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EFFECT OF AUDITORY PROCESSING ON THE PREFERENCE OF MONAURAL AMPLIFICATION FOR ADULTS WITH SYMMETRICAL HEARING LOSS

By

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A Capstone Project submitted in partial fulfillment of the requirements for the degree of:

Doctorate of Audiology

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ABSTRACT: The purpose of this capstone project is to determine if subjects with symmetrical hearing loss who prefer a monaural hearing aid fit to a binaural hearing aid fit may demonstrate an auditory processing disorder causing them to experience binaural interference when fit binaurally.

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INTRODUCTION AND REVIEW OF THE LITERATURE

An auditory processing disorder (APD) may be defined as "difficulties in the perceptual processing of auditory information in the central nervous system as demonstrated by poor performance in one or more of the auditory processing skills" (ASHA, 2005). Auditory processing includes the auditory mechanisms that motivate: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition including temporal resolution, temporal masking, temporal integration, and temporal ordering; auditory performance decrements with competing acoustic signals; and auditory performance decrements with degraded acoustic signals. There are many higher order cognitive-communicative and/or language related functions such as phonological awareness, attention to and memory for auditory information, auditory synthesis, comprehension and interpretation of auditorily presented information and similar skills that may depend on or be a part of the intact central auditory function. However, they are not typically included in the agreed upon definition of auditory processing (ASHA, 2005). It has also been suggested that auditory processing disorder should be viewed as a "deficit in neural processing of auditory stimuli that may coexist with, but is not the result of, dysfunction in other modalities" (ASHA, 2005).

There are numerous tests used to determine if a patient has APD. The Staggered Spondaic Word (SSW) test is used to quantify central auditory dysfunction. This is a dichotic listening task where different spondee words are presented to the two ears in a partially overlapping manner. This test can reveal when the auditory or auditory related pathways are involved in disorders of the brain and brainstem. The SSW test can identify various sites of lesion because of its sensitive nature and all of the processes that are involved (Katz, 1962, 1973, 1977). Another dichotic test is the Dichotic Digits Test (DDT), which is utilized to identify

lesions in the brainstem and corpus callosum (Musiek, 1983). With this test, the listener must identify different digits presented simultaneously to the two ears. Single, double, and triple digit versions maybe utilized. This test is less linguistically loaded than the SSW. The Duration Pattern Test (DPT) is a test of temporal ordering that is sensitive to cerebral lesions (Musiek, Baran, & Pinheiro, 1990). With this monaural task, the listener hears three tones of different duration and must correctly identify the temporal pattern. Although countless other tests exist, these three APD tests assess varying auditory skills and are resistant to peripheral hearing loss, making them ideal for use with adult and elderly patients (Bellis, 1996).

In the elderly, an increased difficulty is seen in the results of dichotic tests and speech understanding that goes beyond what may be expected for patients exhibiting a peripheral hearing impairment. Cooper and Gates (1991) studied 1026, sixty-four to ninety-three year old members of the Framingham Heart Study cohort using the Central Institute for the Deaf (CID) W-22 word lists in quiet. The CID W-22 word lists presented at high sensation levels are used to calculate a performance intensity – phonetically balanced word (PI-PB) rollover index (RI). The RI examines significant differences between word recognition scores (WRS) presented at traditional versus high intensity levels. The difference is calculated using the following equation: PB maximum-PB minimum/PB maximum. A significant difference of 0.45 or greater may indicate a central disorder. Jerger and Jerger (1971) measured speech recognition rollover for 41 subjects with cochlear hearing loss and 16 subjects with retrocochlear pathologies. When the difference was expressed as a proportion of the maximum score using a "rollover index" of 0.45 or greater, there was nearly complete separation between patients with cochlear hearing loss and those with VIII nerve pathology. The Synthetic Sentence Identification (SSI) Test with Ipsilateral Competing Message (SSI-ICM) was also employed with the Cooper and Gates (1991)

study. With the SSI-ICM, the listener must identify a synthetic sentence presented to the test ear while varying competition levels are presented to the same ear. Finally, the Staggered Spondaic Word (SSW) test was administered. In 1018 of the subjects, the authors were able to show the presence or absence of an auditory processing disorder with the results of at least one of three indices: the CID W-22 performance intensity function RI, the difference between maximum CID W-22 and SSI-ICM (0 dB message-to-competition ratio) scores, and performance in SSW scoring categories. The SSW categories examined were over-corrected, normal, and mildly, moderately, and severely abnormal. Normal patients or those with cochlear or conductive hearing loss usually exhibit over-corrected, normal, mildly abnormal, or over-corrected mildly abnormal categories. This could be a sign of no APD. A disorder high in the brainstem or auditory reception area is often marked with moderately or severely abnormal categories. The presence of APD was identified using the moderately and severely abnormal categories in combination with the over-corrected category. 22.6% of the subjects had abnormal results on at least one index. The authors concluded that auditory processing disorder occurs in 23% of people over the age of 63 (Cooper and Gates, 1991).

Stach et al. (1990) conducted a study using a clinical population of 700 patients, 100 patients from each of seven half-decades of life beginning at fifty years of age. From each of the age groups, the pure tone average (500, 1000, and 2000 Hz) was used to match subgroups of 20 subjects for hearing loss. They studied speech audiometric test results in order to assess the prevalence of central auditory disorder as a function of aging. A patient was considered to exhibit an auditory processing disorder if: (1) "rollover" of the PI-PB function for either a monosyllabic word test (PAL PB-50 word lists) or Synthetic Sentence Identification test (SSI) exceeded 20%, (2) the discrepancy between PB and SSI exceeded 20%, or (3) the absolute SSI

score was depressed to a level that could not be explained on the basis of the degree of peripheral sensitivity loss. Their results showed that seventy percent of patients over the age of sixty showed signs of an auditory processing disorder and that ninety-five percent of the patients over the age of eighty demonstrated an auditory processing disorder. The authors also found that the prevalence of auditory processing disorder still increased systematically with age despite the equivalent peripheral sensitivity loss across age groups.

Questions remain in the professional literature as to whether the added difficulty that the elderly experience is due to a specific aging process in the central auditory system or to an agerelated decline in cognitive functions. The speech audiometric deficits of the elderly parallel the deficits of individuals with known lesions of the central auditory system, indicating that auditory processing disorders may be present in the elderly. It is not difficult to associate speech audiometric deficits with auditory processing disorder in a young adult with a circumscribed brain lesion. In this type of case, a coexisting cognitive deficit may be ruled out as the reason for poor performance on speech audiometric tests based on the test findings that the central auditory system is involved and indications that the deficit is usually unilateral. That is, there is typically an asymmetry seen between ears when undergoing APD tasks that would not point to a cognitive deficit. In the elderly, however, there often is a coexisting cognitive deficit and often the difficulty with speech audiometric tasks is seen bilaterally. Because of this and often the lack of central lesion verification, the source of speech audiometric deficits in the elderly has been questioned as to whether they may not be explained by a cognitive deficit alone (Jerger, Manhurin, Pirozzolo, 1990a; Working Group on Speech Understanding and Aging, 1988).

One question that must be addressed is whether performance on speech audiometric tests places a heavy burden on cognitive processing. If it does, then there is no need to consider

auditory processing disorders to justify poor speech audiometric scores in the elderly because they could be attributed to cognitive deficits (Jerger et al., 1990a). However, if performance on speech audiometric tests doesn't rely on cognitive processing then if would be important to consider auditory processing disorders. It also has not been well documented that the elderly patient's ability to perform on speech audiometric tests is affected by the presence of a cognitive deficit (Jerger, Jerger, Oliver, & Pirozzolo, 1989).

Jerger et al. (1990a) evaluated a patient who exhibited both auditory and cognitive deficits due to encephalitis. The role of a cognitive deficit could be observed in its effect upon the auditory test results with this patient. An auditory processing disorder was revealed on the left side through speech audiometry. Neither the degree nor configuration of the hearing loss in the left ear could account for the speech audiometric deficits on the left (Jerger et al., 1990a; Jerger, et al., 1989). The absence of a deficit in speech audiometry findings on the right side strongly indicates that the cognitive deficit was not the cause of the speech audiometry deficit on the left side. In order to determine that the cognitive deficit was the cause of the speech audiometry deficit, then it would have to affect the speech audiometric scores for both ears. In this case, results for the right ear were within normal limits. This demonstrates that an auditory processing disorder can coexist with a cognitive deficit in the elderly and that it is possible to diagnose an auditory processing disorder in these patients (Jerger et al., 1990a).

It has been shown that peripheral hearing loss can cause an increased difficulty in the ability to recognize speech (van Rooij and Plomp, 1990). However, this difficulty appears to be intensified in some elderly persons beyond what is expected for their magnitude of hearing loss. It has been suggested that aging in the central pathways specific for hearing and processing in the brain stem and auditory cortex is the cause for the increase in difficulty. Separating the roles

involved in central auditory functions is complex; therefore, they aren't known in great detail (Hallgren, Larsby, Lyxell, Arlinger, 2001).

Elderly patients constitute the largest percentage of hearing aid users with approximately 61% of all hearing aids being sold to elderly patients. In the elderly hearing impaired population, only 10-21% use hearing aids. This could be due to many different factors. However, there is a growing amount of evidence pointing to an auditory processing disorder possibly playing a substantial role (Stach, Loiselle, Jerger, 1991).

In patients who present with a symmetrical hearing loss, it is logical to fit them with binaural hearing aids. Elimination of the head shadow effect, binaural summation, binaural squelch, and improved sound localization are the advantages obtained with a binaural hearing aid fit as opposed to a monaural fit. A pure tone presented monaurally must be six to ten decibels greater in intensity than the same pure tone presented binaurally for the stimuli to be judged to have equal loudness. Speech understanding scores have also been reported to be better using a binaural mode as compared to a monaural mode (Jerger, Silman, Lew, Chmiel, 1993).

It has been acknowledged that, despite the theoretical advantages of binaural amplification for individuals with bilateral hearing loss, there are some who prefer a monaural fitting. Poorer performance with a binaural hearing aid fitting could be the result of binaural interference, where the response from the poorer ear is interfering with the response from the better ear (Jerger et al., 1993). Hood and Prasher (1990) studied the effect of simulated bilateral cochlear impairment on speech understanding abilities. They showed that, when speech was asymmetrically distorted at the two ears of normal hearing listeners, the speech understanding score in response to binaural stimulation was poorer than the best monaural score.

Carter, Noe, and Wilson (2001) studied four subjects with symmetrical hearing loss who preferred monaural amplification to binaural amplification. Performance on Dichotic Digit tasks using free- and directed- recall response conditions was measured. In the free recall condition patients are to repeat back a series of stimuli presented to both ears in any order. Direct recall is when a series of stimuli must be repeated in a particular order. For example, stimuli presented to the left ear should be repeated first and then stimuli presented to the right ear should be repeated or perhaps even disregarded. In addition, performance with a monaural and binaural hearing aid fitting was measured using a speech in multitalker babble task. A left ear deficit that could not be explained by peripheral auditory findings or a cognitive-based deficit was detected with dichotic testing using a one-, two-, and three-pair dichotic digit task in free and directed-recall conditions. There was little difference between the binaurally aided and unaided word recognition scores when tested in the soundfield using a speech in multitalker babble paradigm. These results revealed that when listening in a competing babble background, the subjects weren't receiving significant benefit from being fit binaurally. When the subjects were aided binaurally and then monaurally in the left ear, their scores were poorer respectively than when aided monaurally in the right ear. This study was indicative of the presence of binaural interference. The authors concluded that a monaural hearing aid fitting in the dominant ear may lead to improved performance for listeners with an auditory based deficit in dichotic listening.

