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EFFECTS OF TEST ENVIRONMENT ON BEHAVIORAL AUDITORY PROCESSING TEST SCORES

by

Deirdre Courtney

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Dr. Stephanie Nagle, Au.D, Ph.D.
Chair, Audiology Doctoral Thesis Committee

4/15/13
Date

Dr. Brian Kreisman, Ph.D.
Committee Member

4/3/13
Date

Dr. Stephen Pallett, Au.D.
Committee Member

4/15/13
Date

Dr. Janet DeLany
Dean of Graduate Studies

April 24, 2013
Date

ABSTRACT

EFFECTS OF TEST ENVIRONMENT ON BEHAVIORAL AUDITORY PROCESSING TEST SCORES

Deirdre Courtney

The effect of ambient environmental noise on performance on three behavioral assessments of auditory processing was examined. Assessments included speech in noise, frequency pattern, and low-pass filtered speech. Twenty-five normal-hearing, typically developing adults were administered these tests in both an ideal sound-treated booth and while ambient environmental noise was routed through a sound field setup. Results yielded no overall effect of the environmental noise on the overall performance on the measures. However, differences noted between individual tests are presented and possible reasons for these differences are explored.

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CHAPTER 1

Introduction

Auditory processing abilities encompass many areas of sophisticated auditory functioning. These areas include monaural low redundancy tasks, temporal processing, dichotic listening, tasks of localization and lateralization, and auditory discrimination tasks (American Academy of Audiology [AAA], 2010). Auditory Processing Disorder (APD) is an up and coming area in audiology and its research and application is being expanded to special populations of children and adults. With these new applications, however, also come new challenges and considerations for clinicians. While literature recommends that certain practices, such as type of transducer used and where testing is conducted, be used when assessing a person for APD, these suggestions are not always applied in clinical practice. These discrepancies between recommended practice and actual clinical practice will be discussed. For example, the effects of environmental noise on the outcome of APD assessment is unclear at this point and needs further exploration. The validity of testing for APD conducted outside of the sound booth is also in question at this time.

CHAPTER 2

Review of Literature

Background on Auditory Processing Disorder

The definition, diagnosis, and treatment of APD have developed over the last two decades (AAA, 2010). The American Speech-Language and Hearing Association [ASHA] Technical Report (2005) defines APD as "difficulties in the perceptual processing of auditory information in the central nervous system and the neurobiologic activity that underlies that processing and gives rise to the electrophysiologic auditory potentials." Suggestions for the areas of assessment of an APD test battery include the assessment of: "sound localization and lateralization, auditory discrimination, auditory temporal processing, auditory pattern processing, dichotic listening, auditory performance in competing acoustic signals, and auditory performance with degraded acoustic signals" (AAA, 2010; ASHA, 2005). While it may not be necessary to assess all of these processes during every APD assessment, careful review of case history and subjective reports from significant persons in a patient's life (i.e., parents, teachers, spouses, etc.) can lead the audiologist to the most appropriate selection of tests (AAA, 2010). Types of assessments for APD can include behavioral assessments of the aforementioned processes, auditory brainstem response (ABR), auditory middle latency response (AMLR), and other cortical auditory evoked responses (AAA, 2010).

Typically, assessment for APD is not considered until other central nervous system involvement and peripheral hearing loss are investigated fully (AAA, 2010). Patients with any neurologic disorder, disease, or injury of the central nervous system that may have an impact on auditory sensation should be considered for APD assessment (AAA, 2010). These populations are some of those often assessed for auditory processing disorder outside of an acoustically controlled sound booth. Other populations commonly assessed outside of the sound booth include children in schools (Lum & Zarafa, 2010), patients with epilepsy, and patients with other neurologic deficits that are confined to a hospital bed.

Several resources cite the need for evaluation of auditory processing abilities to be conducted in an acoustically-controlled environment (AAA, 2010; Boatman et al., 2006), such as a double-walled sound booth. A dearth of research is currently available in the literature regarding the impact of alternative listening environments on the results obtained during an APD assessment. The present study is designed to investigate the effects of ambient environmental noise from an uncontrolled acoustic environment on behavioral tests of APD.

AAA and ASHA scope of practice guidelines state that it is within the scope of practice for audiologists to assess for and diagnose APD (AAA, 2004; ASHA, 2007). The current scope of practice for speech-language pathologists does not specifically detail their role in the diagnosis and treatment of APD (ASHA, 2007). However, recent survey data from Towson University showed that many speech-language pathologists (SLPs) surveyed feel that they, as well as audiologists, psychologists, special educators, otolaryngologists, and classroom teachers, could screen for APD (Marczewski, 2013). As far as the diagnosis of APD, 96% of SLP respondents reported that an audiologist is qualified to make the actual diagnosis and 37% felt that speech pathologists are qualified to make the diagnosis. A small percentage (12%) of SLP respondents felt that a psychologist is qualified to diagnose APD. The majority of SLP respondents (99%) felt that SLPs are qualified to provide remedial therapy, while only 63% felt that audiologists are qualified to provide this therapy. Results of this survey also revealed that 57% of SLP respondents conduct APD screenings using classroom observations, the SCAN A/C, and "other" methods including the Test of Auditory Perceptual Skills (TAPS) and the Clinical Evaluation of Language Fundamentals (CELF). A quarter of SLP respondents reported administering APD diagnostic evaluations. Eighty-nine percent of speech-language pathologists surveyed used one to three of the commonly accepted tests of auditory processing such as speech in noise, frequency patterns, and competing sentences (Marczewski, 2013). Because these professionals are not typically in a setting with access to a controlled sound booth for testing, it can be assumed that this testing is not being conducted in the appropriate test environment by speech-language pathologists. Not only is diagnostic testing not covered under their scope of practice, they are likely not conducting any testing in a controlled environment and may not be able to conclusively diagnose APD as a result. While it is not within SLP's scope of practice to diagnose APD, screening for APD is appropriate for SLPs. Some assessment tools, such as the SCAN-C, may be utilized by speech-language pathologists to screen children for APD in a quiet therapy room (Emerson, Crandall, Seikel, & Chermak, 1997) in order to make the referral to an audiologist for thorough assessment and diagnosis.

Other areas of concern include the setting commonly used for intervention after APD has been diagnosed. Typically, this intervention is provided by SLPs in a "quiet" treatment room, classroom, or hospital room. These real-world settings are very different from the acoustically advantageous setting of the sound booth recommended for assessment. The effects of these unstable intervention environments on positive progress are unknown currently.

