100% with a mean score of 52.27% (32.14). Left ear scores ranged from 5% to 100% with a mean score of 55.91% (29.71). Results of a paired t-test investigating the effect of ear (independent variable) on mean PPS performance (dependent variable) showed no statistically significant effect of ear ($p = 0.07$); thus scores were collapsed for further analyses. Total PPS scores excluding reversals ranged from 5% to 100% with a mean score of 54.10% (30.64). Results of independent t-tests investigating the effects of gender and age (independent grouping variables) on mean overall PPS performance (dependent variable) showed no statistically significant effect of gender ($p = 0.11$) or age ($p = 0.67$) on overall PPS performance. Results of a paired t-test investigating the effect of list (independent variable) on overall PPS performance (dependent variable) showed no statistically significant effect of list ($p = 0.18$). Overall performance when reversals were included as correct ranged from 25% to 100% with a mean score of 69.66% (26.22). Results of a paired t-test investigating the effect of scoring method (excluding reversals versus including reversals as correct) (independent variable) on overall PPS performance (dependent variable) showed a statistically significant effect of scoring ($p < 0.01$).

Pitch pattern difficulty. Descriptive statistics for performance on each individual pitch pattern were calculated by dividing the number of pitch patterns correctly identified, across both ears, by the total number of pitch patterns presented for each of the six pitch patterns contained within the PPS test lists. Mean and standard deviation values for each pitch pattern are seen in Table 9 and Figure 3.

Table 9.

Distribution of Pitch Patterns Across the Pitch Pattern Sequence (PPS) Test Lists Created for Use During this Study and Percent Correct Scores and Standard Deviations for Each Pattern

	HHL	**LLH**	**LHH**	**LHL**	**HLL**	**HLH**
List 1	3	3	3	3	4	4
List 2	3	3	3	3	4	4
Score	67.42	53.03	37.89	38.63	56.82	65.91
	(31.90)	(54.05)	(39.22)	(39.63)	(39.10)	(31.85)

Note. Distribution of pitch-patterns across Pitch Pattern Sequence test lists created for this study and mean performance for each pitch pattern. Standard deviation values are contained within parentheses. HHL= high-high-low, LLH= low-low-high, LHH= low-high-high, LHL= low-high-low, HLL= high-low-low, HLH= high, low, high.

Figure 3.

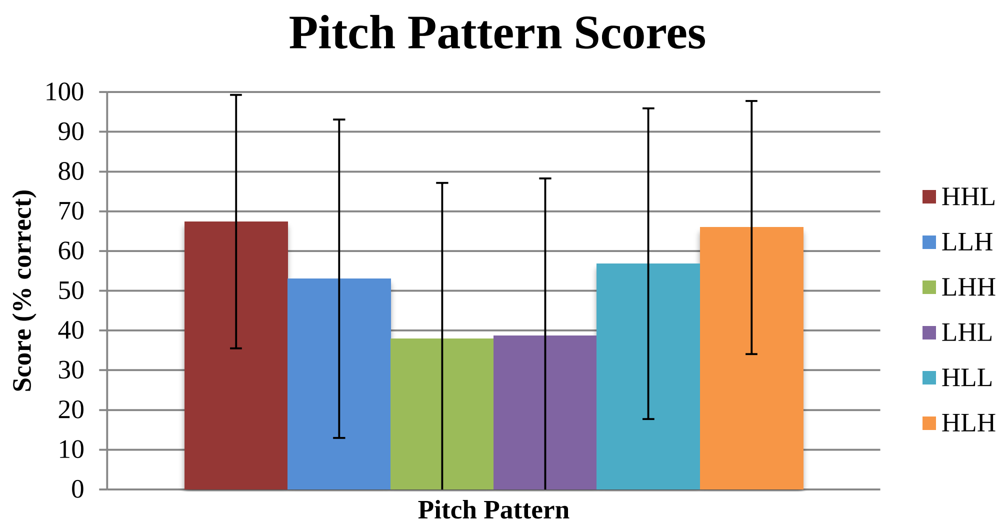

Figure 2. The mean percentage scores for the individual pitch patterns are displayed above. Standard deviations are depicted using the standard error bars. HHL= high-low-high, LLH= low-low-high, LHH= low-high-high, LHL= low-high-low, HLL= high-low-low, HLH= high-low-high.