In cases where individuals with symmetrical hearing loss perform better with one hearing aid than with two, it is possible that the benefits of binaural amplification are canceled out by a binaural interference effect (Jerger, et al., 1993). Jerger et al. (1993) studied the binaural interference effect using four cases of elderly hearing impaired persons. Through the use of

aided speech recognition scores, they were able to show in these subjects that their performance was poorer when stimulated binaurally than when stimulated monaurally.

Binaural interference seems to be a primary reason that most elderly patients prefer monaural to binaural amplification. The relationship between dichotic performance and hearing aid use has been investigated in several studies. It may be helpful to include dichotic testing and other APD tests as part of the hearing aid fitting when elderly patients present with a symmetrical pure tone loss but poorer word recognition scores in one ear over the other. This is a consideration because "previous reports of unsuccessful use of binaural amplification in elderly listeners indicate an associated left ear deficit in dichotic listening performance" (Jerger, 1996; Chmiel et al., 1997). Given et al. (1998) found significant correlations between scores on a dichotic digits test and hearing aid satisfaction measured using the Profile of Hearing Aid Performance. In a group of fifty-eight elderly adult listeners, reduced scores on a Dichotic Digit Task were associated with reduced hearing aid satisfaction. Jerger et al. (1996) evaluated four conditions: no amplification, amplification using a conventional analog hearing aid, assistive listening device (ALD), and a combination of the hearing aid and ALD to determine listening preference in the elderly. Subgroups were formed for the hearing aid and ALD group; listeners in both of these groups demonstrated a left ear deficit on dichotic sentence materials. The authors were also able to establish that the level of improved signal to noise ratio needed may be a factor in deciding between an ALD or a hearing aid in the presence of an auditory based deficit in dichotic listening (Jerger et al., 1996; Carter et al., 2001).

Central auditory function has long been evaluated through the use of dichotic listening and other taxing listening tasks. It has been suggested that in the elderly, central auditory processing abilities are diminished and that this may affect performance with amplification,

successful implementation of other rehabilitation strategies, and overall communication function. Younger subjects typically outperform older subjects, demonstrating a significant age effect on dichotic tests (Hallgren et al., 2001). Jerger et al. (1995) studied this age-related asymmetry by simultaneously measuring both behavioral and electrophysiological responses to dichotic listening tasks. The authors were able to identify on a verbal task, an increase in a left-ear weakness and on a nonverbal task, a right-ear weakness. Rather than a change in the afferent auditory pathways, this points to a possible change in central auditory processing. It may indicate a decrease in the efficiency of interhemispheric transfer. If the decline in performance occurred with age, then the decline should be seen every time the ear is stimulated, no matter what the stimulus is. The main reason for this is perhaps a change in the efficiency of interhemispheric transfer across the corpus callosum. More specifically, Jerger et al. (1994) and Alden et al. (1997) illustrated that, compared to younger subjects; elderly subjects have more difficulty perceiving stimuli presented to the left ear in a situation where speech is being presented to both ears at the same time.

Signals from the ears must use contralateral pathways when dichotic speech tests are used because dichotic stimuli suppress the ipsilateral pathways. In most individuals the left hemisphere is the dominant hemisphere for processing of speech and language. A right ear advantage is therefore seen in many people on dichotic speech tests because signals from the right ear have direct access to the left hemisphere, whereas signals from the left ear have to be conveyed through the corpus callosum in order to reach the speech centers in the left hemisphere. This phenomenon may be particularly noticeable if there is damage to the corpus callosum (Hallgren et al., 2001).

The above studies have delved into many of the areas involved in auditory processing disorders, hearing aids, and the elderly. The authors of these studies have been able to show some of the connections between these topics such as: the effect of aging on auditory pathways, how this may lead to auditory processing disorders in the elderly, and the preference for a monaural hearing aid fit in the presence of a symmetrical hearing loss. There are still many questions that remain. One of these questions is if auditory processing disorders are a factor in the preference for a monaural hearing aid fitting in elderly subjects with a symmetrical hearing loss.

PURPOSE OF STUDY

The purpose of this capstone project is to determine if subjects with symmetrical hearing loss who prefer a monaural hearing aid fit to a binaural hearing aid fit may demonstrate an auditory processing disorder causing them to experience binaural interference when fit binaurally. If so, there may be implications toward the auditory test battery, hearing aid selection procedure, and subsequent user satisfaction.

RESEARCH QUESTIONS

- 1. Do subjects with symmetrical hearing loss who prefer monaural amplification demonstrate evidence of auditory processing disorder?
- 2. How does subject performance on auditory processing tasks compare with published normative data for these measures?
- 3. How does subject performance on auditory processing tasks compare with normative data collected for this study?
- 4. If present, is there a common dominant ear for all subjects?

METHODOLOGY

All methodologies were approved by the Washington University School of Medicine Human Studies Committee prior to initiating the investigation. All subjects signed an Informed Consent Form prior to undergoing his/her testing session. Please see Appendix A for a copy of the Informed Consent Form.

Subjects

Subjects are patients of the Division of Adult Audiology, Department of Otolaryngology, Washington University School of Medicine who have been fit binaurally with hearing aids and returned one hearing aid due to a preference for a monaural fit. They may have also exhibited a monaural preference via use of only one of two hearing aids (with no returns), with the hearing aid worn consistently in the same ear. Subjects were contacted via a letter and a follow up telephone call asking them to participate. Please see Appendix B for a copy of the letter that was sent to each patient, as well as the follow-up telephone script. Twelve potential subjects were sent a letter; two were returned. A follow up telephone call was made to 10 potential subjects, 6 of which declined the invitation to participate. Four subjects were tested including two males and two females. All subjects wore a hearing aid in the right ear at the time of testing. Subjects ranged in age from 53 to 83 years old with a mean age of 71 and a standard deviation (SD) of 14.73.

The inclusion criteria included:

- 1. 18 years of age or older
- 2. Symmetrical sensorineural hearing loss no greater than severe in degree
- 3. Wears one hearing aid, on either ear
- 4. Fit binaurally with hearing aids and prefer a monaural fit
- 5. No known reported history of cognitive deficits or neurological disorders

The exclusion criteria included:

- 1. Under 18 years of age
- 2. Asymmetrical hearing loss
- 3. Conductive or mixed hearing loss
- 4. Profound hearing loss
- 5. Known cognitive deficits or neurological disorders
- 6. ADD or ADHD
- 7. Current ear infection
- 8. Known lesions of the central pathway

Procedures

Testing was performed in the Program of Audiology and Communication Sciences (PACS) student laboratory at the Central Institute for the Deaf (CID) building. An otoscopic evaluation was completed prior to testing. A complete audiologic evaluation was performed: air conduction thresholds performed according to Hughson-Westlake procedures from 250 – 8000 Hz, bone conduction thresholds performed according to Hughson-Westlake procedures from 250 – 4000 Hz, speech recognition thresholds (SRT) obtained for each ear according to "standard of clinical care" procedures, and word recognition scores (WRS) in both quiet and noise using CID W-22 word lists. The WRS was obtained in each ear at +30 - +40 dB SL (re: SRT) in quiet and then in the presence of speech noise presented ipsilaterally at a 0 dB signal-to-noise ratio. Word discrimination was attained in quiet at 90 dB HL in each ear to ascertain presence of word discrimination rollover. The following quantification was made: PB Maximum – PB Minimum /PB Maximum. If this value is greater than or equal to 0.45, a central pathology may be indicated. (Jerger and Jerger, 1971)

The Grason-Stadler 61 audiometer was used for the audiometric testing and for routing the auditory processing tests and other recorded speech stimuli from the Insignia compact disc

player to TDH-50 headphones. Bone conduction testing was completed using the Radio ear B-71 bone conduction oscillator. All equipment is calibrated annually according to American National Standards Institute (ANSI) S3.6 – 1996 standards.

Three auditory processing tests were chosen to help determine if an auditory processing disorder maybe present. These tests were selected in that they measure different auditory skills, including dichotic listening tasks previously described in the literature, and they are more resistant than others to peripheral hearing loss. (Bellis, 1996) The Duration Pattern Test (DPT) was selected in order to include a monaural and temporal pattern task for comparison of each ear separately.

- 1. The Staggered Spondaic Word (SSW) test list EC, a dichotic listening test, was presented at 50dB SL (re: SRT). One subject was tested at 40 dB SL (re:SRT) due to experiencing discomfort at a higher level. The subjects heard a different spondee word in each ear, with the second syllable of the first overlapping with the first syllable of the second. The subjects were asked to repeat both spondee words in the proper order.
- 2. The Dichotic Digits Test (DDT) was presented at 50 dB SL (re:SRT). With this test, one or two digits from 1 through 10 were presented to each ear simultaneously. The number 7 is excluded when two digits are presented to each ear because it is a two syllable word. The subjects were required to repeat all of the digits they heard. The DDT is at a medium level of difficulty because the stimuli are very closely aligned but carry a light linguistic load (Bellis, 1996).
- The Duration Pattern Test (DPT) holds the frequency of the tone constant at 1000
 Hz and short (200 msec) and long (500 msec) tone bursts are presented in

sequences of three-tone patterns at 50 dB SL (re:SRT). The subjects were asked to describe the pattern heard. Examples of patterns are "long, long, short" or "short, long, short" with six possible combinations. This test helps to identify difficulty with temporal patterns (Bellis, 1996).

The same methods were utilized to collect normative data on 10 adult subjects. The age range for these subjects was 22 to 25 years with a mean age of 23 years and a SD of 1.03. All subjects demonstrated hearing within normal limits.

RESULTS

The raw data for the experimental group are reported in Appendix C. The collected normative raw data are shown in Appendix D. Table 1 shows the results for a paired sample t-test that was conducted to test for significant differences between right ear scores and left ear scores in the experimental group for the SSW Ear Effect, single and double pairs DDT, DPT, and WRS in noise. The purpose of utilizing the paired sample t-test was to attempt to answer the question of ear dominance in the experimental group. A paired sample t-test was not conducted for WRS in quiet or PI-PB RI because WRS in quiet is not a test used to determine APD and all PI-PB RIs obtained for subjects and normal controls were less than 0.45. For each t-test, the alpha level (probability of Type I error) was set at 0.05. No significant differences were found between right and left ear scores of the experimental group for any test. It should be noted that this does not test for differences between ears for each subject, only the difference between ears for the group. The lack of significance can be seen in the last column, listing the obtained probabilities associated with the t-value for each t-test. All probabilities were greater than 0.05.

Table 1: Paired Samples Test for SSW Ear Effect, single and double pair DDT, DPT, and WRS in noise. No significant differences were seen between ears of the test group as a whole for any of the tests.

	MEAN	SD	Т	DF	SIG.
					(2-
					TAILED)
Pair 1 SSW Ear Effect (EE) REF – SSW EE	2.0%	4.0%	1.0	3	0.391
LEF					
Pair 2 DD single R – DD single L	1.25%	2.5%	1.0	3	0.391
Pair 3 DD double R – DD double L	7.5%	10.85%	1.38	3	0.261
Pair 4 DP R – DP L	1.75%	2.06%	1.7	3	0.188
Pair 5 WRS in Noise R – WRS in Noise L	1.5%	13.2%	0.24	3	0.835

One explanation for the non-significant findings could be due to the low statistical power to detect a difference between the left and right ear scores. Observed power estimates were computed for each t-test. The results are shown in Table 2. In the present context, observed power is the probability of the paired-samples t-tests to detect differences between the scores for left and right ears given that differences actually existed. Power is determined, in part, by sample size. All else being equal, statistical tests computed using larger samples are more powerful than statistical tests computing using smaller samples. Cohen (1992) recommends sample sizes large enough to detect an effect with a power of at least .80.