Transducer Attenuation Properties

Another area of inconsistency in APD assessment protocols is that of transducer used while testing. Research from the early 1990's stated that commonly used transducers at that time, supraaural and circumaural earphones, was inadequate to provide the necessary attenuation to achieve thresholds down to 0 dB HL in the test booth based on maximum permissible ambient noise levels (MPANLs) suggested by American National Standards Institute (ANSI) and International Organization for Standardization (ISO) (Frank & Wright, 1990; Franks, Engel & Themann, 1992). Frank and Wright (1990) showed that the TDH 49 supraaural earphones provided about 4.5 dB of attenuation from 125 to 500Hz and about 24 dB of attenuation from 3150 to 8000Hz. The same study revealed that the ER-3A insert earphones provided approximately 29 dB of attenuation from 125 to 1000Hz and as much as 41 dB from 3150 to 8000Hz (Frank & Wright, 1990). According to Frank and Wright (1990), of the four transducers tested in the test booth, the ER-3A insert earphones were the closest to suggested attenuation values at that time. However, the ER-3A insert earphones were reportedly fairly new technology and great variability was seen in the literature depending on the insertion technique and depth (Frank & Wright, 1990). While most research supported the use of insert earphones for testing because of the increase in attenuation of environmental noise, often in clinical and educational settings, supraaural earphones are used due to their convenience and ability to be reused with every patient or student. Many studies involving APD assessment and diagnosis cited using TDH 39, 49, or 50 supraaural headphones for the acoustic transducer (Bornstein, Wilson, & Cambron, 1994; Musiek, Chermak, Weihing, Zappulla, & Nagle, 2011; Musiek & Pinheiro, 1987; Neijenhuis, Snik, Priester, van Kordenoordt, & van den Broek, 2002).

Special Populations and Transducer/Environmental Effects on APD Assessment Results

Most studies cited the use of an acoustically controlled test booth environment when testing auditory processing disorders as recommended (AAA, 2010; ASHA, 2005; Boatman et al., 2006; Lewis et al., 2006; Musiek et al., 2011; Musiek & Pinheiro, 1987). Domitz and Schow (2000) cited the use of a quiet room provided in a school for administration of several tests of auditory processing ability. This scenario was also noted in several other studies including Lum and Zarafa (2010), Jerger and Martin (2006), and Emerson and colleagues (1997). Emerson et al. (1997) stated that screening procedures for APD may be "confounded by problems of test environment," as well as by comorbid disorders. Currently, little published research is available regarding the effects on test results when testing is completed in a less than ideal setting, such as a hospital bed, school classroom, or therapy room, which is not acoustically controlled. Emerson et al. (1997) looked at the effects of background noise versus controlled test environment on children being screened for APD using the SCAN. The acoustically controlled environment was an audiology test booth equipped with a GSI-61 audiometer and TDH-

39 supraaural earphones. The other test setting was a public school room using a portable audiometer and TDH-49 supraaural earphones (Emerson et al., 1997). Results of this study showed a common decrease in composite scores and standard scores on the Competing Words (CW), Filtered Words (FW) and Auditory Figure Ground (AFG) subtests of the SCAN (Emerson et al., 1997). Although this study assessed a small group of children, it suggested that differences may be caused by the amount of ambient noise in the test environment and supported the argument for accurate evaluation in a sound-treated environment. This particular study sparked a debate in the literature regarding how much ambient noise may actually impact the results on the SCAN (Keith, 1998).

In general, assessment or screening for APD conducted outside of the acoustically controlled sound booth setting is typically accompanied by some amount of uncontrolled ambient noise. While little is known currently about the effects of this ambient noise, it is believed that it can have a negative effect on the scores obtained for tests of auditory processing due to detraction of attention from the task at hand. This could be due to the potential for ambient noise to mask the auditory information in the test stimuli. An example of this would be low-frequency environmental noise masking the speech stimuli during the low-pass filtered speech test. If the noise is low frequency, it can mask the low frequency speech information in the test stimuli; in a low pass filtered speech test, there is no high frequency information available to supplement the masked low frequencies. This can make the task more difficult than normal and potentially alters scores on this test. In addition to a decrease in the accuracy of assessment results obtained in these less than ideal listening environments, these detractions in attention and interference with auditory stimuli could affect the efficacy of and the ability to provide auditory training therapies or assess progress with treatment in similar type settings. As much environmental noise is centered in the lower frequency range and supraaural earphones have been shown to poorly attenuate lower frequencies, the use of these earphones in the presence of ambient noise would likely be susceptible to interference during APD assessment.

Noise and Cognition. Various studies document the adverse effects of environmental noise on cognition. Noise is defined differently than sound, as sound is considered a stimulus of interest where noise is defined as bothersome and unwanted (Cohen & Weinstein, 1981). Sources of noise can include extraneous conversations, heating and ventilation systems, machinery running, aircraft overhead, near-by road traffic, and, in some cases, music. Riley and McGregor (2012) assessed the ability of children to learn novel words in varying environments. It was found that the children exposed to the novel words in a quiet environment were more successful at learning to produce the new words than those exposed to the same novel words in the presence of broadband white noise at a +8dB signal to noise ratio (SNR). The authors believed that the presence of environmental noise is detrimental to the expressive language growth of children (Riley & McGregor, 2012). Szalma and Hancock (2011) discussed several effects of noise that may contribute to stress on humans. These effects included decreasing in working memory, impairing information processing accuracy, increasing mental workload and decreasing the focus available for necessary cognitive processes. These studies supported the idea that the presence of noise in the environment has detrimental effects on the human ability to focus and cognitively process a signal of interest, especially when the signal of interest is also an auditory stimulus. It was believed that these detrimental effects would also be seen in the current study.

Energetic Masking. Energetic masking is described as a target stimuli's audibility reduced by a distracting noise due to signal blending in the peripheral auditory system (Mattys, Brooks, & Cooke, 2009). While speech is generally a broad-frequency stimulus, altering the acoustic properties through techniques such as filtering out certain frequencies above or below a cut-off, heightens the impact of the lower frequency ambient noise. Mattys and colleagues (2009) pointed out that energetic masking effectiveness is dependent on this relationship between the target stimulus and the distractor. This idea of energetic masking becomes important during APD assessment because much of the stimulus is altered to make perception of the stimulus more difficult. Additional noise in the test environment could unintentionally provide a source of energetic masking of the target stimuli, thus altering the outcomes of testing.