A series of paired t-tests were performed to determine if pitch pattern (independent variable) impacted performance (dependent variable). A Bonferroni adjustment was performed to account for the multiple t-tests being performed. The criteria for statistical significance after the adjustment was p < 0.0033. Significant p-values are displayed in Table 10.

Table 10.

Significant t-test Results for Pitch Pattern Effect on Performance

Patterns	**Sig. (2-tailed)**
HHL vs. LHH	< 0.01*
HHL vs. LHL	< 0.01*
HLH vs. LHH	< 0.01*
HLH vs. LHL	< 0.01*
LLH vs. LHH	< 0.01*
LLH vs. LHL	< 0.01*

Note. Significant results of the paired t-tests investigating effect of pitch pattern on mean performance. Standard deviation values are contained within parentheses. HHL= high-high-low, LHH= low-high-high, LHL= low-high-low, HLH= high-low-high, LLH= low-low-high, Sig. (2-tailed)= p-value. *= p< 0.05.

Case History Information

A bivariate correlation was performed to evaluate the relationship between otologic history and LIFE UK scores and language and AP measure performance. The Pearson Product Moment Correlation coefficient (r) was used to determine the strength of relationships and an alpha value of 0.05 was used to determine significance. A moderate positive correlation (r = 0.58) was found between history of ear infections and history of PE tubes. Moderate negative correlations were found between history of ear infections (r= -0.56) and history of PE tubes (r= -0.60) and CTOPP performance. A moderate positive correlation (r = 0.53) was found between history of ear infections and degree of right ear advantage (REA) on the DDT.

Chapter 5: Discussion

APD affects approximately 2 to 3% of children and can lead to a wide range of academic difficulties (ASHA, 2005; Chermak & Musiek, 1997; Witton, 2010). APD is often identified in childhood since children are tasked with learning through listening in acoustic conditions that are often less than ideal (Bamiou et al., 2001). Currently, APD diagnostic assessment is limited to children 7 years of age and older since AP abilities have been shown to be highly variable in younger children (Bavin et al., 2010; Dawes & Bishop, 2008; Smart et al., 2012; Stollman et al., 2003; Stollman et al., 2004a; Stollman et al., 2004b). It has been recommended that children younger than 7 years of age be screened for APD; however only one screening measure appropriate for use with younger children is commercially available and as mentioned previously, this measure is not ideal. The primary purpose of this pilot study was to develop an APD screening test battery for 6-year old children that could be used in the future clinically to assist with early identification and management of children at risk for APD. The second purpose of this study was to gather normative data on the screening battery on typically developing 6-year old children.

Relationship between Otologic History and Language and AP Abilities

Questions regarding otologic history were included on the case history form. A history of ear infections was correlated with a history of PE tubes, although the correlation was only of moderate strength. This finding is not surprising considering PE tubes are a surgical form of treatment of chronic otitis media (COM) (Mandel & Casselbrant, 2006). All participants performed within normal limits compared to age matched peers on both language measures; however participants with a history of ear infections and/or PE tubes demonstrated poorer phonological awareness abilities, as evidenced by performance on the three CTOPP subtests administered, when compared to participants with unremarkable otologic histories. This finding agrees with research in the literature that has shown that recurrent OME during early childhood can result in language and/or reading delays when abilities are compared to aged-matched peers with unremarkable otologic histories (Kindig & Richards, 2000; Nittrouer & Burton, 2005; Shriberg et al., 2000; Winskel, 2006; Zumach et al., 2010). In the study conducted by Nittrouer and Burton (2005) where children with a history of recurrent OME were found to have poorer phonological awareness abilities than children with unremarkable otologic histories, a task titled Three-Choice Initial-Consonant-The-Same (ICTS) task was used which is very similar to the Sound Matching subtest of the CTOPP administered in the present study (Nittrouer & Burton, 2005). Due to the fact that this was a pilot study with a small number of participants and that there is controversy in the literature surrounding OME and its long-term effects, more research with a larger sample size is needed.

No correlation between otologic history and AP abilities was observed in the current study, which is consistent with the findings from Emerson et al. (1997) and Hartley and Moore (2005). This insignificant finding may be due to the small sample size in the present study. Since AP abilities can be affected by otologic history, future research should study this relationship with a larger number of participants (Dawes et al., 2008; Whitton & Polley, 2011). Participants with a history of ear infections did demonstrate greater REAs on the DDT than participants with no otologic history, which agrees with the finding of Asbjornsen et al. (2000).