Table 2: Observed power values for the SSW Ear Effect, single and double pairs DDT, DPT, and WRS in noise

	Observed Power Value
SSW EE	.111
DD single	.111
DD double	.167
DPT	.225
WRS Noise	.053

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As seen in Table 2, the largest observed power was .225. This meant that with a difference of 1.75% between the right and left ear DPT scores, the probability of this difference being detected by the paired-samples t-test with the sample of 4 subjects was far below Cohen's recommendation. Consequently, the results of the statistical tests were inconclusive.

CASE REPORTS

Figure 1 shows the averaged audiogram for the experimental group. All tested subjects had a bilateral sensorineural hearing loss. Bone conduction thresholds were superimposed on the air conduction thresholds for all subjects.

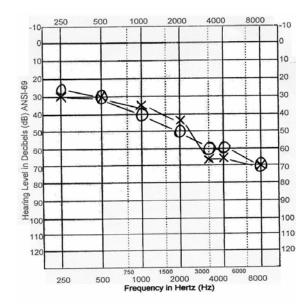


Figure 1: Averaged audiogram for the experimental group.

Subject 1

Subject 1 was an 82 year old female, monaurally fit in the right ear. Figure 2 shows the pure-tone air conduction results for this subject. The SRT was in good agreement with the pure tone average (PTA) in both ears for this subject. The two frequency PTA in the right ear at 1000 and 2000 Hz was 45 dB HL with an SRT of 45 dB HL. The three frequency PTA in the left ear was 38 dB HL at 500, 1000, and 2000 Hz, with an SRT of 45 dB HL. Results for WRS in quiet and noise can be seen in Figure 3. WRS in quiet were 100% in the right ear and 94% in the left ear. In the presence of ipsilateral noise (0 dB SNR), the WRS were 16% in the right ear and 12% in the left ear. The mean of normative data for WRS in noise (0 dB SNR) was 31.4% with a SD of 14.07% for the right ear and 30.1% with a SD of 12.48% for the left ear. This subject's scores for WRS in noise for both ears fell 1 SD below the mean in both ears. Figure 4 represents the PI-PB RIs that were calculated for each ear. Indices of 0.0 and 0.02 were seen in the right and left ears respectively. Scores less than 0.45 indicate that there most likely is not a central pathology.

Figure 5 shows the ear effect or ear first effect for the SSW test for this subject. A comparison between the total errors made when the spondees are presented to the right ear first

(REF) versus the total errors made when the spondees are presented to the left ear first (LEF) are used to determine if there is an ear effect. The total REF errors are given first regardless of in which ear the test was started. For example, if the REF errors equaled 5 and the LEF errors equaled 10 the ear effect would be reported as 5/10 even if the test began in the left ear. The ear effect can also be reported as Low/High or High/Low; for this example it would be Low/High. Low/High and High/Low brain lesions tend to group together in different areas of the brain (Katz, 1973; 1977). The total errors for Subject 1 were 5 when the spondees were presented to both the right ear first (REF) and the left ear first (LEF); therefore, there is no ear effect. For an ear effect to be present, there must be a difference of 5 or more errors between the REF and LEF conditions (Katz, 1973; 1977).

Results of the DDT for both single and double digit pairs are in Figure 6. Scores of 100% were achieved for both ears when single digits were presented and 98% for both ears when double digits were presented. Normative data collected within the author's clinic demonstrated a mean of 100% in the right ear with a SD of 0.0% and 99.5% in the left ear with a SD of 1.58% for single digits and a mean of 98.1% in both ears with SDs of 3.9% in the right ear and 3.6% in the left ear for double digits. Published normative data states that 90% and above is within normal limits. 90% was slightly greater than 2 SD below the mean for their data (Musiek, 1983). The scores for both subtests of the DDT were within normal limits eliminating the possibility for APD or an ear dominance to be shown from this test. Figure 7 displays the DPT scores. When the stimulus was presented to the right ear the score was 21% and when presented to the left ear the score was 17%. The DPT scores for both ears fall outside of the published range of normal and 2 SD below the mean of the collected normative data. This could possibly suggest a temporal processing deficit. The means for clinic collected normative data are 80.5% with a SD

of 19.99% for the right ear and 76.2% with a SD of 16.54% for the left and 73% is the recommended cutoff score for both ears for published normative data (Bellis, 2003). In summary, scores for PI-PB RI, SSW ear effect, single and double pairs DDT, all fell within normal limits. The WRS in quiet was poorer for the right than for the left. The WRS in noise scores did not appear to meet criterion suggestive of significance. Scores for the DPT were below normal limits pointing to a possible temporal processing deficit.

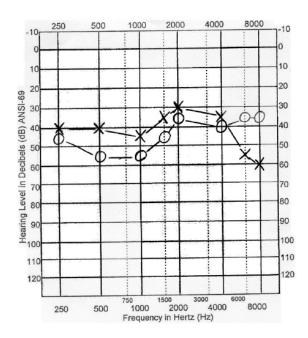


Figure 2: Pure tone audiogram for Subject 1

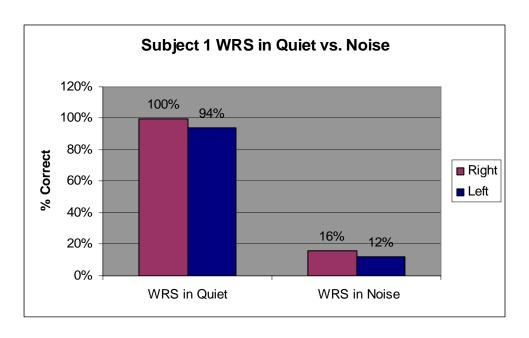


Figure 3: WRS in quiet versus WRS in ipsilateral noise (0 dB SNR)

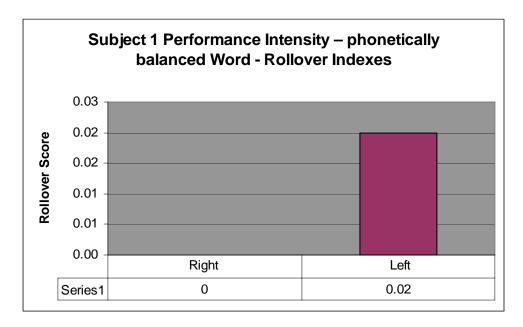


Figure 4: PI-PB RI for the right and left ears. Less than 0.45 represents no rollover effect.

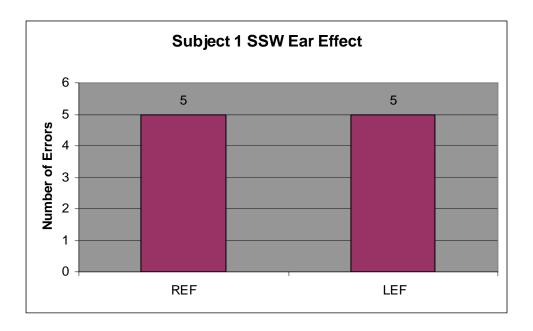


Figure 5: SSW Ear Effect for REF and LEF. A difference of 5 or more between ears is a significant ear effect.

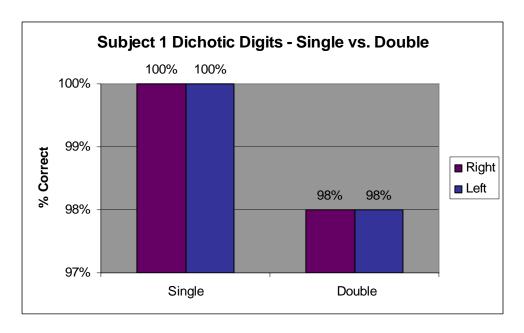


Figure 6: Single and Double Pairs DDT scores for the right and left ears.

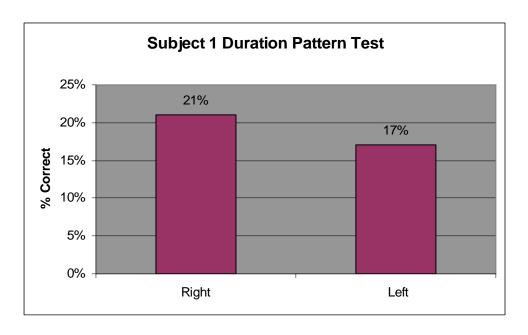


Figure 7: Duration Pattern Test scores for the right and left ears.

Subject 2

Subject 2 was an 83 year old male, monaurally fit in the right ear. Figure 8 shows the pure-tone air conduction results for this subject. The SRT was in good agreement with the PTA in both ears for this subject. The two frequency PTA in the right ear at 500 and 1000Hz was 30 dB HL with an SRT of 40 dB HL and the two frequency PTA in the left ear was 35 dB HL with an SRT of 40 dB HL. Results for WRS in quiet and noise can be seen in Figure 9. WRS in quiet were 88% in the right ear and 80% in the left ear. In the presence of ipsilateral noise (0 dB SNR) WRS were 14% in the right ear and 0% in the left ear. The difference of 14% between ears in this subject is of interest. The mean WRS in noise score for normal hearing listeners was 31.4% in the right ear and 30.1% in the left ear with a standard deviation (SD) of 14.07% and 12.48% respectively. This subject's scores are 1 SD below the mean for the right ear and greater than 2 SD below the mean of the collected normative data in the left ear. This 2 SD method is a standard cutoff procedure for APD measures in clinical audiology. The difference between ears could suggest that the right ear is stronger than the left ear when listening in noise. There are no

published norms for WRS in noise. Figure 10 represents the PI-PB RIs that were calculated for each ear, resulting in rollover scores of -0.05 in the right ear and -0.08 in the left ear. These scores are less than 0.45, indicating that there most likely is not a central pathology for the right or left ear.

Figure 11 shows the ear effect from the SSW test for this subject. The total errors were 29 when the spondees were presented to both the REF and LEF; therefore, there is no ear effect. For an ear effect to be present there must be a difference of 5 or more errors between ears (Katz, 1973; 1977). Results of the DDT for both single and double pairs are shown in Figure 12. A score of 95% was achieved for both ears on the DDT single digits. The scores were within normal limits when compared to published normative data, but fell 2 SD below the mean of collected normative data. The mean of the collected normative data for single digits was 100% in the right ear with a SD of 0.0% and 99.5% in the left ear with a SD of 1.58%. The presentation of double digits resulted in scores of 93% in the right ear and 70% in the left ear. This difference of 23% between ears is of interest because the performance in the right ear is better than performance in the left ear. The mean of the control group's scores for the DDT when double digits were presented were 98.1% for each ear with SDs of 3.9% for the right ear and 3.6% for the left ear. This subject's scores were greater than 2 SD below mean of the collected normative data in the left ear, but only 1 SD below the mean in the right ear. This 2 SD below the mean criterion is a standard cutoff procedure for APD measures in clinical audiology. The mean of the published normative values are 97.8% for the right ear and 96.5% for the left ear. The SDs are 2.9% and 1.7% respectively. For the published normal hearing group a score of 90% is approximately 2 SD below the mean. Therefore, scores of 90% or better are consider within normal limits (Musiek, 1983). This demonstrates again that the score for the right ear was within normal limits while the score for the left ear was below the normal limit. This finding points to a possible ear dominance for the right ear. These results also stress the importance of normative data, collection methods, and obtaining normative data in one's own clinic. This will be discussed in a later section.