APD Assessment

Assessment for APD encompasses the areas of monaural low redundancy, temporal processing, dichotic listening, tasks of localization and lateralization, and auditory discrimination tasks (AAA, 2010). Each of these areas can be examined in a variety of ways due to the number of commercially available tests for each area of processing. For example, multiple versions of the frequency pattern test, dichotic listening tasks, and auditory discrimination tasks are commercially available from different corporations. Monaural low redundancy tasks include speech stimuli filtered using a high, low, or band pass filter or compressed and reverberated speech, and are available commercially.

Frequency Pattern Test. One sub-category of auditory processing assessment is temporal processing. Temporal processing includes temporal masking, temporal resolution, and temporal sequencing (AAA, 2010). The temporal sequencing category includes tests of duration patterning and frequency (pitch) patterning (AAA, 2010). For these tasks, the patient is asked to describe duration-related or frequency-related (or pitch-related) changes in the auditory stimuli. The frequency pattern test specifically has a sensitivity and specificity of 90% and the greatest overall sensitivity, specificity, and efficiency compared to some other commonly used behavioral APD tests (Musiek et al., 2011).

Filtered Speech. Filtered speech is a monaural low redundancy task that assesses auditory closure abilities. In filtered speech tests, the spectrum of sound energy for a stimulus is passed through an acoustic filter, resulting in the presentation of a stimulus with a limited frequency range to the participant's ears. Frequency filtering mechanisms include high-pass filtering, low-pass filtering, and band-pass filtering. One example of this type of test uses two lists of the NU-6 words, which were spoken, recorded, digitized, and altered using a cutoff frequency of 1500 Hz for the low-pass condition and 2100 Hz for the high-pass filtered condition (Bornstein et al., 1994; VA CD disc 2.0). The current research will focus on words presented in the low-pass filtered condition due to the propensity of environmental noise to be focused in the low frequency region. Musiek and colleagues (2011) found the overall sensitivity of this test to be 72% while the specificity was 63%. When paired in a battery, the frequency pattern and filtered speech tests yielded a sensitivity of 50%, a specificity of 100%, and an overall efficiency of 80% (Musiek et al., 2011). As the name of the category of tests would imply, these lists are administered monaurally with 25-50 words presented to each ear in the desired filtered conditions.

Speech in Noise. Patients with APD are commonly reported to struggle in the presence of background noise (AAA, 2010; ASHA, 2005; Anthony, Kleinow, & Bobiak, 2009; Dawes & Bishop, 2009; Emanuel, Ficca, & Korczak, 2011; Lagace, Jutras, & Gagne, 2010; Lagace, Jutras, Giguere, & Gagne, 2011). Several tests are available commercially to assess this difficulty understanding in the presence of noise including the Listening in Spatialized Noise (LISN) test, Auditory Figure Ground (AFG) subtests of the SCAN, the Synthetic Sentence Identification (SSI) test, and the Speech Perception in Noise (SPIN) test (Lagace et al., 2010). These tests are designed to degrade the speech signal of interest by incorporating speech spectrum noise or multi-talker babble into the background. The subject is asked to repeat the signal of interest while ignoring the interfering background signal. However, many of these commercially available tests are complicated by complex speaker set up, as is the case with the LISN, heavy linguistic load, context clues provided by linguistically rich stimuli, and difficult to interpret scoring, such as with the SNR loss calculated with the SPIN. Another option for assessing speech perception difficulties in noise is to present commonly used recorded word lists, such as the NU-6 or CID W-22, in the presence of multi-talker babble. While the SNR of the word list to the multi-talker babble may vary, research suggests the appropriateness of a +8dB SNR to obtain a 50% recognition threshold for a word list presentation level of 45 or 65 dBHL (Beattie, 1989). McArdle, Wilson, and Burks (2005) also suggest that adults with normal hearing require a +2-6 dB SNR to achieve a 50% correct performance on the same discrimination task. Participants would be expected to perform even better in a +8dB SNR.

The Central Institute for the Deaf (CID) W-22 word lists (4) are 50-word lists phonetically balanced to represent words commonly encountered in daily living (Hirsch et al., 1952; Gelfand, 2001; Brandy, 2002). The list is considered suitable for testing persons over the age of eight (Gelfand, 2001). Typical speech recognition performance is expected to be 90-100% for normal hearing patients in an ideal listening environment (Gelfand, 2001). Moderate decreases in performance are expected in the presence of multitalker babble at +8dB SNR for this population. The presence of additional uncontrolled environmental noise will inherently have adverse compounding effects on subject performance on these tests by nature of further degrading the signal of interest.

Summary

Assessment for APD is complex and involves the examination of many processes through multiple avenues of assessment. These assessments can include behavioral tests, such as frequency pattern, low pass filtered speech, or speech in noise tests, electrophysiologic measures, such as ABR and AMLR, as well as thorough and detailed patient history and interview (AAA, 2010). While many of these tests are standardized in their administrative norms, application to new populations and in new settings creates new challenges and questions regarding best practices. Other factors not clearly defined and regulated include the type of transducer used for test administration as well as the effects of test environment on test outcomes.

Statement of Purpose

With the discrepancies noted in the existing literature regarding the effects of ambient noise on performance on tests of auditory processing, the purpose of the current study is to assess the impact of ambient noise in combination with supra-aural headphones on the performance or normal hearing adults on three common assessments of auditory processing. Assessments will include a frequency pattern test, low-pass filtered speech, and the CID W-22 presented in +8 dB multi-talker babble. This study aims to increase the current research available on effects of ambient noise on tests of auditory processing in the typically-developing, normal-hearing adult population in order to examine special populations in the future.

CHAPTER 3

Methods and Materials

Participants

The population for the current study included males and females age eighteen to forty years. To be considered for inclusion in the research, participants were typically developing with no history of brain lesions, cognitive disabilities, or other developmental differences by participant report. Inclusion criteria included: 1) normal hearing thresholds less than or equal to 25 dB HL at 250, 500, 1000, 2000, 4000, and 8000 Hz bilaterally, assessed via screening at 25 dB HL (Goodman, 1965); 2) normal middle ear function as indicated by type "A" tympanograms bilaterally upon screening, including an ear canal volume of 0.6-1.5 cm^3, static admittance of 0.3-1.4 cm^3, and a peak pressure of -150 to 100 daPa; 3) normal findings upon otoscopic inspection, including limited cerumen in the ear canals, no foreign bodies in the ear canals, and tympanic membranes that appeared intact; and 4) English as the primary spoken language.