Language Abilities

Language abilities were screened in all participants since research has shown that APD frequently co-occurs with expressive and/or receptive language disorders in young children (Bavin et al., 2010; Stollman et al., 2003). All participants demonstrated normal syntax, morphology, semantics, working memory, and phonological awareness abilities when compared to age-matched peers, as evidenced by performance on the CELF-4 screening test and phonological awareness subtests of the CTOPP (Semel et al., 2003; Wagner et al., 1999). Results were consistent with parental reports of normal language development.

Behavioral Auditory Processing Abilities

Feasibility of test battery. As noted previously, APD assessment is currently limited to children 7 years of age and older (AAA, 2010; ASHA, 2005). Concerns regarding assessment of children younger than 7 years of age surround attention, working memory abilities, and task difficulty (ASHA, 2005; Moore, 2011). Attempts have been made to modify the administration, stimuli, and scoring of AP measures to improve their appropriateness for use with younger children and successful administration of AP measures to 6-year olds has been documented in the literature (Amos & Humes, 1998; Moncrieff, 2011; Smart et al., 2012; Stollman et al., 2003; Stollman et al., 2004a; Stollman et al., 2004b). The APD screening test battery used in this study could be successfully administered to all participants. Several modifications to test administration were made in the present study to improve the feasibility of the test battery for use with 6-year olds based on previous comments in the literature, including the use of stickers and toys as reinforcements/motivators, several short breaks throughout the test session, a training phase during the PPS test, and pausing between stimuli as needed (Silman et al., 2000; Smart et al., 2012; Stollman et al., 2004a). The training phase for the PPS test was adopted from the methodology of Smart et al. (2012) to ensure understanding of the task. Pausing of the stimuli on the CD was used in this study to allow for sufficient response time since researchers who were able to successfully administer APD tests to 6-year olds reported using longer pauses between stimuli than typically used (Stollman et al., 2004a). It should be noted that while all aspects of the screening battery were successfully administered to the participants, diagnostic assessment for APD has been recommended to not exceed 45 to 60 minutes, therefore this screening battery may be best administered over two separate sessions in the clinical environment.

Variability of performance. Six-year-old children have been shown to have highly variable AP abilities, thus test interpretation can be difficult (Smart et al., 2012; Stollman et al., 2003; Stollman et al., 2004a; Stollman et al., 2004b). Little variability was noted in performance on the AFG + 8 dB SNR test in this study because a ceiling effect was found; all participants had total scores that were 75% or greater with an average score of 89.66%. Similarly, Amos & Humes (1998) found that first graders' AFG +8 dB SNR scores averaged approximately 87% and that variability was low as well. It is important to minimize ceiling and floor effects when creating an APD test (Jerger & Musiek, 2000). Based on these results, task difficulty should be increased so that a more normal distribution of scores is obtained. With the AFG testing paradigm, task difficulty can be increased by decreasing SNR. The SNR of typical occupied classrooms has been shown to range from -7 to +5 dB SNR with an average SNR of 3.5 dB SNR (Crandell & Smaldino, 2000; Knect et al., 2002). In future studies, the AFG + 0 dB SNR subtest of the SCAN-3:C: Tests for Auditory Processing Disorders in Children (Keith, 2009b) should be administered or an AFG test with a SNR of 3 or 4 dB should be created and administered as these tests will likely better represent children's functional listening abilities in the classroom and allow for a more normal distribution of scores. In order to assess changes in performance over time, a test must have good reliability (Bellis, 2003). A ceiling effect, such as the one observed on the AFG + 8 dB SNR test in this study, influenced a tests reliability making interpretation of change in performance difficult (Bellis, 2003).

A moderate amount of variability was observed on the DDT and the PPS test. The criterion scores for passing the DDT for 6-year olds in the present study, calculated by subtracting two standard deviations from the mean, were 50% for the left ear and 60% for the right ear. The criterion scores for passing for 7-year olds are 55% and 70% for the left and right ears respectively (Bellis, 2003). Only two participants scored below the 7-year old criterion score for the left ear and only 1 participant scored below the 7-year old criterion score for the right ear. Despite the variability observed in this pilot study, it is likely that with the addition of more data from future studies with 6-year olds, useable normative data ranges could be developed for the DDT.