Figure 13 displays the DPT scores. When the stimulus was presented to the right ear the score was 32% and when presented to the left ear the score was 29%. The means for clinic collected normative data were 80.5% with a SD of 19.99% for the right ear and 76.2% with a SD of 16.54% for the left. Published normative data indicates that the cut off of 73% correct, the recommended cutoff, or better for both ears is within normal limits (Bellis, 2003). The DPT scores for both ears fell outside of the range of normal suggesting a possible temporal processing deficit. In summary, the WRS in noise fell within 2 SD of the mean in the right ear, there was no rollover effect or ear effect, both ears scored within normal limits for the single DDT, and the right ear score was within 2 SD of the mean for the double DDT. In the left ear both WRS in noise and the double DDT were below 2 SD of the means for these tests and the DPT was below normal limits in both ears. These results suggest a possible right ear dominance and a temporal processing deficit.

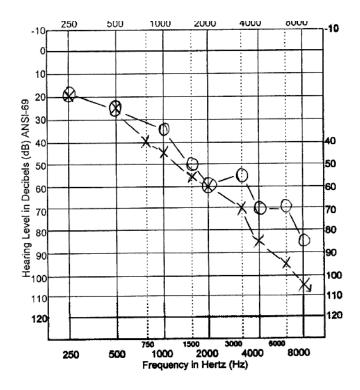


Figure 8: Pure tone audiogram for Subject 2.

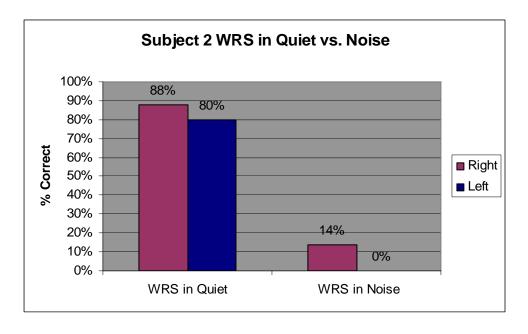


Figure 9: WRS in quiet versus WRS in ipsilateral noise (0 dB SNR)

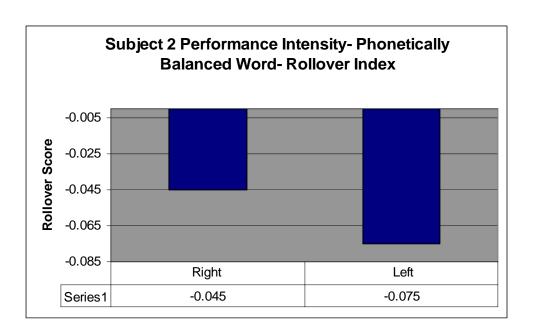


Figure 10: PI-PB RI for the right and left ears. Scores less than 0.45 represent no rollover effect.

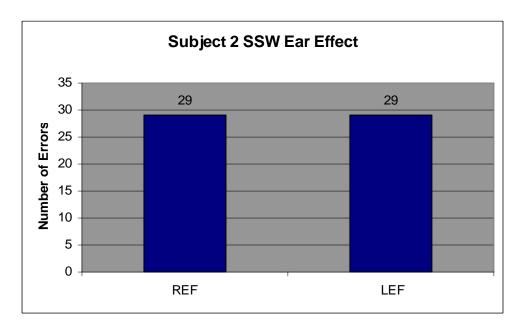


Figure 11: SSW Ear Effect for REF and LEF. A difference of 5 or more between ears is a significant ear effect.

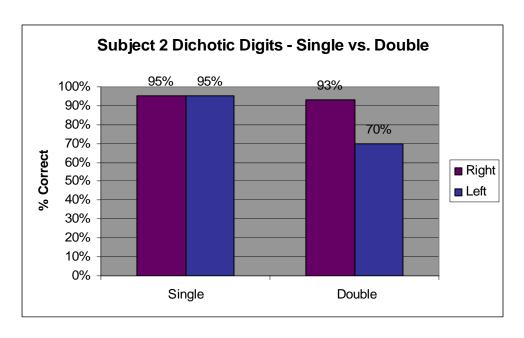


Figure 12: Single and Double Pairs DDT scores for the right and left ears.

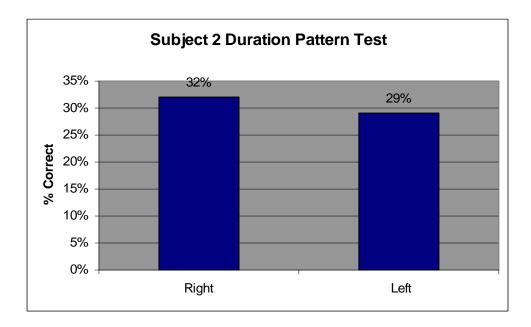


Figure 13: Duration Pattern Test scores for the right and left ears.

Subject 3

Subject 3 was a 63 year old male, monaurally fit in the right ear. Figure 14 shows the pure-tone air conduction results for this subject. The two frequency PTA for this subject in the right ear at 500 and 1000 Hz was 23 dB HL with an SRT of 35 dB HL and the two frequency

PTA in the left ear was 20 dB HL with an SRT of 35 dB HL. Results for WRS in quiet and noise may be seen in Figure 15. WRS in quiet were 90% in the right ear and 98% in the left ear. In the presence of ipsilateral noise (0 dB SNR) WRS were 4% in the right ear and 12% in the left ear. The mean WRS in noise score for normal hearing listeners was 31.4% in the right ear and 30.1% in the left ear with a standard deviation (SD) of 14.07% and 12.48% respectively. This subject's WRS in noise fell 1 SD below mean. Figure 16 represents the performance intensity – phonetically balanced word (PI-PB) rollover indexes (RI) that were calculated for each ear, resulting in rollover scores of -0.11 in the right ear and 0.0 in the left ear. These scores were less than 0.45, indicating that there most likely is not a central pathology for the right or left ear.

Figure 17 shows the ear effect or ear first effect from the SSW test for this subject. The total errors were 10 when the spondees were presented to the REF and 2 when presented to the LEF. The difference between the REF and LEF is greater than 5; therefore, there is an ear effect. The ear effect in this subject was a High/Low ear effect. This information may help to locate a brain lesion, if one was present. Results of the DDT for both single and double pairs are shown in Figure 18. Scores of 100% were achieved for both ears when single digits were presented and 98% when double digits were presented. Normative data collected within the author's clinic demonstrated a mean of 100% in the right ear with a SD of 0.0% and 99.5% in the left ear with a SD of 1.58% for single digits and a mean of 98.1% in both ears with SDs of 3.9% in the right ear and 3.6% in the left ear for double digits. Published normative data states that 90% and above is within normal limits. 90% was slightly greater than 2 SD below the mean for their data (Musiek, 1983). The scores for both subtests of the DDT were within normal limits eliminating the possibility for APD or an ear dominance to be shown from this test.

Figure 19 displays the DPT scores. When the stimuli were presented to the right and left ears, the scores were 61% for each ear. The means for clinic collected normative data were 80.5% with a SD of 19.99% for the right ear and 76.2% with a SD of 16.54% for the left. Published normative data states that 73% correct or better for both ears is within normal limits (Bellis, 2003). The DPT scores for both ears fell outside of the range of normal compared to published normative data, suggesting a temporal processing deficit. However, the scores were within 1 SD of the mean for collected normative data. Scores of 2 SD below the mean are a standard cutoff procedure for APD measures in clinical audiology. In summary, The WRS in noise fell within 2 SD of the mean for both ears and both single and double pair DDT were within normal limits for the right and left ears. There was a significant SSW Ear Effect, which may be able to help locate a lesion in the brain, if there is one. DPT scores in both ears were outside of normal limits compared to published but not collected normative data. The results for this subject suggest a possible left ear dominance and temporal processing deficit.

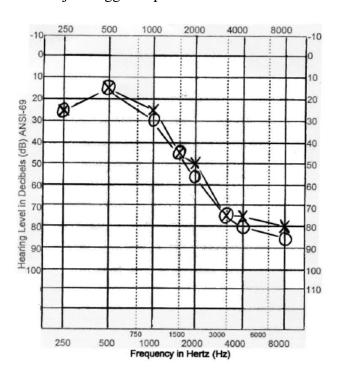


Figure 14: Subject 3 pure tone audiogram

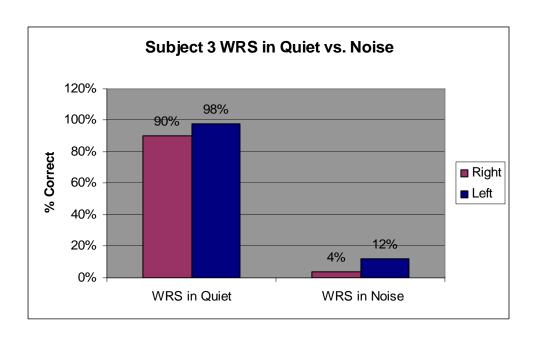


Figure 15: WRS in quiet versus WRS in ipsilateral noise (0 SNR)

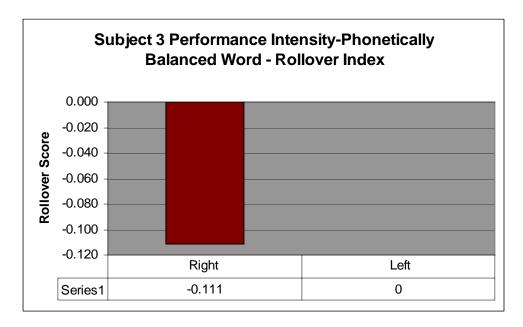


Figure 16: PI-PB RI for the right and left ears. Less than 0.45 represents no rollover effect.

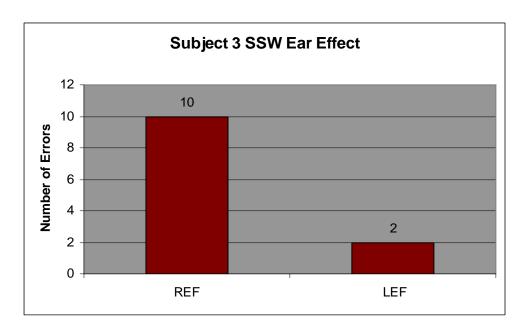


Figure 17: SSW Ear Effect for REF and LEF. A difference of 5 or more between ears is a significant ear effect. This subject has a significant ear effect with a difference of 8 between ears.

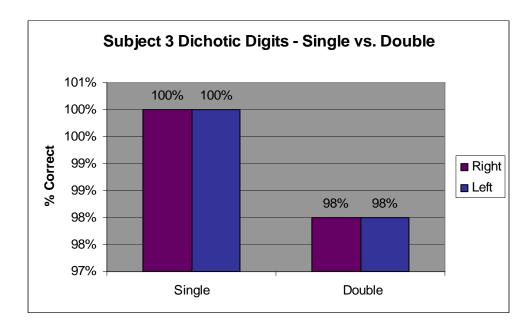


Figure 18: Single and Double DDT scores for the left and right ears.