Materials

Testing was administered using a two channel Grason-Stadler (GSI) 61 audiometer in a sound treated booth using TDH-50P supraaural earphones with Telephonics cushions for use with TDH earphones. The frequency pattern and low-pass filtered speech tests of auditory processing were administered from the Audiology Illustratred CD played using a Sony CD player routed through the external port of the audiometer. The speech in noise test was administered from an Auditec CD using the W-

22 word list in the presence of 20-speaker multitalker babble at +8dB SNR routed through the audiometer in a similar fashion.

Procedures

As the project was approved by the Towson University Institutional Review Board (protocol number: 11-A050), all participants reviewed and signed an informed consent form. Testing lasted approximately one hour per participant. The screening measures to determine inclusion began each session. The order of the individual tests was randomized for each participant for each condition. The order of the test condition, noisy vs. quiet environment, was also randomized for each participant. Test sequence and results were recorded on an organized score sheet to maintain flow of the test process for efficiency.

Frequency Pattern Test. According to Musiek (1994), the frequency pattern test is typically administered monaurally using some type of earphones and the participant is asked to describe the pattern of three 150-msec tones heard in terms of "high" (1122 Hz) and "low" (880 Hz) (Musiek, 1994). An example of a participant response is "high, high, low" indicating that the participant heard two 1122 Hz tones followed by one 880 Hz tone. Normative data for this assessment in typically developing, normal hearing individuals indicates a percent correct cutoff score of 78% or better for each ear individually (Musiek, 1994). Typically, 30 frequency pattern series are presented to each ear monaurally for a total of 60 pattern series in one test administration (Musiek, 1994). Stimulus for this test is usually presented 50 dB HL to ensure ability to hear the stimuli (Musiek, 2002). One 30-word list was presented to each ear in each condition for this study. The first three patterns on the list were used to practice the test and then the track was restarted and scoring began.

Low Pass Filtered Speech. According to Bornstein and colleagues (1994), the low pass filtered speech can be administered in a monaural or binaural condition using any type of earphones. In this study, the participant was asked to repeat the NU-6 word they heard. A presentation level of 50 dB HL was used. Normative data for this assessment in typically developing, normal hearing individuals indicates a percent correct cutoff score of 76% or better for each ear individually when the frequency cutoff of the low pass filter is at 1500 Hz (Bornstein et al., 1994). One 50-word list was presented to one ear in each condition for this task. The ear selected for each participant was randomized. The same ear was used for each condition.

Speech in Noise. The CID W-22 spondee word lists with multitalker babble was administered in a binaural fashion with one list presented in each condition. Lists presented (1-4) were varied among participants to eliminate list effects. The participant was asked to repeat the W-22 word they heard through the multitalker babble. A speech presentation level of 50 dB HL was used with a +8 dB SNR for the multitalker babble. One 50 word W-22 list was administered binaurally in each condition.

Environmental Alterations

Environmental alterations were made to the ideal test administration environment to simulate a less than ideal listening environment. A recording of typical noise recorded in a speech language pathologist office in a school was played through the soundfield speakers set up in the sound booth. More information on this recording follows in the section titled "Description of Environmental Noise Sample." The participant was given a brief break following testing in the first condition. Once returning from the break, the participant was given the same instructions as previously given and the tests were re-administered in the second test condition.

Description of Environmental Noise Sample

Using the BlueFire application for the iPad, a school-based SLP made a recording of environmental noise in her office during a typical school day. The recording was made during a time that no students were present in her office for therapy in order to maintain confidentiality and simulate the typical listening environment in the office. The SLP was instructed to set the microphone gain within the app to 18 dB and use the default microphone on the iPad. She was asked to obtain a clip approximately 30 minutes in length and save the recording as an .AIFF file. This sample was emailed to the researchers, converted to a .WAV file, and burned onto a CD for use in the present study. A 50 dBA, 1000 Hz tone was recorded using identical settings to the noise recording for use as a calibration tone for the noise track. The intensity of this tone was verified using a calibrated sound level meter. This calibration tone was then used to set the output for the soundfield speakers in the sound booth. Upon calibration of the soundfield, the peak and average output of the environmental noise sample was found and is detailed in the following table by full octave frequency bands. A screenshot of these measurements is included in appendix A.

Table 1

Peak and Average Output per Octave Band of Noise Recording in the Sound Field

Frequency (Hz)	31	63	125	250	500	1000	2000	4000	8000	16000
Peak	19.6	12.8	44.6	62.0	70.9	70.9	65.1	54.6	39.1	26.8
Average	8.6	4.0	20.6	45.3	49.5	57.0	53.1	32.6	25.0	22.4

The speakers were placed at four points, at 0 degrees azimuth, 90 degrees azimuth, 180 degrees azimuth, and 270 degrees azimuth, around a chair for the participant centered in the sound booth. The speakers were placed on stands 66 centimeters from the patient, at an elevation of 99 centimeters from the floor, the approximate level of the head when the participant is seated in the chair. The noise sample track was burned onto a compact disc (CD) and played using a CD player. The noise was then routed through a power amplifier and to the four speakers. All setup and wiring was completed and verified by the researchers. Appendix B is a screenshot of the Adobe Audition frequency analysis of the noise sample showing the propensity of the noise on the sample below 1000Hz. Appendix C is a screenshot of the spectral view of the energy in the noise sample upon analysis using Adobe Audition.

Statistical Analyses

Upon completion of data collection, data was grouped for each test in each test condition. Once data across subjects were compiled for each condition and test, descriptive statistics including mean, standard deviation, and variance were calculated. Paired t-tests were performed to compare the quiet and noise condition of each test to assess for statistically significant changes in the noise condition. Once these analyses were complete, a repeated measures multiple analysis of variance (MANOVA) was performed to examine the effect of environmental noise on test scores across the tests and determine if there was any interaction between the tests and the environmental noise.

CHAPTER 4

Results

A total of 15 females and 10 males ranging in age from 19 to 40 years completed the test battery. Data were converted from raw scores to percent correct data for analysis. Group means and standard deviations are detailed in Table 2.