PPS total scores when reversals were not included as correct ranged from 5% to 100% with a mean score of 54.10%. Auditec reported a normative data range of 45% to 100% with a mean score of 60% when reversals were not included as correct. While mean performance in the present study is comparable to in Auditec's study, greater variability was noted in this study. This could be due to differences in response method and/or number of stimuli administered. In Auditec's normative data sample, children were administered 60 patterns to each ear and in the present study, children were administered 20 patterns to each ear due to time constraints and concerns regarding attention. Additionally, Auditec's normative data represents the outcomes of several response methods including verbalized responses, hummed responses, and manual responses (pointing to blocks). Only verbal responses were allowed during this study to eliminate tester bias. Performance was significantly better and less variable when reversals were included as correct, which is in agreement with the finding from Smart et al. (2012). This finding suggests that a scoring method that includes reversals as correct should be used with 6-year olds to decrease PPS variability and result in more usable normative data ranges. Overall performance ranged from 25% to 100% with a mean score of 69.66% when reversals were included as correct. Auditec reported a normative data range of 45% to 100% with a mean score of 82% when reversals were included as correct, thus variability was slightly higher in the present study. Again, this difference may be due to the differences in methodology described above. It appears that employing a scoring method, which includes reversals as correct decreases PPS test variability in 6-year olds and improves the appropriateness of its administration to this population but it is unknown if the test would then be sensitive enough to identify children with APD.

Gender effect. No gender effects were found for language or AP abilities. Previous research suggests that AP and language abilities are similar in males and females (Bavin et al., 2010; Boiano, 2012; Smart et al., 2012; Stollman et al., 2003; Stollman et al., 2004; Stollman et al., 2004b). Stollman et al. (2003) found no gender effects on language or AP abilities in 6- year olds and Boiano (2012) found no gender effects on AP abilities in typically developing 7 to 12 year olds. It is important to note that this was a small sample size, which was further degraded when divided into two groups (gender); therefore additional analyses should be performed with a larger sample size to confirm or contradict the finding from this study.

Age effect. Research has shown that language and AP abilities generally improve with age (Colon, 2012; Semel et al., 2003; Stollman et al., 2004a; Stollman et al., 2004b; Wagner et al., 1999). Significant age effects (6:0 to 6:5 vs. 6:6 to 6:11) were seen for both language measures. These findings agree with the normative data reported by Semel et al. (2003) and Wagner et al. (1999). No age effects (6:0 to 6:5 vs. 6:6 to 6:11) were seen for AP abilities. According to the literature, speech recognition abilities in noise mature by 6-years of age, thus no age effect would be expected on the AFG + 8 dB SNR subtest (Amos & Humes, 1998; Stollman et al., 2004b). Otherwise, research has shown that generally, AP abilities continue to improve into adolescence (Stollman et al. 2004b). This suggests that age affects should be seen on the DDT and the revised PPS test however; no studies to date have investigated differences in the AP abilities of young 6-year olds (6:0 to 6:5) versus old 6-year olds (6:6 to 6:11). More research should be done with a larger sample size to determine if APD assessment is more feasible in children who are closer to 7 years of age than those who are newly 6-years of age.

Ear effect. The effect of ear on AP abilities was investigated and a significant ear effect was found on DDT performance. Participants displayed significantly greater right ear scores than left ear scores. This finding was expected because of what is known about the dichotic listening paradigm and the maturation of the corpus callosum (Noffsinger et al., 1995; Musiek et al., 1984). This finding also agrees with several reports in the literature (Moncrieff, 2011; Stollman et al., 2004a). No significant ear effects were found on performance on the PPS test or the AFG + 8 dB SNR test in this study. These results agree with other research studies which investigated AP abilities in 6-year old children and found no significant ear effects on measures of monaural low redundancy and/or temporal processing abilities (Smart et al., 2012; Stollman et al., 2004b).