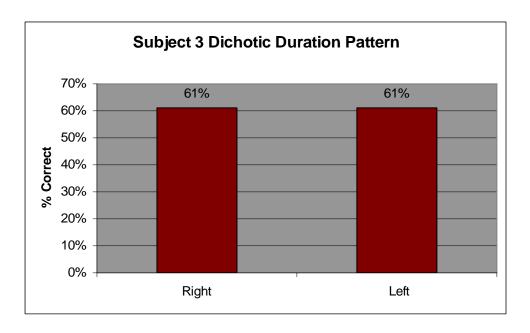


Figure 19: Duration Pattern Test scores for the right and left ears.

Subject 4

Subject 4 was a 53 year old female, monaurally fit in the right ear. Figure 20 shows the pure-tone air conduction results for this subject. The SRT was in good agreement with the PTA in both ears for this subject. PTA in the right ear at 500, 1000, and 2000 Hz was 28 dB HL with an SRT of 30 dB HL and the PTA in the left ear was 28 dB HL with an SRT of 30 dB HL.

Results for WRS in quiet and noise can be seen in Figure 21. WRS in quiet were 92% in the right ear and 100% in the left ear. In the presence of ipsilateral noise (0 SNR) WRS was 10% in the right ear and 26% in the left ear. The difference of 16% between ears in this subject was of interest. The mean WRS in noise score for normal hearing listeners was 31.4% in the right ear and 30.1% in the left ear with a SD of 14.07% and 12.48% respectively. This subject's scores fell 1 SD below mean for the right ear and within 1 SD of the mean of the collected normative data. Determination of scores 2 SD below the mean are a standard cutoff procedure for APD measures in clinical audiology. There are no published norms for WRS in noise. Figure 22 represents the performance intensity – phonetically balanced word (PI-PB) rollover indexes (RI)

that were calculated for each ear, resulting in rollover scores of -0.09 in the right ear and 0 in the left ear. These scores were less than 0.45, indicating that there most likely was not a central pathology for the right or left ear.

Figure 23 shows the ear effect or ear first effect from the SSW test for this subject. The total errors were 11 when the spondees were presented to both the REF and the LEF therefore; there was no ear effect. For a significant ear effect to be present there must be a difference of 5 or more errors between the ears. Results of the single and double pair DDT are shown in Figure 24. A score of 95% was achieved when single digits were presented to the right ear and 100% when presented to the left ear. When double digits were presented scores of 95% for the right ear and 88% for the left ear were obtained. The author's collected normative data demonstrated a mean of 100% in the right ear with a SD of 0.0% and 99.5% in the left ear with a SD of 1.58% for single digits and a mean of 98.1% in both ears with SDs of 3.9% in the right ear and 3.6% in the left ear for double digits. Observance of scores 2 SD below the mean is a standard cutoff procedure for APD measures in clinical audiology. Published normative data states that 90% and above is within normal limits. 90% was slightly greater than 2 SD below the mean for the data (Musiek, 1983). Scores for the single digit DDT were below 2 SD of the mean for the right ear and within normal limits for the left ear for collected normative data. Both ears were within normal limits when compared to published normative data. For the double digit DDT, the right ear fell within normal limits when compared to published normative data and within 1 SD of the mean of collected normative data. The left ear fell just outside of 2 SD below the mean and published normal limits. The score in the left ear falls outside of the range of normal by 2%.

Figure 25 displays scores for the DPT. When the stimulus was presented to both the right and left ears the scores were 64%. The means for clinic collected normative data were 80.5%

with a SD of 19.99% for the right ear and 76.2% with a SD of 16.54% for the left. Published normative data states that 73% correct or better for both ears is within normal limits (Bellis, 2003). The DPT scores fell within 1 SD of the mean for collected normative data. The DPT scores for both ears fell outside of the range of normal for published data. In summary, WRS in noise was within normal limits and there was no significant SSW ear effect. The DDT single digits score for the left ear was within normal limits for both collected and published normative data. The right ear was within normal limits compared to published normative data but not within normal limits when compared to collected normative data. The right ear score for DDT using double digits was within normal limits for both collected and published normative data. The left ear fell outside of normal limits for both collected and published normative data. Right and left ear scores for DPT were within 2 SD of the mean of collected normative data, but below normal limits for published normative data.

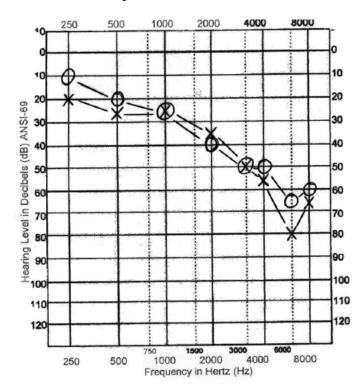


Figure 20: Subject 4 pure tone audiogram.

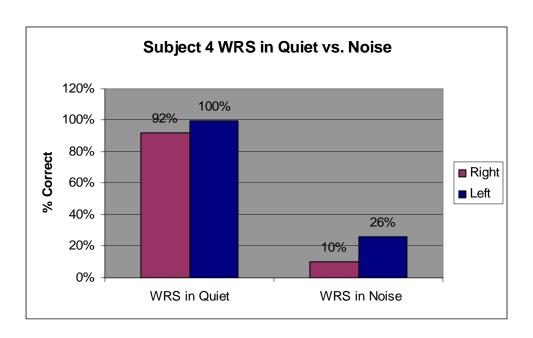


Figure 21: WRS in quiet versus WRS in ipsilateral noise (0 SNR)

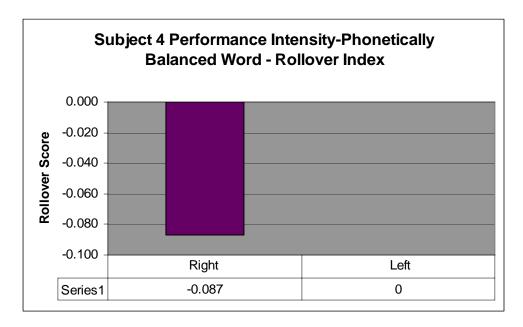


Figure 22: PI-PB RI for the right and left ears. Less than 0.45 represents no rollover effect.

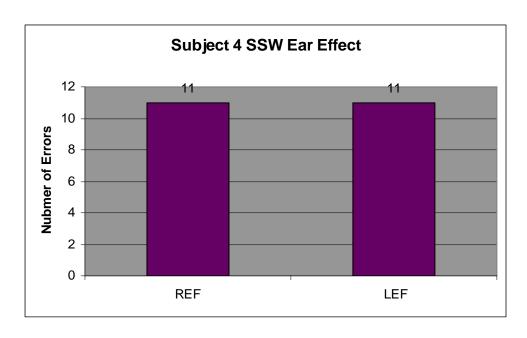


Figure 23: SSW Ear Effect for REF and LEF. A difference of 5 or more between ears is a significant ear effect.

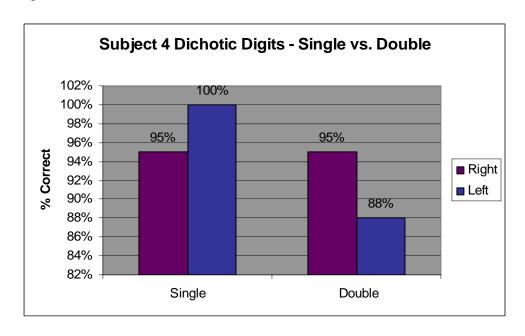


Figure 24: Single and Double DDT scores for the right and left ears.

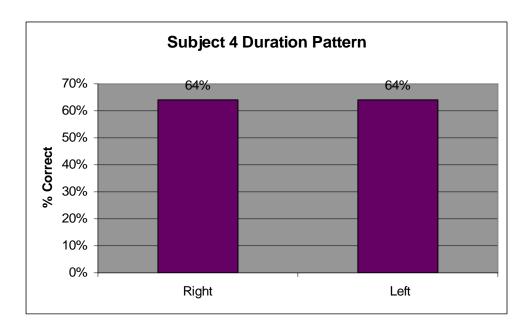


Figure 25: Duration Pattern Test scores for the right and left ears.

Table 3 shows the results for an independent sample t-test that was conducted to test for significant differences for right ear scores and left ear scores between the experimental and control groups for SSW Ear Effect, single and double pairs Dichotic Digits Test, and Duration Pattern Test, WRS in noise. An independent sample t-test was not conducted for WRS in quiet or PI-PB RI because WRS in quiet is not a test used to determine APD and PI-PB RIs were less than 0.45 for all subjects in both groups. For each t-test, the alpha level (probability of Type I error) was set at 0.005 using the Bonferroni Correction. The Bonferroni Correction allows for a more accurate alpha level to be determined using the following equation: 0.05/number of tests. The correction is used when a large number of tests are utilized. For this study there were 10 tests: WRS in noise right ear (RE) and left ear (LE), SSW Ear Effect REF and LEF, single RE and LE and double RE and LE Dichotic Digits and Duration Pattern Test RE and LE. No significant differences were found for the right or left ears between groups for SSW Ear Effect, single and double Dichotic Digits pairs, and Duration Pattern. There was no significant difference between groups for WRS in noise in the left ear as well. The lack of significance can

be seen in the obtained probabilities associated with the t-value for each t-test (sig. 2-tailed). All probabilities were greater than 0.005. A significant difference was observed between groups for WRS in noise in the right ear with a p value of 0.002.

Table 3: Independent Samples Test for between group comparisons for each ear, for WRS in noise, SSW EE, DDT, and DPT. WRS in noise for the right ear was the only test that showed significance with a Sig. (2-tailed) of 0.002.

		t	df	Sig. (2-tailed)
WRS noise R	Equal variances assumed	2.765	12	.017
	Equal variances not assumed	3.940	11.992	.002
WRS noise L	Equal variances assumed	2.471	12	.029
	Equal variances not assumed	2.659	6.554	.035
SSW EE REF	Equal variances assumed	-4.352	12	.001
	Equal variances not assumed	-2.580	3.004	.082
SSW EE LEF	Equal variances assumed	-3.193	12	.008
	Equal variances not assumed	-1.893	3.004	.155
DD single R	Equal variances assumed	2.928	12	.013
	Equal variances not assumed	1.732	3.000	.182
DD single L	Equal variances assumed	.684	12	.507
	Equal variances not assumed	.557	4.003	.607
DD double R	Equal variances assumed	.988	12	.343
	Equal variances not assumed	1.208	9.063	.258
DD double L	Equal variances assumed	2.222	12	.046
	Equal variances not assumed	1.433	3.181	.242
DP R	Equal variances assumed	2.993	12	.011
	Equal variances not assumed	2.907	5.270	.032
DP L	Equal variances assumed	3.059	12	.010
	Equal variances not assumed	2.614	4.268	.055

The results for each test are discussed here in terms of each subject's performance and how his/her performance compares to collected and published normative data for each test. As shown in Figure 26, the mean collected WRS in noise (0 dB SNR) score for normal hearing listeners was 31.4% in the right ear and 30.1% in the left ear with a standard deviation (SD) of 14.07% and 12.48% respectively. The scores for Subjects 1 and 3 were 1 SD below the mean for both ears. Subject 2 demonstrated a score in the right ear 1 SD below the mean. Subject 2's left ear was 2 SD below the mean. There was a difference of 14% between Subject 2's right and left ear scores. Subject 4's left ear scored within 1 SD of the mean and the right ear scored 1 SD below the mean. There was a difference of 16% between the right and left ear scores.