Table 2

Descriptive Statistics for Scores (as percent correct) for Each Test in Each Condition

Test Name	Condition	Mean Score	Standard Deviation	Number of Participants
Filtered Speech	Quiet	.737	.156	25
	Noise	.664	.192	25
Frequency Pattern Right	Quiet	.933	.081	25
	Noise	.936	.076	25
Frequency Pattern Left	Quiet	.931	.102	25
	Noise	.937	.059	25
Speech in Noise	Quiet	.861	.062	25
	Noise	.826	.141	25

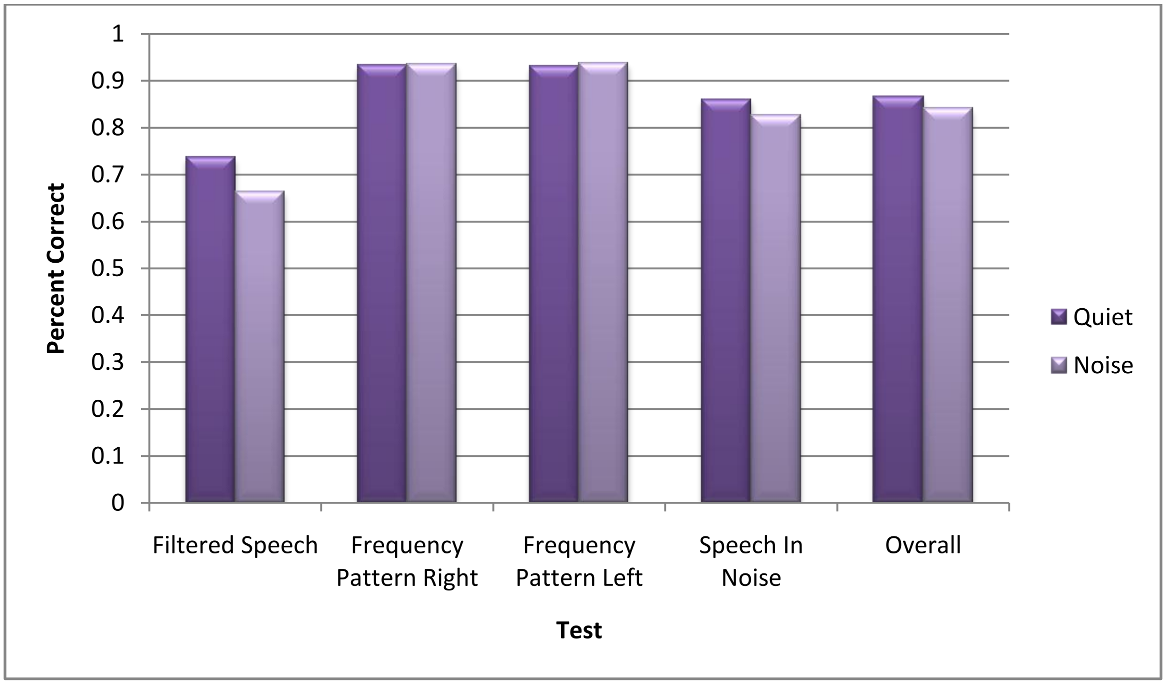


Figure 1. Comparison of overall performance between conditions for each test. This is a graphical depiction comparing group means between conditions on each test. The 'overall' columns combines mean data across all tests for each condition to show a minimal difference overall between the two conditions.

No effects of ear or gender were found, so all data were collapsed within the groups. Paired samples t-tests were conducted to assess for statistically significant changes between the quiet and noise conditions for each test. No statistically significant change ($p<.05$) between conditions was noted for any of the tests (filtered speech $p=.091$, frequency pattern right $p=.836$, frequency pattern left $p=.691$, speech in noise $p=.139$). A visual depiction of the data can be found in Figure 1.Overall condition means are also compared in this figure.

Correlations were calculated between scores in quiet and noise for each test. Statistically significant positive correlations between conditions were noted for frequency patterns in both ears (right $r=.673$, $p=.000$; left $r=.587$, $p=.002$) and speech in noise ($r=.492$, $p=.013$), consistent with similar distribution of scores for participants with the introduction of environmental noise. No trend toward correlation is noted for the filtered speech tests with the introduction of environmental noise, consistent with little consistency in scores between conditions for individual participants. While the group means displayed in Figure 1 (above) may suggest consistent distribution of scores between conditions for filtered speech, when scores for individual participants were examined, differences were noted between conditions, leading to lesser correlation. Detailed results from these analyses are shown in Table 3.

Table 3

Correlation and t-test Statistics

Test	Correlation Coefficient (r)	Significance of Correlation (p)	Significance of t-test (p)
Filtered Speech	.091	.665	.090
Frequency Pattern Right	.673	**.001**	.836
Frequency Pattern Left	.587	**.002**	.691
Speech in Noise	.492	**.013**	.139

Note. (bolded).Statistical significance if $p<.05$. Positive correlation reached statistical significance for the frequency pattern tests for both ears and the speech in noise test.

To assess for an overall interaction between test and condition, a Multiple Analysis of Variance (MANOVA) was conducted. It yielded no significant interaction effect ($F=1.244$; $p=.295$). The MANOVA also revealed no overall effect of the noise on performance on the behavior assessment measures.

CHAPTER 5

Discussion

The current study was designed to examine the impact of ambient environmental noise combined with supra-aural headphones on performance on three behavioral auditory processing assessments. Although clinical and anecdotal experience indicates that APD testing is being performed in environments with ambient noise, few studies have examined the potential effects of this noise. The current study assessed performance of 25 normal hearing, typically developing adults on three APD tests in an ideal test booth environment and a simulated school SLP office. While some participants showed individual differences on some measures between conditions, mean group data showed no overall noise effects on test performance. Paired samples t-tests that assessed changes in performance between test conditions yielded no significant results. Between-conditions analysis revealed positive correlations between performance in quiet and in noise on the frequency pattern tests for both ears as well as the speech in noise task. The results of the filtered speech test analysis showed no correlation between conditions, suggesting that the introduction of noise into the environment may alter the complexity of the task and/or the auditory processes involved in the task when noise is introduced, unlike the other two tests given in this study. However, overall between-conditions analysis revealed no statistically significant impact of the noise on behavioral auditory processing performance in this sample, and no interaction between noise effects and individual tests.

It was hypothesized that the current research would show a difference in performance with the introduction of environmental noise. The environmental noise was expected to be most detrimental to the speech in noise and filtered speech tasks. This was due to the compounding effect of the environmental noise on the competing speech during the speech in noise task and the concentration of noise in the lower frequency region, impacting the ability to clearly understand the words presented during the filtered speech task. Given this, the lack of any significant difference on the speech in noise test was an unexpected result. A trend toward a significant difference between quiet and noise conditions was seen for the filtered speech test, and this may have become significant with a larger sample. It was suspected that the frequency pattern tests would be least susceptible to the introduction of environmental noise due to ceiling effects, and this was in fact the case.