List effect. Smart et al. (2012) administered the first two lists of the PPS test unmodified and found a significant list effect when reversals weren't included as correct. Since the lists were comprised of varying numbers of the six individual pitch patterns, the researchers subsequently assessed the difficulty of the individual pitch patterns and found that the patterns were of unequal difficulty, Statistical analysis showed that the PPS lists created for use in this study, which were comprised of equal numbers of the individual patterns, were balanced and that performance was nearly identical on both lists. Despite this, pitch pattern difficulty was still investigated and the results obtained were similar to those reported by Smart et al. (2012).

Scoring effect. The effect of two different scoring methods on PPS performance was investigated in this study. It was found that performance was significantly higher and that there was less variability in overall PPS performance when pitch pattern reversals were included as correct. This agrees with the finding from Smart et al. (2012). More research examining the effect of scoring on PPS performance and variability is needed to determine if one method has greater clinical utility.

Study Limitations

Sample size. This pilot study screened language and AP abilities in 23 typically developing 6-year old children from the greater Baltimore area. For some analyses, the sample was further divided into gender and age groups. In the gender groups, there were

12 male and 11 female participants. In the age groups, there were 13 participants between the ages of 6:0 and 6:5 and 10 participants between the ages of 6:6 and 6:11. These small group sizes make it difficult to generalize the findings from this study to the general population. Similar studies with larger sample sizes need to be conducted to further investigate language and AP abilities and the relationship between these variables in 6-year olds. The present study suggests that it is feasible to administer this APD screening test battery to 6-year olds; however additional research will add to the power of these results.

Recruitment. All subjects were recruited through the use of a flier and by word of mouth from the greater Baltimore area. The participant group was rather homogenous. Twenty-two of the 23 participants were Caucasian and participants were likely from mid to high socioeconomic status (SES) areas. Monetary compensation and transportation to and from the testing site were not provided. Such circumstances likely attracted participants from mid to high SES areas. The participants in this study, being that they were likely from mid to high SES areas, are more likely to have received quality language and auditory experience growing up than children from lower SES areas, thus the present data may be skewed. Research suggests that SES may affect speech perception, phonological awareness, and AP abilities in children (ASHA, 2005; Nittrouer & Burton, 2005). Future studies should aim to recruit participants of various races and of various SES' Testing could be performed at the participant's schools in future research studies to improve compliance and overcome the obstacle of commuting to and from the test location.

Additional information. APD commonly presents in conjunction with language, reading, learning, and attention disorders and difficulties in any of these domains may affect AP performance (Banai et al., 2005; Bradlow et al., 2003; Fraser et al., 2010; Friederichs & Friederichs, 2005; Iliadou et al., 2009; Keller et al., 2006; Sollman et al., 2003, Sharma et al., 2009). In the present study, parents/guardians were asked to indicate whether or not their child had been diagnosed with any of the above disorders. Due to time constraints, only language abilities were screened prior to administration of the APD tests. There were no formal non-verbal intelligence or attention screeners or tests administered during this study; therefore it is unknown if intelligence quotient (IQ) or attention played a role in participant scores. Research suggests that the variability noted in performance on AP tests in young children is in part due to factors such as IQ or attention (ASHA, 2005; Moore et al., 2011). In an attempt to control for the potential effect of IQ, task instructions were delivered in simple language and practice items were administered until the participant demonstrated sufficient understanding of the tasks. In an attempt to control for lack of attention, short breaks were given frequently throughout the test sessions. Future studies may consider including nonverbal IQ and/or attention screeners as a part of the battery to investigate their effects on AP abilities.

Motivation. Research has shown that motivation can significantly affect the performance of young children on AP measures (Silman et al., 2000). Silman et al. (2000) reported on three case studies in which children who had been diagnosed with APD previously were subsequently tested on two separate occasions, one during which they received no reinforcement and the other during which they received reinforcement (i.e. baseball cards, candy, or money). AP abilities significantly improved in all three cases and they improved to within normal limits in two cases (Silman et al., 2000). It appears that some form of motivation should be used to ensure that participants are performing at the highest level possible. Participants in this study were motivated with a checklist, on which they placed stickers to keep track of the tasks that they had completed, and small toys (i.e. bubbles, silly putty, puzzles etc…). All participants appeared highly motivated by these prizes. Reinforcement with toys may not be possible in the clinical environment; therefore verbal praise and the use of a checklist (with stickers or stamps) should be considered to maintain motivation throughout the session in a clinical environment.