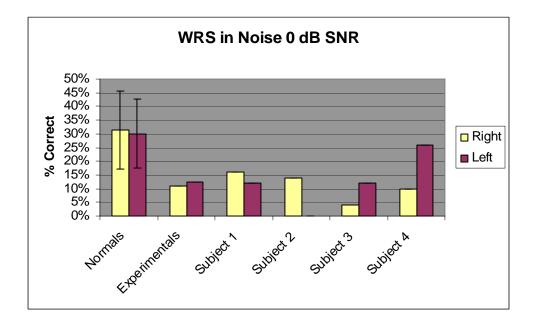


Figure 26: Mean WRS in noise scores for normal and experimental subjects and individual scores for experimental subjects for the right and left ears.

Figure 27 shows the results of the SSW ear effect. A significant SSW ear effect is marked by a difference of 5 errors or more between the right ear first (REF) condition and the left ear first (LEF) condition. There was not a significant ear effect present in Subjects 1, 2, and 4. Subject 3 exhibited a significant ear effect with a difference of 8 errors between conditions.

There were 10 errors when the spondee was presented to the right ear first and only 2 errors when presented to the left ear first. Testing of normal hearing subjects resulted in a mean of 0.2 errors in the REF and 0.3 errors in the LEF with SDs of 0.42 and 0.48, respectively. All experimental subjects' number of errors for both the REF and LEF are 2 SD below the mean for normal hearing subjects.

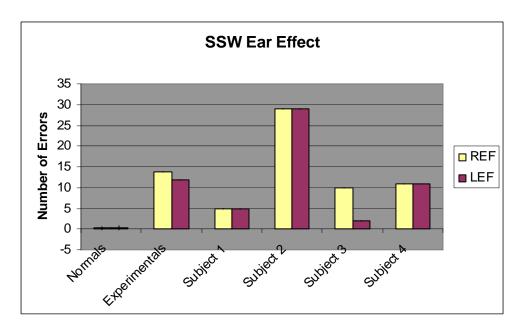


Figure 27: Mean number of errors for normal and experimental subjects and individual number of errors for experimental subjects for the right and left ears.

Results of the DDT single digits are shown in Figure 28. The author's collected normative data demonstrated a mean of 100% in the right ear with a SD of 0.0% and 99.5% in the left ear with a SD of 1.58% for single digits. Observance of scores 2 SD below the mean is a standard cutoff procedure for APD measures in clinical audiology. Published normative data states that 90% and above is within normal limits. 90% was slightly greater than 2 SD below the mean for the data (Musiek, 1983). Subjects 1 and 3 demonstrated scores in both ears that fell within the set normal limits for collected and published normative data. Subject 2 exhibited scores in both ears that were within normal limits when compared to published normative data,

but 2 SD below the mean when compared to collected normative data. The right and left ear scores for Subject 4 were within normal limits compared to the published normative data. The left ear was also within normal limits when compared to the collected normative data. The right ear score was 2 SD below the mean of collected normative data.

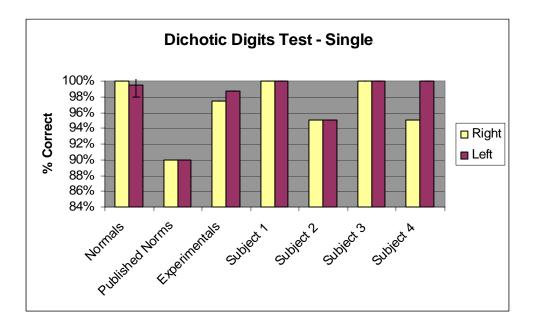


Figure 28: Mean DDT single digit pair scores for normal and experimental subjects and individual scores for experimental subjects for the right and left ears.

Figure 29 displays the DDT double digit pair scores. Collected normative data demonstrated a mean of 98.1% in both ears with SDs of 3.9% in the right ear and 3.6% in the left ear for double digits. Observance of scores 2 SD below the mean is a standard cutoff procedure for APD measures in clinical audiology. Published normative data states that 90% and above is within normal limits. 90% was slightly greater than 2 SD below the mean for the data (Musiek, 1983). Subjects 1 and 3 demonstrated scores within normal limits when compared to both collected and published normative data for double digit pairs. Subject 2 exhibited a right ear score within normal limits and within 2 SD of the mean for published and collected normative data, respectively. The left ear score was not within published normal limits and was 2 SD

below the mean of the collected normative data for both Subject 2 and 4. Subject 4 demonstrated a right ear score that was within published normal limits and within 1 SD of the mean of the collected normative data.

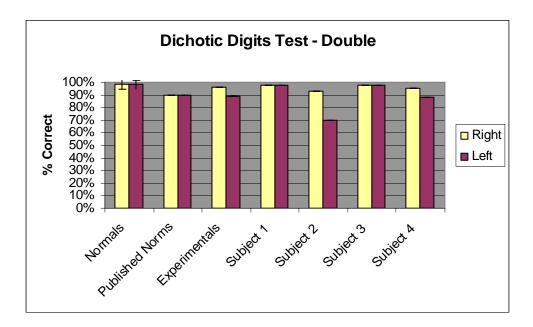


Figure 29: Mean DDT double digit pair scores for normal and experimental subjects and individual scores for experimental subjects for the right and left ears.

Scores for the DPT are shown in Figure 30. The means for clinic collected normative data were 80.5% with a SD of 19.99% for the right ear and 76.2% with a SD of 16.54% for the left. Published normative data states that 73% correct or better for both ears is within normal limits (Bellis, 2003). Subjects 1 and 2 demonstrated scores that fell 2 SD below the mean for collected normative data and outside of the published normal limits. Subjects 3 and 4 exhibited scores that were within 1 SD of the mean for collected normative data and below normal limits for published normative data.

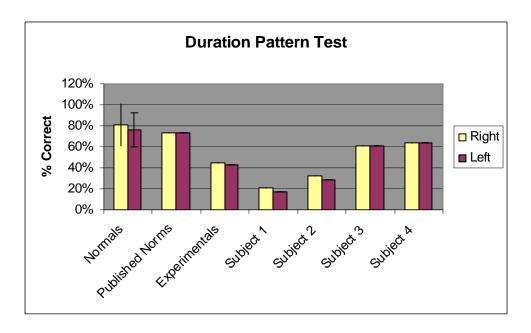


Figure 30: Mean DPT scores for normal and experimental subjects and individual experimental subject DPT scores for right and left ears.

The results obtained by the current study were not able to provide significant evidence of APD in adult subjects with symmetrical hearing loss who prefer monaural amplification. The lack of significance could be due to the small subject number and large number of tests performed. The subjects' preference for monaural amplification versus performing better with monaural amplification could have also been a factor.

A comparison between subject performance and published normative data was used to determine the presence or absence of APD. There is no published normative data for WRS in noise. The SSW ear effect has a published standard of a difference of five or more errors between the REF and LEF as being significant. Three subjects had no ear effect and one subject had a High/Low ear effect. Published normative data for the single pair DDT states that 90% correct and above is within normal limits. All four subjects demonstrated scores within published normal limits. For the double digit pair DDT, published normative data maintains that 90% correct and above is within normal limits. Two subjects scored within normal limits for

both ears. The other two subjects scored within normal limits in the right ear and not within normal limits in the left ear. The DPT has a published normal limit of 73% correct. None of the experimental subjects were within published normal limits.

Normative data was collected by the author of the current study in order to make further comparisons in the data. A standard cutoff procedure was used to set a normal limit. A score within 2 SD of the mean for each test was considered within normal limits. Three subjects were within normal limits for the right and left ears for WRS in noise. One subject scored within normal limits in the right ear and below normal limits for the left ear. Determination of the presence of a significant ear effect is a set standard. However, if the total number of errors in each condition alone is examined, all four subjects are outside of the normal limits for number of errors. Two subjects were within normal limits for the single pair DDT in both ears. One subject was within normal limits in the left ear and below normal limits for the right ear. The remaining subject was below normal limits in both ears. The double digit pair DDT resulted in two subjects within normal limits for the left ear. The DPT resulted in two subjects within normal limits for the left ear. The DPT resulted in two subjects within normal limits for the right and left ears.

The presence of ear dominance was examined in order to determine if there was a common dominant ear among the experimental subjects. A common dominant ear was not discovered. No ear dominance was observed in Subject 1. Subject 2 exhibited a dominant right ear for WRS in noise and the double digit pair DDT. Subject 3 demonstrated an SSW ear effect only. Finally, Subject 4 exhibited a left ear dominance on WRS in noise and a right ear dominance on double digit pair DDT.

DISCUSSION

Statistical analysis of between ear data for the experimental group revealed no significant difference between ears for the group as a whole on any measure; however, the between ear difference for each subject varied, with some differences being of interest. For WRS in quiet, three subjects demonstrated excellent scores in both ears with a mean of 94% and SD of 5.29% in the right ear and a mean of 97.3% and SD of 3.06% in the left ear. Subject 2 demonstrated good WRS in quiet for both the right and left ears, with scores of 88% and 80% respectively.

All four subjects exhibited greatly diminished performance when CID – W22 words were presented in ipsilateral speech noise at a 0 dB SNR. As a group, their scores showed a mean of 11% and SD of 5.29% in the right ear and a mean of 13% and SD of 10.63% in the left ear. Two subjects demonstrated an interaural difference that was of interest. Subject 2 had scores of 14% in the right ear and 0% in the left ear and Subject 4 had scores of 10% in the right ear and 26% in the left ear. This difference between ears could point to a dominance in one ear over the other (right for Subject 2 and left for Subject 4), perhaps suggesting the better ear for fitting these subjects monaurally. Both of these subjects wore a hearing aid in their right ear at the time of testing. Results of this test may possibly suggest that Subject 4 may benefit more from wearing a hearing aid in the left ear than the right. Diminished performance in noise may indicate limited benefit with amplification for all subjects, at least within very taxing listening environments.

The PI-PB RI for all subjects was well below 0.45, which indicated that there was not a central pathology affecting any of the subjects, at least according to this measure. Cooper and Gates (1991) presented the CID W-22 lists in quiet at a "lower level" and a "higher level" in order to determine a rollover index in their subjects. They were able to show a separation between subjects with cochlear hearing loss and those with VIII nerve pathology. Stach et al.

(1990) considered a patient to exhibit an auditory processing disorder if the rollover score of the PI-PB function for either a monosyllabic word test (PAL PB-50 word lists) or Synthetic Sentence Identification test (SSI) exceeded 20%. Although results of the current study were not able to determine a connection between rollover and the preference for a monaural fit, other studies were able to determine a difference between cochlear hearing loss and an VIII nerve pathology and to identify APD through the use of the rollover index. It should be noted that the current study utilized different stimuli and calculation for determination of the RI. However, it may be a viable recommendation to include it the audiological test battery for some select patients.