Emerson and colleagues (1997) also examined the effects of an uncontrolled acoustic environment when they compared scores on several subtests of the SCAN in quiet versus noisy test environments. Their results were not consistent with those obtained in the current study. The results of that study showed a common decrease in composite scores and standard scores on the auditory figure ground subtest of the SCAN among a small sample of children (Emerson et al., 1997). However, several differences exist between the current research and that of Emerson and colleagues (1997). For example, the previous research was conducted using pediatric participants (N=6) compared to adult participants (N=25) in the current study. Due to the small sample size of Emerson et al. (1997), parametric examination of results was not completed; therefore, statistical significance could not be determined. The sample assessed by Emerson and colleagues (1997) was also heavily weighted with females (N=5) to males (N=1) compared to the current research comprised of 15 females and 10 males. Also, Emerson et al. (1997) administered subtests of a common screening measure compared to the diagnostic assessment tools used in the current study. Another difference between the two experiments is that Emerson and colleagues (1997) conducted their measures in an actual school room and a sound booth, whereas the current study merely simulated a school's SLP office in the sound field of an acoustically controlled sound booth. Emerson and colleagues (1997) also assessed the children two separate times, one week apart, once in a school and once in an acoustically controlled sound booth. Because of the time elapsed between test sessions, some variation in performance among the children could be accounted for by test-retest reliability. Participants of the current research were tested twice in the same day, in the sound booth, once with the noise recording playing and once without, using different forms of the same tests. It is unclear if the same or different test versions were administered during the different test sessions or if condition was varied for participants for Emerson and colleagues (1997). The plethora of differences between methods combined with the difference in participant age and the lack of thorough statistical analysis to determine significance by Emerson and colleagues (1997) are likely responsible for the lack of agreement of findings between the two studies.

Results of the current study do not align with previous research regarding the effects of environmental noise and cognition. Szalma and Hancock (2011) and Riley and McGregor (2012) reported that the presence of noise in the environment had detrimental effects on the human ability to focus and cognitively process a signal of interest. These findings are not supported by the current research in which participant's performance experienced little impact from the introduction of environmental noise into the soundfield. Riley and McGregor (2012) assessed the ability to learn novel words in children (N=31) in quiet and in the presence of white noise. While the sample size was comparable to the current research, the age range and type of environmental alterations applied were vastly different. These methodological differences likely contribute to the difference in outcomes for the two studies. Szalma and Hancock (2011) reviewed much of the current research on the effects of noise on cognition and identified effects on working memory, information processing accuracy, mental workload, and focus available for necessary cognitive processes. These effects were not seen in the current research; however differences in the type of noise and the overall SNR may have contributed to these differences.

Greater research into the effects of energetic masking on these tests for auditory processing is warranted. It is likely that many of these tests with altered speech stimuli, such as filtered, compressed, or reverberated speech would be susceptible to the effects of energetic masking. This is because many of these changes in the spectral characteristics blur what sets speech apart from noise, thus increasing the likelihood of energetic masking by competing distractions in the environment. Wilson, Trivette, Williams, and Watts (2012) offered preliminary investigation into the effects of masking, both energetic and informational, on the Words-In-Noise (WIN) test, one type of auditory processing assessment. This phenomenon could account for some of the differences seen in the low-pass filtered speech results when compared to the speech in noise and frequency pattern tests. The propensity of steady state noise in the environmental noise sample was isolated between 200 and 300Hz throughout the sample. Because the speech stimuli for the low-pass filtered speech was concentrated below 1500Hz, it is likely that this steady state noise from 200 to 300Hz throughout the sample could have some energetic masking effects on the signal of interest and participant performance.

Implications for Clinical Practice

The results of the current study have important implications for clinical practice. First, these results suggest that normal-hearing, typically developing adults with no auditory complaints experience little detriment to auditory processing abilities by ambient environmental noise. A peak output of 70.5 dB SPL was found for the noise sample used in this study. This suggests that this adult population is able to adequately filter out environmental noise to focus on the auditory processing tasks assessed. However, the filtered speech task seems to be different than the other two tasks when conditions are compared. While statistical significance was not reached on the paired samples t-test for the filtered speech task, a trend toward significance in conjunction with a lack of correlation between scores in quiet vs. noise conditions suggests that this task may be more impacted by ambient environmental noise than its counterparts in the current study. This trend should be investigated further to conclusively determine the effects of ambient environmental noise on behavioral auditory processing outcomes. While the current research suggests that environmental noise has little impact on results, evidence supports the use of an acoustically controlled test environment for the administration of behavioral auditory processing assessment to further avoid possible effects of environmental noise (AAA, 2010; ASHA, 2005; Boatman et al., 2006; Lewis, et al., 2006; Musiek, et al., 2011; Musiek & Pinheiro, 1987) and should be followed as best practice. The current research supports the notion that adults assessed in an uncontrolled environment when an acoustically controlled environment is unavailable will yield similar results. Also, clinicians should not assume that the results of the current study hold true for all screening and diagnostic measures of auditory processing abilities. For example, Emerson and colleagues (1997) suggests that subtests of the SCAN screening measure are susceptible to environmental noise. The current research should not be applied to the SCAN subtests nor the pediatric population, as these two variables were not investigated in the present study.

Limitations of Current Research

Several limitations of the current study should be considered. First, the environmental noise sample collected for the current study was not the most applicable for the population tested. Rarely would adults be tested in an environment such as a speech language pathologist's office. A sample of hospital noise may have been more appropriate, however was not possible due to privacy standards.

Another limiting factor of the current study was the recording hum noted on the environmental noise recording likely due to the method of recording. This hum was not able to be filtered out effectively prior to testing. While it appears to have had no effect on participant performance, it was an artifact in the recording not native to the target environment. The presence of this hum in turn increased the overall noise level and consistency of the ambient noise. While this hum may have been considered a weakness early on, the lack of an overall effect of the noise even with this additional noise may strengthen the overall results.

Also, the current research only investigated the effects of environmental noise on three diagnostic tests: low-pass filtered speech, frequency pattern, and speech in noise. The effects of environmental noise on other behavioral tests of auditory processing, such as dichotic tests, duration pattern, and gap detection tests, could not be determined based on the current research.

Finally, the speech in noise test and the frequency pattern test were susceptible to ceiling effects, as many participants scored over 80% in both conditions on the speech in noise task and 90% in both conditions on the frequency pattern test. With scores so high in the noise condition, little room was left for improvement in the quiet condition; hence a ceiling effect was experienced. Bellis and Ross (2011) experienced similar limitations due to ceiling effects when reviewing performance on several APD assessment measures and their corresponding visual analogs. Due to a lack of variation among already high performers, statistical analysis was not possible for some of the measures.