Clinical Relevance

Presently, APD assessment is limited to children 7 years of age and older due to the variability of younger children’s AP abilities (AAA, 2010; ASHA, 2005; Jerger & Musiek, 2000). Six-year old children presenting with listening complaints, in spite of normal peripheral hearing, may benefit from an APD screening to determine if they are at risk for APD. No consensus exists in the literature regarding how to screen 6-year old children for APD. Only one screening measure is available for use with 6-year old children at this time and a more appropriate screening measure, with a lower linguistic load and a test of temporal processing, is warranted. The APD screening battery created for this study was successfully administered to 23 typically developing 6-year old children and with modifications to testing procedures, variability was similar to what has been reported in the literature. The PPS test, using the scoring method that counted reversals as correct, and the DDT appear to be highly appropriate for use with 6-year olds. Based on the results of this study, a more challenging AFG test should be employed.

After this slight methodological change is made to the battery, it should be administered to a larger sample size. Once normative data as well as sensitivity, specificity, and reliability data are collected, the screening test battery can be used in the clinical environment to improve early identification and management of APD. Early intervention or management, such as the implementation of an FM system or metacognitive strategies, has been shown to lessen the educational impact of APD (ASHA, 2005a; Hurley & Singer, 1985).

Future Directions

Future research should focus on collecting data on a much larger sample of typically developing 6-year olds to improve the power of this study's findings and to develop normative data. Recruitment strategies should be amended so that participants are more diverse. Once normative data is collected on a larger sample, sensitivity (likelihood of classifying someone as at risk for APD with this screening test that goes on to be diagnosed with APD when reassessed at 7 years of age or older) and specificity (likelihood of classifying someone as at risk for APD with this screening test battery that has normal auditory processing abilities when reassessed at 7 years of age or older) should be evaluated before the screening battery is used in the clinical environment. The reliability of the screening battery with 6- year olds should also be assessed (Moore et al., 2011). Since research suggests that attention and IQ can affect AP abilities in young children, it may be worth the additional test time required for administration of attention and IQ screeners if concerns are present (ASHA, 2005). Finally, additional research is needed to further support or contradict the findings that children with a history of OME or PE tubes have poorer language abilities than those with no otologic history.

APPENDIX A:
IRB APPROVAL

TOWSON UNIVERSITY

APPROVAL NUMBER: 13-A032

To: Jennifer Smart
8000 York Road
Towson MD 21252

From: Institutional Review Board for the Proctection of Human Subjects Debi Gartland,Chair

APPROVED
DG/MRP
JAN 25 2013
TOWSON IRB

Date: Friday, January 25, 2013

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

Office of University Research Services

Towson University
8000 York Road
Towson, 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:

A Screening Test Battery for APD in 6-Year Olds

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. Sperling
File

TOWSON UNIVERSITY

Date: Friday, January 25, 2013

NOTICE OF APPROVAL

TO: Jennifer Smart **DEPT:** ASLD

PROJECT TITLE: *A Screening Test Battery for APD in 6-Year Olds*

SPONSORING AGENCY:

APPROVAL NUMBER: 13-A032

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: 25-Jan-2013

This research will be reviewed every year from the date of first approval.

Debi Gartland

Debi Gartland,Chair

Towson University Institutional Review Board

WRO

APPENDIX B:
THESIS RECRUITMENT FLYER

Participants needed for Auditory Processing Research

Does your 6– year old child have normal hearing and normal speech, language, learning, and reading abilities?

If so, please consider participating in this research project!

Why?

We are gathering normative data on an Auditory Processing Disorder (APD) screening test battery with 6-year old typically developing children. These measures are routinely used in the clinical environment with children 7 years of age and older but there are no tests sensitive enough for the younger population (less than 7 years old). The data collected in this study will be used in the clinical environment to assist in the early identification of children at risk for APD.

What is auditory processing?

It is a term used to describe the way the auditory pathways in the brain process what is heard, or how we listen.

Where?

Testing will be conducted in Dr. Smart's laboratory located on Towson University's campus in Van Bokkelen Hall or at Towson University Speech Language and Hearing Center at the Institute for Well-Being.

When?

Appointments will be offered throughout the year during after-school hours, weekends, and school holiday breaks. Total test time is estimated at around 1 hour 15 minutes maximum. Children will be rewarded with stickers and/or small toys.