The SSW ear effect was calculated for all subjects, with three subjects showing no ear effect. Subject 3 did exhibit a High/Low ear effect, with more errors in the right ear first condition than in the left ear first condition. This qualitative interpretation of the response bias may help to identify site of lesion in some patients. The investigator for the current study concentrated mainly on the ear effect to try to determine ear dominance. However, there are other notable SSW scores. The total Corrected SSW (C-SSW) score can be applied to help determine purely cerebral auditory effects in the absence of other significant findings. Subjects 1 and 3's C-SSW scores fell within the SSW normal category. The total C-SSW score range for the normal category is -4 to 5; Subjects 1 and 3 demonstrated scores of 3 and 1 respectively. Subject 4 fell within the mildly abnormal category with a score of 10. The range for the mildly abnormal category is 6-15. Mild deviation is sometimes seen in patients with peripheral hearing loss or non-auditory reception center lesions. Subject 2 had a C-SSW total score of 20. A score of 20 falls in the moderately abnormal SSW category range of 16-35. An Adjusted SSW (A-SSW) total score was calculated for Subject 2 because the C-SSW score was moderately abnormal, which brought into question the status of the auditory reception center. The A-SSW

measures dysfunction of the auditory reception center. The total A-SSW score for Subject 2 was 18, still in the moderately abnormal category. When the total A-SSW score remains in the moderate to severe range it may indicate that Heschl's gyrus is involved. Part of the brainstem and/or other deep structures of the brain may also affect the C-SSW score, causing it to be in the moderate or severe range (Katz, 1973; 1977). There were no reversals or significant order effects for the any of the subjects in the experimental group.

Two subjects scored within normal limits for both ears when the single pair DDT was presented. One subject was below normal for both ears when compared to collected normative data and the fourth subject was within normal limits in the left ear but below normal limits when compared to collected normative data for the right ear. Two subjects scored within normal limits for both ears and two subjects were within normal limits for the right ear only when double digits were presented. Subjects 2 and 4 were both outside of normal limits in the left ear for the double pairs DDT. These results may point to the presence of binaural interference. Carter, Noe, and Wilson (2001) found a left ear deficit that could not be explained by peripheral auditory findings or a cognitive-based deficit when using a Dichotic Digits Test with a one, two-, and three-pair digit task in free and directed-recall conditions. The authors concluded that a monaural hearing aid fitting in the dominant ear may lead to improved performance for listeners with an auditory based deficit in dichotic listening. A patient's score on the DDT may also point to satisfaction with hearing aids. Given et al. (1998) found significant correlations between scores on a Dichotic Digits Test and hearing aid satisfaction measured using the Profile of Hearing Aid Performance. Reduced scores on a Dichotic Digit Task were associated with reduced hearing aid satisfaction. Both binaural interference and reduced satisfaction with hearing aids in correlation

with a reduced DDT score could lead to a patient with symmetrical hearing loss preferring a monaural hearing aid fit.

Scores for both ears on the DPT were outside of the normal range for all subjects when compared to published normal limits. Two subjects were also outside of normal limits and two were within normal limits when compared to collected normative data. Musiek, Baran, and Pinheiro (1990) found that subjects with normal hearing and those with cochlear hearing loss exhibited no significant differences between their scores on the DPT. Performance on the DPT was much poorer for subjects with cerebral lesions, however. It appeared that there were no differences in the scores for the ears ipsilateral and contralateral to the side where the lesion was present in these subjects. It was concluded that when a cerebral lesion was present, scores obtained in both ears may be abnormal. This study may suggest that the clinician could use the DPT as a screening tool for cerebral lesions. In light of the current study's results, however, it appears that more research must be performed before including the DPT in the audiologic test battery. In the current study all four subjects with cochlear hearing loss scored abnormally in both ears, as did two of the ten normal subjects that were tested when compared to published normal limits.

Results of the DPT also revealed an additional interesting finding. Subjects 3 and 4 demonstrated scores that were double the scores of subjects 1 and 2. There are two factors that could have contributed to this difference between subjects. The PTA could have contributed, in that the author found a mean of 38 dB HL in the right ear and 37 dB HL in the left ear for Subjects 1 and 2 while a mean of 26 dB HL in the right ear and 24 dB HL in the left ear were seen for Subjects 3 and 4. Secondly, there may be age effects in that a mean of 82.5 years was seen for Subjects 1 and 2 and mean of 58 years was noted for Subjects 3 and 4. Since DPT is

relatively unaffected by peripheral hearing loss, the difference in PTA may not play a big role in the difference between scores but it is something to note. Bellis and Wilber (2001) have shown that there may be a significant effect on temporal patterning performance with increasing age.

The present results of this study were unable to arrive at significant conclusions regarding the presence of APD in adult subjects with symmetrical hearing loss who prefer monaural amplification. Continuations of this study would benefit from a larger sample size, recruiting subjects who perform poorer using two hearing aids versus one, including a control group of adults with symmetrical hearing loss who prefer binaural amplification, and collection of normative data in older adults with varying ages and degrees of hearing loss.

The small sample size of subjects in this study made it difficult to make significant conclusions about the presence of APD in subjects with symmetrical hearing loss who prefer monaural amplification. A larger number of subjects could help to increase the significance of the data and increase the statistical power to detect differences between ears. This could aid in detecting APD in subjects.

This study utilized subjects who received no self reported, additional benefit from using two hearing aids versus one. It is more likely that APD would be seen in subjects who performed poorer when wearing two hearing aids than when wearing one. If performance was poorer when the subject wore two hearing aids, it may point to binaural interference which may reflect APD. Carter, Noe, and Wilson (2001) studied four subjects with symmetrical hearing loss who preferred monaural amplification to binaural amplification. When the subjects were aided binaurally and monaurally in the left ear, their scores were poorer than when aided monaurally in the right ear. Jerger et al. (1993) studied the binaural interference effect using four

cases of elderly hearing impaired persons. The authors were able to show in these subjects that their performance was poorer when tested binaurally than when tested monaurally.

The formation of a control group including adults with symmetrical hearing loss, who prefer using two hearing aids versus one would allow for comparisons to be made between hearing aid use and APD. If subjects who perform better with a binaural fit aren't found to have APD and those who perform better with a monaural fit are, this could possibly imply that patients who have known APD should be fit monaurally or patients who perform better when fit monaurally may have APD. This information would be beneficial to audiologists in the clinic when they are fitting hearing aids.

It is important for clinics and researchers to collect their own normative data because most published normative data are only a guideline. Published normative data are often collected using young normal hearing subjects. In studies such as this one where subjects are advanced in age and have hearing loss it is especially important to collect one's own normative values. Normative data were collected for this study using young normal hearing adults. The collected normative values, for the most part were in good agreement with published normative data. It would be advantageous to collect data on subjects in different age groups with varying degrees of hearing loss, who are known to not have APD. This would help to distinguish between APD and what may be an age related or hearing loss related deficit.

Clinical implications that arose from this study cover many areas including testing, hearing aid selection and fitting, and recommendations. The results of this project and others suggest that perhaps PI-PB rollover and dichotic testing could be included in the audiologic test battery for some patients. The rollover index, if 0.45 or greater, appears to have the ability to differentiate between cochlear hearing loss and VIII nerve pathology and to help determine if

APD is present. A deficit in dichotic listening may point to improved performance with a monaural hearing aid fit over a binaural hearing aid fit and to a patient's satisfaction with hearing aid(s). Musiek, Gollegly, Kibbe, and Verkest-Lenz (1991) have proposed that the DDT could be used as a screening test for APD. The DDT's ability to effectively detect central auditory lesions and its resistance to peripheral hearing loss are the two main reasons that it has been suggested as a screening tool. It also has a short administration time, good test-retest reliability, uses stimuli familiar to most patients and the equipment required is not expensive or elaborate.

The topics discussed in this paper could benefit from investigating the factors that affect and are affected by those factors further. Finding an effective adult screening method for APD would allow for patients who may experience binaural interference due to APD to be identified and treated properly. There has already been some work done in this area with the DDT as discussed previously. Carter, Noe, and Wilson (2001) agree that a dichotic listening test could be of benefit if included in the evaluation of potential amplification patients. They also suggested that including both free and directed recall tasks may help to differentiate between auditory specific deficits and deficits that involve the cognitive aspects of audition. Existing screening methods for children, such as the SCAN, could also be further investigated for use with adults. An investigation of this type could also include modification of currently existing questionnaires for school aged children. If a screening method can be devised, it would then be necessary to have an appropriate test battery designed to test those patients identified. It would be beneficial for more testing to be completed, investigating the effect of different degrees of hearing loss on all available auditory processing tests, in order to determine which tests are able to identify APD in the presence of hearing loss. Collection of normative data in these different categories would be necessary for use of these tests in the clinic for diagnostic purposes. An

investigation of the use of electrophysiologic and imaging measures to help determine the status of the auditory pathways may also be beneficial in identifying patients with APD. To help identify or exclude a correlation between APD and better performance with a monaural hearing aid fit, research should be conducted contrasting subjects with symmetrical hearing loss who perform better with a monaural fit and those who perform better with a binaural fit. Research that investigates optimizing monaural hearing aid fittings would benefit not only patients with possible APD but also all patients who require a monaural fitting. This research could examine areas including binaural squelch, gain requirements, directional microphone patterns of amplification, and many others. Many patients with APD experience difficulty in noise; therefore, a study of the benefit of FM technology with subjects with APD would prove useful. Jerger et al. (1996) established that the level of improved signal to noise ratio needed by some subjects may be a factor in deciding between an assistive listening device or a hearing aid in the presence of an auditory based deficit in dichotic listening. Finally, when fitting a patient with monaural amplification, auditory deprivation is almost always a concern. For patients with symmetrical hearing loss, it is even more of a concern to try to preserve hearing in the unaided ear. Therefore, it would be beneficial to investigate options for introducing auditory stimuli to the unaided ear.

Continued research in this area is important because of studies that are being done regarding corpus callosum structure, interhemispheric function, and how the efficiency of interhemispheric transfer of information decreases with increasing age in adults. Such a decrease in interhemispheric transfer may be expected to result in functional difficulties across a wide range of sensory modalities, many of them communication related (Bellis and Wilber, 2001).

For audiologists, this could mean seeing more elderly patients with symmetrical hearing loss who are not performing as expected when fit binaurally.

In conclusion, there were no significant findings of the presence of APD in adult subjects with symmetrical hearing loss who prefer monaural amplification. The importance of collecting one's own normative data was seen in the absence of published normative data for WRS in noise. When the DPT results were examined, all subjects' scores were not within normal limits when compared to published normative data. However when compared to the author's collected normative data two subjects were within normal limits and two subjects were not. There was not a common dominant ear revealed for all subjects included in the current study. Future research investigating APD and the performance/preference of monaural or binaural amplification is necessary to try to determine if including auditory processing testing for some patients would be beneficial.

APPENDIX A

Washington University in St. Louis Human Research Protection Office [x] Adult [] Minor

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Participant				HRPO Approval Number	
Principal Investigator	Lynch	Valerie D.	B.A.	PI's Phone Number	(314)853- 9168
	Last	First	Credent	tials	
Title of Project:		•	_	he Preference of Monau nmetrical Hearing Loss	

You are invited to take part in a research study by Valerie Lynch, Dr. L. Maureen Valente, and Jennifer Listenberger.

Please ask for an explanation of any words you do not understand.

You may want to talk about the study with your family or friends before you decide to be in it.

1. Why is this study being done?

- 1. To determine if there is an ear dominance in adults with symmetrical hearing loss who prefer one hearing aid to two hearing aids.
- 2. To determine if there is a common dominant ear for all subjects.
- 3. To determine if some type of auditory processing disorder is occurring in addition to hearing loss in adults with symmetrical hearing loss who prefer one hearing to two hearing aids.

4. To determine if including an auditory processing test battery could help with the hearing aid selection process and increase user satisfaction.