Future Research

Future research should expand upon current research to examine the effects of noise on other behavioral assessments of APD including gaps in noise tests, duration patterns, and dichotic listening tasks. Also, future researchers should work to eliminate recording artifact if the noise condition is to be simulated as it was for this study or perform testing in the non-controlled environment. More assessment of the pediatric population to deepen the evidence pool is also necessary. Research should also investigate the effects of non-controlled test environment while testing those with compromised auditory or central nervous systems, such as those with Multiple Sclerosis

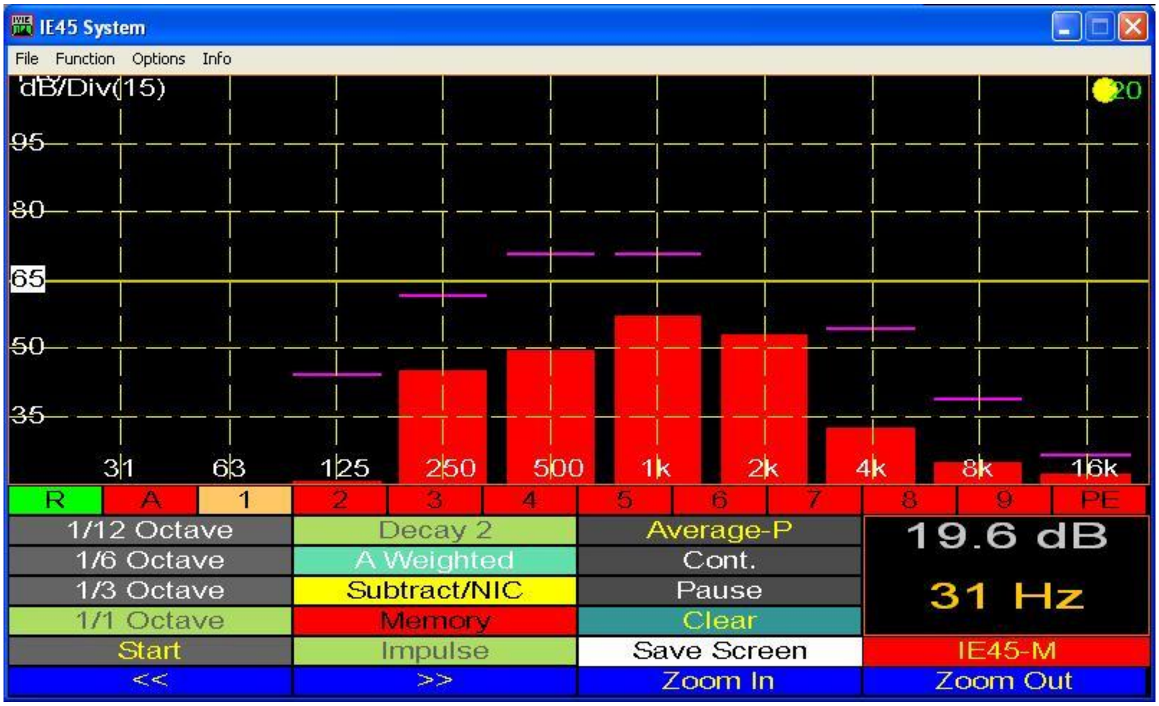
(MS), deficits of the temporal lobe, or other neurological ailments. All of these areas of future research would serve to expand upon the dearth of evidence currently available on the effects of environmental noise on behavioral APD assessment outcomes.

Conclusion

APD is a very complex disorder affecting various levels of auditory functioning. The knowledge base on auditory processing and its assessment techniques is challenged more and more every day by more complex demands on assessment. There is currently a dearth of literature available to guide clinicians in challenging situations such as when testing is needed outside of a controlled test environment. The current research broadened the current literary base for behavioral assessment for APD outside of the controlled sound booth scenario. While the current evidence supports using the frequency pattern, low-pass filtered speech, and speech in noise test in an uncontrolled test environment with no significant impact on performance, further research is needed to elucidate the many nuances of behavioral measures of auditory processing and the many populations susceptible to APD.