Who?

We are looking for typically developing children (males and females), aged 6 years, with no history of learning, language, reading, or hearing difficulties.

Interested in learning more?

If your child fits the profile above and is willing to volunteer in our study, please contact **Dr. Jennifer Smart** (Assistant Professor) at **410-704–3105** or **JSmart@towson.edu** for more information.

Your child's participation is greatly appreciated!

This study has been reviewed by the Towson University Institutional Review Board for the Protection of Human Participants.

**APPENDIX C:
INFORMED CONSENT FORM**

TOWSON
UNIVERSITY

Department of Audiology, Speech-Language Pathology, and Deaf Studies

INFORMED CONSENT FORM

Project title: A Screening Test Battery for APD in 6-Year Olds

Principal Investigators:
Jennifer L. Smart, 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 with 6-year old children.

Procedures:

If your child participates in this study, a series of screening measures will be performed. This will involve one test session lasting a total of approximately 1 hour 15 minutes. During this session, your child will participate in a number of different listening 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. The test session will take place at Towson University in Dr. Smart's research laboratory or at the Towson University Speech Language and Hearing Center at Towson University. 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, very few APD screening measures, appropriate for use with 6-year old children exist. Additionally, there there are no local norms for any of these tests with 6-year olds. The data collected during this research study will not only be used to assist in the early identification and rehabilitation of children at risk for auditory processing disorder (APD) 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:

There is no monetary compensation for your child's participation. Small toys and/or stickers will be used as reinforcement when necessary.

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.

APPENDIX D:
INFORMED ASSENT FORM

TOWSON UNIVERSITY

Department of Audiology, Speech-Language Pathology,
and Deaf Studies

INFORMED ASSENT FORM

Project title: A Screening Test Battery for APD in 6-Year Olds

Principal Investigators:
Jennifer L. Smart, 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 pictures in a book and blending sounds together. 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 raise your hand 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 one time at Towson University to complete the tasks I described.

The visit will last about 1 hour 15 minutes.

Child Assent Form

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

Title of Project: A Screening Battery for APD in 6-Year Olds

Primary Investigators: Jennifer Smart, 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:…………………………………..

APPENDIX E:
CASE HISTORY FORM

TOWSON UNIVERSITY

CHILD CASE HISTORY FORM

Please fill in the information requested below and bring it to your child's testing session or email it directly to the Principal Investigator (JSmart@towson.edu). *Electronic copies are available

Child's Name: ____

Date of Birth: ______________________________ Age: ______________________________

Parent/Guardian names: ____

School & Teacher: __________________________ Current Grade: ______________________

I. BIRTH HISTORY

A. Pregnancy (check where appropriate):

1. Was the pregnancy full term? Yes __ No __
2. Delivery via cesarean section? Yes __ No __
3. Were there any complications during the pregnancy or delivery? Yes __ * No __

If there were any complications please explain here: ____
____
____

B. Neonatal Period (check where appropriate):

1. Normal Yes __ No __

2. Neonatal Intensive Care Unit (NICU)? Yes __ No __

If there was a NICU stay please explain here:

____

____

____

C. Speech/Language/Hearing:

1. Were (Are) there any concerns about your child's hearing? ___________
2. At what age did your child use his/her first word? _________
3. Does your child communicate in:

   Complete, grammatically correct sentences? __________
4. Does your child mispronounce words? _________
5. Is English your child's primary language? Yes __ No __
6. Are any other languages spoken at home? Yes __ No __ (if yes, list other

   language(s) here ____)

D. Motor Development (check where appropriate):

1. Normal __ Delayed __

If delayed please explain:

____

______

E. Other Diagnoses:

Has your child been diagnosed with any of the following disorders or difficulties? If yes, please not specific diagnosis, date and professional who made the diagnosis.

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:______________________________

F. Medical History

1. List any significant medical problems, operations, and injuries including age of occurrence:

   ____

   ______

G. Otologic History

1. History of ear infections? Yes __ No __

   If yes, how many? ______ Which ear(s)? _________ Age(s)? _______

2. Pressure Equilization (P.E.) tubes? Yes __ No __

   If yes, how many times? ___ Which ear(s)? ________ Age(s)? _______

COMMENTS
Please provide any additional information regarding your child's listening behaviors, school performance or development below.