2. What am I being asked to do?

Your participation will involve:

- 1. A standard hearing test including air conduction, bone conduction, and speech reception thresholds for both ears to assure that hearing is the same in both ears.
- 2. Three word recognition tests; in quiet, in noise, and at a higher intensity level.
- 3. A tympanogram to assess middle ear function. For this test you will be asked to remain still and not respond. A probe will be placed in your ear and you will feel a slight pressure change and hear a low intensity tone.
- 4. Auditory Reflexes. For this test you will again be asked to remain still and not respond. A probe will be placed in both ears and you will hear a pure tone.
- 5. The Staggered Spondaic Word (SSW) test: this is a dichotic listening test, presented at a level above your hearing threshold. You will hear a different word in each ear, with the second syllable of the first word overlapping with the first syllable of the second word; you will be asked to repeat both of the words.
- 6. The Dichotic Digits test presents two digits from 1 through 10, excluding seven to each ear simultaneously. You are supposed to repeat all four digits.
- 7. The Duration Pattern test presents a tone three times each being either short or long in duration. You must describe the pattern that you hear.

How long will I be in the study?

Your participation in this study is expected to last approximately 2-3 hours, involving one visit to the Program in Audiology and Communication Sciences student laboratory at the Central Institute for the Deaf building.

3. What are the Costs?

Standard of care: No cost to participant Research related: No cost to participant

4. What are the Risks?

Likely: none anticipated Less likely: none anticipated

Rare: Fatigue due to the length of testing. If you are to experience any fatigue the testing can be stopped so that you may take a break or if necessary testing may be continued on another day.

What happens if I am injured because I took part in this study?

Washington University investigators and their staffs will try to reduce, control, and treat any complications from this research. If you feel you are injured because of the study, please contact the Investigator and/or the Human Studies Chairperson from

Item 8. Decisions about payment for medical treatment for injuries relating to your participation in research will be made by Washington University.

5. Are there Benefits to taking part in the study?

The benefits of your involvement in this study are:

- 1. Helping to improve the hearing aid selection process for patients with symmetrical hearing loss.
- 2. Helping to improve testing for patients with symmetrical hearing loss who don't do well with two hearing aids.

6. What other Options are there?

Taking part in this research study is voluntary. You may choose not to take part in this research study or you may withdraw your consent at any time. Your choice will not at any time affect the commitment of your health care providers to administer care. There will be no penalty or loss of benefits to which you are otherwise entitled.

7. What about Confidentiality?

WUMC will protect your information according to State and Federal laws. Your identity will not be revealed in any publication that may result from this study.

Protected Health Information (PHI) is health information that identifies you. PHI is protected by federal law under HIPAA (the Health Insurance Portability and Accountability Act). To take part in this research, you must give the research team permission to use and disclose (share) your PHI for the study explained in this consent form.

In addition to health information that may be created by the study, the research team may access the following sources of your health information to conduct the study: Audiology Records

The research team will follow state and federal laws and may share your information with:

- Government representatives, to complete federal or state responsibilities
- Hospital or University representatives, to complete Hospital or University responsibilities
- Your primary care physician if a medical condition that needs urgent attention is discovered

Once your health information is shared with someone outside of the research team, it may no longer be protected by HIPAA.

The research team will only use and share your information as talked about in this form. When possible, the research team will make sure information cannot be linked to you (deidentified). Once information is de-identified, it may be used and shared for other purposes not discussed in this consent form. If you have questions or concerns about your privacy and the use of your PHI, please contact Joan Podleski, the University's Privacy Officer, at 866-747-4975.

Lynch

Indicate the individual's access to the research record if kept separate from the medical record. If you would like to access your research record you may contact Valerie Lynch at lynchv@msnotes.wustl.edu or 314-853-9168.

If you decide not to sign this form, it will not affect

- your treatment or the care given by your health provider.
- your insurance payment or enrollment in any health plans.
- any benefits to which you are entitled.

However, it will not be possible for you to take part in the study.

If you sign this form:

- You authorize the use of your PHI for this research
- Your signature and this form will not expire as long as you wish to participate.
- You may later change your mind and not let the research team use or share your information (you may revoke your authorization).
 - To revoke your authorization, complete the withdrawal letter, found at hsc/hipaa/, or you may request that the Investigator send you a copy of the letter.
 - o If you revoke your authorization:
 - The research team may only use and share information already collected for the study.
 - Your information may still be used and shared if necessary for safety reasons.
 - You will not be allowed to continue to participate in the study.

Please specify any contact restrictions you want to request for this study only. (Example – no calls at home, no messages left for you, no –emails, etc.)

8. Who do I call if I have Ouestions or Problems?

If you have any questions, concerns or complaints about the study, or feel that you are injured because of the study call Valerie Lynch at 314-853-9168 or Dr. L. Maureen Valente at 314-747-0107. If you wish to talk to someone else, or have questions or concerns about your rights as a research subject, call Dr. Philip Ludbrook, Chairman of the University's Human Research Protection Office, at (314) 633-7400 or (800) 438-0445.

9. The Principal Investigator (PI) may withdraw you from the study without your consent if considered appropriate. For safety, it may be in your best interest to allow follow-up outside the study. You may be removed from this study if your hearing is no longer symmetrical in both ears and/or if initial testing suggests that there is middle ear involvement. The PI will share any new information that could change how you feel about continuing in the study.

10. Being in a research study does not take the place of routine physical exams or visits to your own doctor and should not be relied on to diagnose or treat medical problems. I have read this consent form and have been given the chance to ask questions. I will also be given a signed copy of this consent form for my records. I give my permission to participate in the research described above, titled: Monaural amplification preference: An exploration of binaural interference.

Participant's Signature or Legally Authorized Representative Date

Signature of person providing Informed

Consent Date

The HRPO does not require participants to re-sign the consent (If designee, see guideline Who May Obtain *Consent*)

form unless a change is made; the investigator, however, may choose to have participants sign annually.

Relationship to Participant

Thank you for your important contribution to research studies that are trying to improve medical care.

This form is valid only if the Human Research Protection Office's current stamp of approval is shown below.

APPENDIX B	
Date:	
Dear	

I got your name from the Washington University Audiology Department. I am a third year Doctorate of Audiology student at Washington University School of Medicine. I am studying the effect of ear dominance and binaural interference on the preference of monaural amplification in subjects with symmetrical hearing loss. Your audiologic records show that you have a symmetrical hearing loss in both ears and that you prefer to wear one hearing aid versus two; due to this I would like to invite you to participate in my research.

There is no cost to you to be involved other than your transportation to and from the Central Institute for the Deaf building located at 4560 Clayton Ave. St. Louis, MO 63110 and your time. Your participation would require one visit lasting approximately 2-3 hours. There are no risks to you to be involved and the benefits include helping to improve the hearing aid selection process for patients with symmetrical hearing loss and helping to improve testing for patients with symmetrical hearing loss who don't do well with two hearing aids.

Your involvement would include:

- 8. A standard hearing test including air conduction, bone conduction, and speech reception thresholds for both ears to assure that hearing is the same in both ears.
- 9. Three word recognition tests; in quiet, in noise, and at a high level.
- 10. A tympanogram to assess middle ear function
- 11. Auditory Reflexes
- 12. The Staggered Spondaic Word (SSW) test: this is a dichotic listening test, presented at a level above your hearing threshold. You will hear a different word in each ear, with the second syllable of the first word overlapping with the first syllable of the second word; you will be asked to repeat both of the words.
- 13. The Dichotic Digits test presents two digits from 1 through 10, excluding seven to each ear simultaneously. You are supposed to repeat all four digits.
- 14. The Duration Pattern test presents a tone three times each being either short or long in duration. You must describe the pattern that you hear. This test helps to identify difficulty with temporal patterns.

Included with this letter is a consent form for you to read that discusses your involvement. Please bring the consent form unsigned with you when you come for testing; we will sign it at that time. If you have any questions you can contact me at 314-853-9168 or lynchv@msnotes.wustl.edu. You may also contact Dr. L. Maureen Valente at 314-747-0107 or valentel@wustl.edu

time for you to come in for testing, but again you may call me at anytime. I appreciate your time and participation.
Thank you,
Valerie D. Lynch B.A. Au.D. Student
Telephone Script:
Hello Mr./Mrs
My name is Valerie Lynch. I am a third year Doctorate of Audiology student at Washington University School of Medicine. I got your name from the Washington University Audiology Department. I sent you a letter asking you to participate in my research project, have you received that letter?
I would be happy to answer any questions that you have at this time regarding the letter, consent form, the study, or your involvement.
I would again like to invite you to participate in my research. If positive response: Thank you for your participation. Can you come in at(time) on(day) Thank you and I look forward to meeting you. Please bring the consent form with you and we will sign it together at that time.

If negative response:

contact me.

I will call you within the next week to answer any questions that you may have and to set up a

Thank you for your time. If you change your mind and would like to be involved please

APPENDIX C

Subject ID	WRS in	WRS in	WRS in	WRS in	PI-PB RI R	PI-PB RI L
	Quiet R	Quiet L	Noise R	Noise L		
1	100%	94%	16%	12%	0.0	0.02
2	88%	80%	14%	0%	-0.045	-0.075
3	90%	98%	4%	12%	-0.111	0
4	92%	100%	10%	26%	-0.087	0
Subject ID	SSW EE	SSW EE	DDT	DDT	DDT	DDT
	REF	LEF	Single R	Single L	Double R	Double L
1						
1	5	5	100%	100%	98%	98%
2	5 29	5 29	100% 95%	100% 95%	98% 93%	98% 70%
2 3		5 29 2				

Subject ID	DPT R	DPT L
1	21%	17%
2	32%	29%
3	61%	61%
4	64%	64%

APPENDIX D

Subject	WRS	WRS	WRS	WRS			PI-PB	PI-PB
ID	quiet R	quiet L	noise R	noise L	Rollover R	Rollover L	RIR	RIL
1	100%	100%	57%	56%	100%	100%	0	0
2	100%	100%	38%	27%	100%	100%	0	0
3	100%	100%	33%	22%	96%	100%	0.04	0
4	96%	96%	18%	32%	100%	100%	-0.04	-0.04
5	100%	100%	34%	46%	100%	100%	0	0
6	100%	100%	50%	26%	100%	100%	0	0
7	96%	100%	22%	34%	100%	96%	-0.04	0.04
8	96%	100%	24%	22%	96%	100%	-0.04	-0.04
9	100%	100%	26%	20%	88%	100%	0.12	0
10	100%	100%	12%	16%	100%	100%	0	0
Mean	98.8%	99.6%	31.4%	30.1%			0.004	-0.004
SD	0.019	0.013	0.141	0.125			0.0479	0.023
Subject	SSW EE	SSW EE	DDT	DDT	DDT	DDT		
ID	REF	LEF	Single R	Single L	Double R	DoubleL	DPT R	DPT L
1	0	0	100%	100%	100%	100%	61%	64%
2	0	1	100%	100%	100%	100%	55%	85%
3	0	0	100%	100%	95%	93%	70%	77%
4	0	0	100%	100%	100%	100%	100%	80%
5	1	1	100%	95%	88%	90%	93%	80%
6	0	0	100%	100%	100%	100%	100%	100%
7	0	0	100%	100%	100%	100%	93%	70%
8	0	0	100%	100%	100%	100%	97%	91%
9	1	1	100%	100%	98%	98%	48%	39%
10	0	0	100%	100%	100%	100%	88%	76%
Mean	0.2	0.3	100%	99.5%	98.1%	98.1%	80.5%	76.2%
SD	0.422	0.483	0.0	0.016	0.039	0.036	0.199	0.165

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