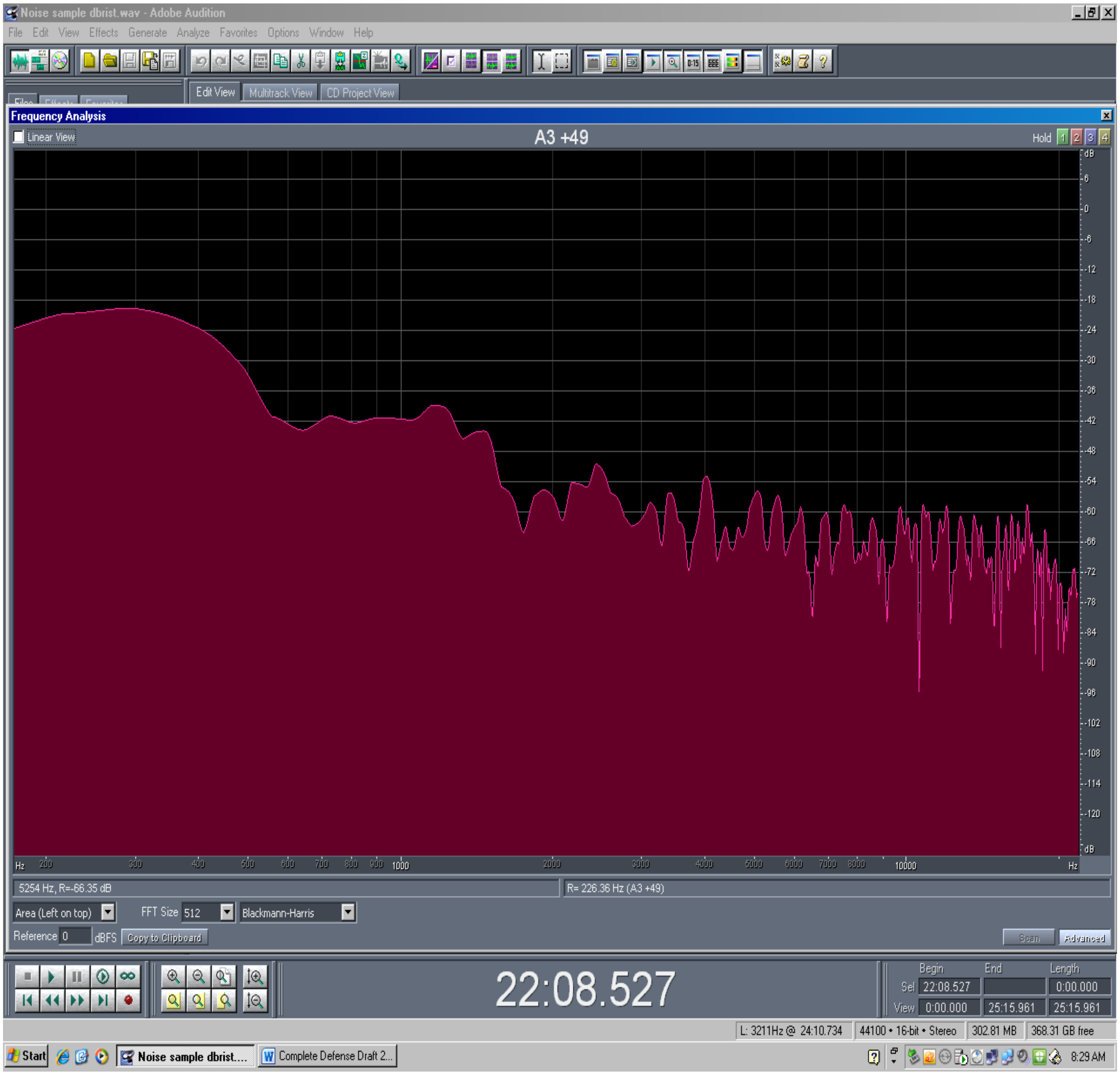
Appendix A

Screenshot of Peak and Average Output Measurements



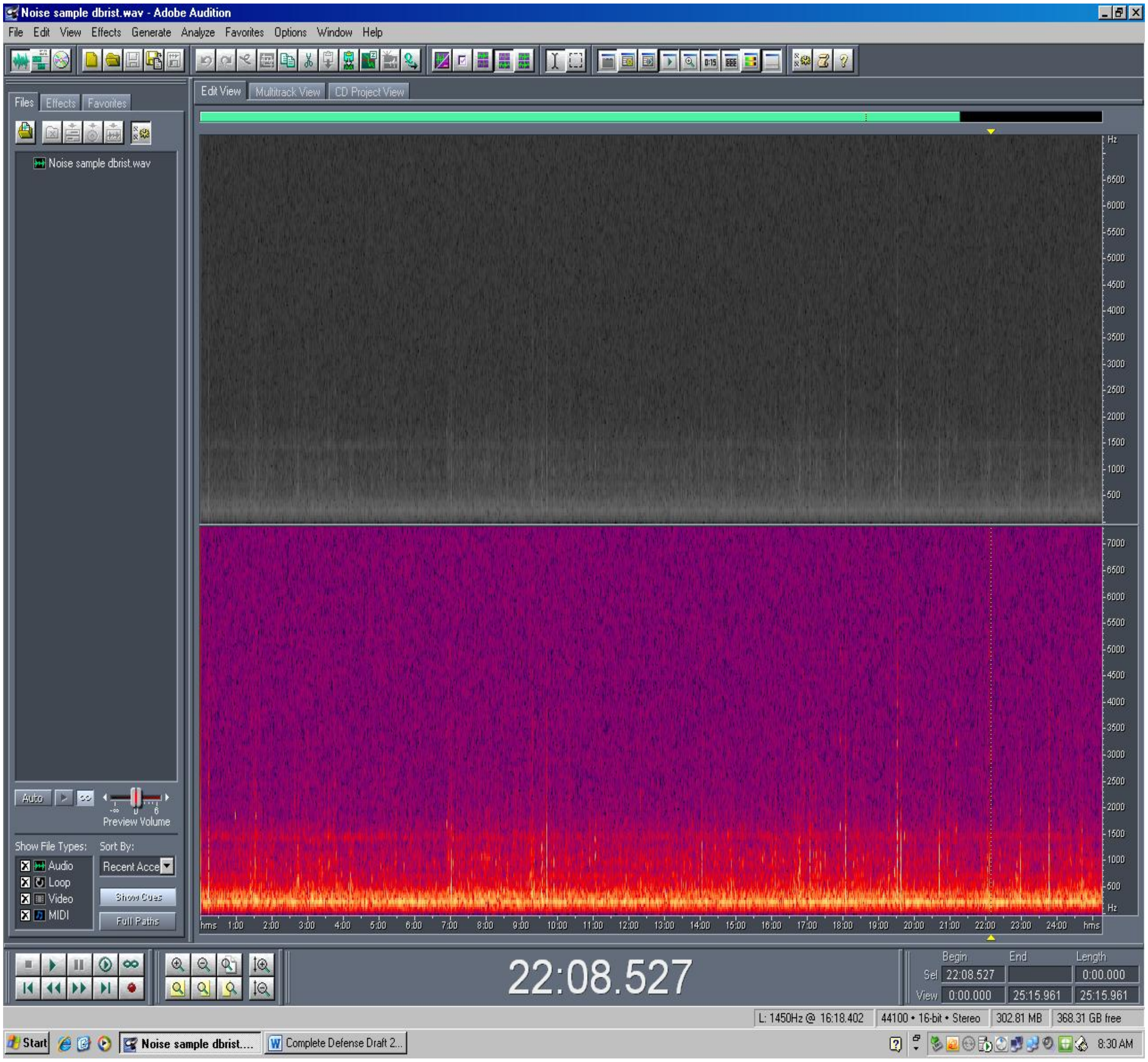
Appendix B

Screenshot of Adobe Audition Frequency Analysis



Appendix C

Screenshot of Adobe Audition Spectral View



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CURRICULUM VITAE

NAME: Deirdre Courtney

PERMANENT ADDRESS:
62 Vienna Court
Frederick, MD 21702

EMAIL:
Dbrist1@students.towson.edu

PROGRAM OF STUDY:
Audiology

DEGREE AND DATE TO BE CONFERRED:
Doctor of Audiology, May 2014

COLLEGIATE INSTITUTIONS ATTENDED:
Au.D. Towson University, 2014
Major: Audiology

B.S. Towson University, 2010
Major: Speech-Language Pathology and Audiology

A.A.T. Carroll Community College, 2007
Major: Elementary Education

POSITIONS HELD:
Audiology Extern
Central ENT Consultants, Hagerstown, MD
June, 2013- May, 2014