____

____

____

____

____

____

Thank your for taking the time to fill out this questionnaire

APPENDIX F:
LIFE UK

L.I.F.E[1]. UK
Listening Inventory for Education
Teacher Appraisal of Listening

Name | **Date**__________
School ___________ | **Teacher**____

Classroom soundfield amplification trial yes/no | Length of trial: Weeks
Personal f.m. amplification trial yes/no | Length of trial: Weeks
Details of Amplification system used_________

Instructions: Read the statement below and then circle the score that best describes the behaviour of the child (or children). You should make a judgement as to whether or not the following behaviours are a cause for concern or not.

		Rating				
	In your opinion	*Very good* ←		*Satis-factory*		*Very Poor* →
1	Following class directions					
2	Following individual directions					
3	Overall attention span					
4	On task behaviour					
5	Rate of learning (speed of following instruction)					
6	Involvement in class discussions (volunteers more, makes appropriate contributions)					
7	Contributes when working in a group					
8	Paying attention to multimedia (e.g. video, OHP)					
9	Willingness to answer questions					
10	Answering questions in an appropriate and relevant manner					
11	Amount of repair behaviour (this refers to asking questions, to teacher or peer, in order to clarify what is required)					
~~12*~~	~~Overall noise levels in the class while working in groups~~					
~~13*~~	~~Noise levels in the class during whole class teaching~~					

Additional Comments:

____

[1] Based on LIFE by Karen Anderson and Joseph Smaldino 1997
* Only appropriate for classroom soundfield amplification systems

APPENDIX G:
PARENT SUMMARY

Dear Parent,
Thank you so much for allowing your child to participate in our research study. Below is a summary of the results and any recommendations if warranted. Please feel free to contact us if you have any questions or concerns.
Kind Regards,

Jennifer L. Smart, Ph.D., CCC-A
Assistant Professor
JSmart@towson.edu

Lindsay Sperling, B.A.
Doctor of Audiology research student
Lmsperlin@gmail.com

Test	**Pass**	****Refer**
Pure tone hearing screening		
Tympanometry screening		
Language screening, CELF		
Language screening, CTOPP		

**Recommendations

- A pure tone hearing and/or tympanometry screening “refer”warrants a full diagnostic audiological assessment by a clinical audiologist. Please let us know if you need a referral.
- A language screening “refer” warrants a full diagnostic language evaluation by a clinical speech language pathologist. Please let us know if you need a referral.

APPENDIX H:
PITCH PATTERN SEQUENCE LISTS

Pitch Pattern Sequence (List 1)

Track 1: 1 KHz Calibration Tone
Track 2: Practice Items

Practice Items	**Time**	**Pattern**
1		H-H-L
2		H-L-L
3		L-H-L
4		L-H-H
5		L-L-H
6		H-L-H

Track 3: Test Items
Ear: Right/Left (circle one)

Test Items	**Time**	**Pattern**
1		H-H-L
2		L-L-H
3		L-H-H
4		L-H-L
5		L-H-H
6		H-L-L
7		L-H-L
8		L-H-L
9		H-H-L
10		H-L-L
11		H-L-H
12		H-L-L
13		H-L-H
14		L-L-H
15		H-L-H
16		L-H-H
17		H-L-H
18		H-L-L
19		H-H-L
20		L-L-H
	Total Correct	**______/20**
	Percent Correct	**______%**

Pitch Pattern Sequence (List 2)

Track 1: 1 KHz Calibration Tone

Track 2: Practice Items

Practice Items	**Time**	**Pattern**
1		H-H-L
2		H-L-L
3		L-H-L
4		L-H-H
5		L-L-H
6		H-L-H

Track 4: Test Items

Ear: Right/Left (circle one)

Test Items	**Time**	**Pattern**
1		L-L-H
2		H-L-L
3		H-H-L
4		L-H-H
5		L-H-L
6		L-H-H
7		L-L-H
8		H-L-L
9		H-L-H
10		L-H-L
11		H-L-H
12		H-L-L
13		H-L-L
14		H-L-H
15		H-H-L
16		L-H-H
17		L-H-L
18		H-L-H
19		H-H-L
20		L-L-H
	Total Correct	**______/20**
	Percent Correct	**______%**

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